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FORECASTING STOCK PRICES FOR MARITIME SHIPPING COMPANY IN COVID-19 PERIOD USING MULTIVARIATE MULTI-STEP CONVOLUTIONAL NEURAL NETWORK - BIDIRECTIONAL LONG SHORT-TERM MEMORY

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Mihai Daniel ROMAN *[2]

Abstract: *The COVID-19 pandemic has triggered a global crisis in health and economic sectors, causing profound impacts on sea transport and trade. This research paper investigates the ramifications of the pandemic on maritime shipping prices, and, hence, their subsequent influence on the stocks of shipping companies. This global upheaval disrupted international trade significantly, resulting in an unprecedented demand surge for shipping services and a substantial spike in freight rates. This study is intended to propose a predictive method based on Multivariate Multi-step convolutional neural network - Bidirectional Long Short-Term Memory (Multivariate Multi-step CNN-BiLSTM) networks in order to forecast the prices of three of the most prominent stocks of big organizations operating in maritime transport. The proposed method is composed of Convolutional Neural Networks (CNN) and Bidirectional Long Short-Term Memory (BiLSTM), where the research utilizes CNN to help for feature extraction from the inputted data, alongside BiLSTM that forecasts the closing stock price for the upcoming five days, utilizing the extracted feature data. Hence, stock price prediction can be realized by applying a novel optimization strategy, which was founded on the Multivariate Multi-step CNN-BiLSTM model and utilizing the Adam optimizer. Prediction accuracy can be assessed by incorporating four metrics into the system: Root Mean Square Error, Mean Absolute Error, Mean Absolute Percentage Error, and Median Absolute Percentage Error. Experimental findings demonstrate that Multivariate Multi-step CNN-BiLSTM yields the most dependable stock price forecasts with the highest accuracy. The proposed prediction method, correctly applied, can yield economic benefits at the macr and micro levels; the prediction accuracy can help policy makers make better future outlook estimates in relation to inflation, gross domestic product (GDP), and unemployment levels that might be impacted by the volatile, uncontrolled, or unexpected fluctuations of stock prices of some leading economic sectors that are closely connected to global shipping and supply chain operations; thus, leading to serious impacts at the microeconomic level in relation to costs, supply and demand, and behavior of individual consumers and companies.*

Keywords: *Multivariate, COVID-19, Forecasting, Stock price, Maritime transport, CNN-BiLSTM. Macro and microeconomic implications.*

JEL Code: *C22, C87, E27, F17.*

UDC: *[336.761:656.61]:338.124.4*

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Introduction

The COVID-19 pandemic, which originated in late 2019 and continues to impact the world in 2023, has ushered in an era of unprecedented global crisis, nearly affecting every aspect of human existence. Among the various sectors profoundly influenced by this crisis, sea shipping stands as a critical linchpin in the global economy, playing a crucial role in the transportation of goods and commodities across international waters. The multifaceted effects of the COVID-19 pandemic on the global economy and, more specifically, on sea shipping prices are intrinsically linked, highlighting the complex interplay between international trade and maritime transport.

Several years before the crisis hit, the global economy was marked by increasing interconnectedness, where the economic growth of nations relied heavily on international trade. Sea shipping was the backbone of this interconnected web, serving as the primary mode of transporting goods and commodities across the seven continents of the world. The rapid expansion of globalization facilitated the exchange of goods and services on a global scale, with international trade routes, particularly those involving sea shipping, being the lifeblood of the global economy, ensuring the efficient flow of goods from manufacturing hubs to consumer markets.

However, the emergence of COVID-19 and its rapid global spread caused a disruption and halt to the world, leading governments across the world to implement drastic strict measures, such as, but not limited to, lockdowns, travel restrictions, and quarantine protocols, in an endeavor to curb the virus's transmission (Tok et al., 2022). These measures had far-reaching consequences for various aspects of the global economy, especially in relation to sea shipping prices. Lockdowns and restrictions in manufacturing hubs disrupted global supply chains. The resulting factory closures and production delays had a cascading effect, impacting the availability of critical components and goods on a global scale, leading to an upheaval in the sea shipping sector, causing unprecedented large-scale disruptions in supply chains.

In addition to supply chain disruptions, pandemic-induced economic uncertainty brought about fluctuations in consumer demand. The reduced demands for goods further strained supply chains, leading to a surplus of cargo at ports and warehouses. Sea shipping prices resonated with the reverberations of these shifts in demand patterns as well (UNCTAD, 2021). Freight rates fluctuated as demand waned in some sectors and surged in others, creating a dynamic pricing landscape within the maritime shipping industry.

The sea shipping industry faced unprecedented challenges during the early stages of the pandemic. However, it quickly adapted to the evolving landscape, demonstrating resilience and flexibility in the face of adversity. Ports around the world implemented safety measures to protect their workforce while ensuring the uninterrupted flow of goods. These measures included temperature checks, social distancing protocols, and remote work arrangements for administrative staff (WHO, 2021). The digitization and automation of port operations accelerated, reducing the need for physical contact and improving efficiency. Shipping crews aboard vessels faced unique challenges, including isolation and quarantine due to travel

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restrictions and safety concerns. Companies developed protocols to ensure the safety and well-being of crew members, including regular tests and quarantine measures.

Despite the disruptions, sea shipping played a crucial role in mitigating the impact of the pandemic and in supporting the global response effort. It became a lifeline for the transportation of critical medical supplies, personal protective equipment (PPE), and vaccines to affected regions. The industry's adaptability ensured that vital supplies reached their destinations, even in the face of logistical challenges. Furthermore, the pandemic confirmed the importance of sea shipping in maintaining food supplies and security. It transported food and agricultural products from surplus regions to areas facing shortages, helping to mitigate the risks of food crises. Some governments have implemented policies to ensure the continuous flow of food supplies through sea shipping.

The COVID-19 pandemic has prompted researchers at a global scale to enable cutting-edge machine learning techniques to gain insights in identifying and predicting the trajectory of such an unprecedented health crisis. Recent advancements in computing technology have accelerated the development of sophisticated algorithms of mathematical and machine learning with the aim of forecasting the virus spread patterns. In their relevant study, Zain and Alturki (2021) designed a hybrid CNN-LSTM model, and trained it on a time-series dataset as a means for forecasting the number of confirmed COVID-19 cases. They assessed performance of this model in much depth, and compared it against 17 baseline models on both sets of tests and forecast data. A substantial breakthrough resulted from this research, demonstrating how the CNN-LSTM hybrid model outperformed all baseline models.

The potential of the hybrid model, CNN-LSTM, to excel in COVID-19 case prediction bears profound implications for public health. Accurate forecasts of the pandemic's trajectory empower policymakers and healthcare authorities to implement their timely targeted interventions, thereby curbing the spread of the virus and mitigating its impact on communities. Furthermore, the study's demonstration of the model's effectiveness, even with a limited dataset, confirms its versatility and applicability in regions where data availability may be constrained.

BiLSTMs have shown considerable potential in stock market prediction by increasing their ability to capture intricate temporal dependencies from both directions of a time series. Researchers have found that BiLSTMs often outperform unidirectional LSTMs in tasks such as sentiment analysis, price prediction, and trend forecasting. For example, a study by Mo Yang and Jing Wang (Yang et al. 2022) demonstrated that BiLSTM networks provided more accurate stock price predictions compared to traditional LSTM models, highlighting their ability to learn more comprehensive temporal features.

Combining LSTM, BiLSTM, and CNN models can maximize the strengths of each architecture, leading to more robust and accurate predictions. For instance, combining Bidirectional Long Short-Term Memory (BiLSTM) networks and Convolutional Neural Networks (CNNs) into a single module for prediction tasks capitalizes the strengths of both architectures, resulting in a more powerful model (Chen et al.. 2021). BiLSTMs are adept at capturing temporal dependencies and context from sequential data by processing input in both

forward and backward directions, which is particularly useful for understanding the nuances in time-series data, natural language processing, and speech recognition. On the other hand, CNNs excel at extracting local features through convolutional layers, making them highly effective for tasks involving spatial hierarchies, such as image processing and certain aspects of text analysis. When integrated into a unified model, CNNs can preprocess data to extract salient features, which are then passed to the BiLSTM to capture the temporal dynamics and context.

The remainder of the paper is structured as follows: Section 2 presents the literature review. Section 3 covers the concept of CNN and BiLSTM, expounding their functions. Section 4 outlines the proposed structure and methodology employed for estimating stock prices. The results are presented in Section 5. Lastly, Section 6 provides a summary of the conclusions and outlines future directions.

Literature Review

Zhanhong He et al. (2019) introduced an innovative gold price forecasting approach that integrates Long Short-Term Memory Neural Networks (LSTM) and Convolutional Neural Networks (CNN) with an Attention Mechanism, denoted as the LSTM-Attention-CNN model. They conducted extensive experiments using real-world daily gold price data to assess the model's performance. The key finding of their study was that the proposed model outperformed conventional methods such as Autoregressive integrated moving average (ARIMA), deep regression, Support Vector Regression (SVR), and CNN. They also proposed that exploring different types of recurrent neural network (RNNs), away from the LSTM component, could further enhance the model's performance. For instance, employing bidirectional LSTM networks in the LSTM-Attention-CNN model might yield improved results.

In October 2020, Cheng-Hong Yang, and Po-Yin Chang introduced a novel mixed-precision neural architecture for forecasting container throughput demand. The proposed mixed-precision architecture is the first of its kind to utilize a combination of convolutional neural networks (CNNs) and long short-term memory (LSTM) networks for container throughput forecasting. The architecture enables CNNs to learn the feature strengths and LSTM to capture essential internal representations of the time series, depending on the feature strengths. Experiments were conducted on the demand for container throughput at five ports in Taiwan, comparing the performance of the proposed deep learning architecture with other forecasting approaches, including adaptive momentum, random forest regression, and support vector regression. The results demonstrated that the mixed-precision neural architecture outperformed the classic machine learning methods, exhibiting higher forecasting accuracy. The proposed architecture effectively predicts the demand for port container throughput, offering potential cost reductions in port planning and development. It combines the feature learning capabilities of CNNs with the ability of LSTM to capture time dependencies, leading to improved forecasting performance compared to traditional methods.

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From another perspective, Yu Chen et al. (2021) introduced a novel stock price prediction model called CNN-BiLSTM-ECA. This model utilizes various time series data, including changes in price such as stock closing price, highest and lowest prices, in terms of relevant information such as: opening price, previous day's closing price, as input for forecasting the stock closing price of the next day. The "proposed CNN-BiLSTM-ECA model, as one of the key findings of this study, demonstrated how it delivers the highest prediction accuracy and overall performance", simply by achieving the smallest MSE, RMSE, and MAE values, particularly, 1956.036, 44.227, and 28.349, respectively, in relation to the Shanghai Composite Index. In comparison to a single LSTM model, these error metrics, in this model, were reduced by 53.67%, 31.94%, and 43.96%, respectively. This highlights the challenge of achieving high prediction accuracy using a single network and the potential for improved accuracy through network complexity.

Haiyao Wang et al. (2021) introduced a composite model named CNN-BiSLSTM for predicting stock closing prices. To assess the model's effectiveness, they utilized historical data from the Shenzhen Component Index spanning from July 1, 1991, to October 30, 2020, for training and testing the model. CNN-BiSLSTM was validated against various models, including multilayer perceptron (MLP), recurrent neural network (RNN), long short-term memory (LSTM), BiLSTM, CNN-LSTM, and CNN-BiLSTM. Their primary finding in this study was that CNN-BiSLSTM outperformed the reference models in terms of mean absolute error (MAE), root-mean-squared error (RMSE), and R-square (R2) evaluation indicators, demonstrating superior predictive capabilities.

Similarly, Harya Widiputra et al.(2021) introduced a hybrid ensemble model for time-series data forecasting, using combined features from various time-series analysis models. This model incorporates elements from both CNN and LSTM models, creating an evolved ensemble model. During the COVID-19 pandemic, the effectiveness of the model was tested using stock market indices, extracted from four Asian stock markets, concluding mainly that, adversely to CNN and LSTM models, using multivariate CNN-LSTM demonstrated the highest statistical accuracy and reliability, as manifested by the smallest RMSE value. Such a key finding confirms the underlying value of effectively integrating relationships between variables into the formats of prediction models, with the aim to addressing the challenges of forecasting using multiple time-series that involve related time-sensitive variables.

Still in the same direction, Mahdi Ahmed et al. (2022) conducted a comprehensive review of contemporary deep learning time series models and their performance across diverse domains. They found that the LSTM model was extensively used in several industries, including healthcare, finance, weather, energy, and more. Hybrid models explicated exceptional forecasting capabilities. Additionally, combining time series forecasting methods like TCNN and LSTM with optimization techniques like Adam yielded favorable results. Python, along with the Keras package, emerged as the predominant choice for implementing deep sequential models in real-world applications. While the rectified linear unit (ReLU)

activation function was very common in the publications they reviewed, the study did not determine a definitive preference among activation functions.

Approaching the concept from a different angle, Zhang et al. (2023) introduced a CNN-BiLSTM-Attention-based model designed to increase the accuracy of stock price and index predictions, by using the CSI 300 index data. Their key finding revealed that among the four models assessed - LSTM, CNN-LSTM, CNN-LSTM-Attention, and CNN-BiLSTM-Attention - the CNN-BiLSTM-Attention model achieved the highest accuracy in predicting stock price indices. These four models were utilized to predict stock prices or indices using data from 12 selected indices in stock markets from China and other countries or regions. As per the test results, the proposed model effectiveness was manifested in predicting stock indices for both Chinese and international stock markets, indicating a certain level of generalizability.

CNN- BiLSTM

Convolutional Neural Networks (CNNs), introduced by LeCun et al. in 1998, have since demonstrated exceptional performance in various domains, including image processing, natural language processing, and time series forecasting. CNNs are particularly efficient due to their local perception and weight-sharing mechanisms, which significantly reduce the number of parameters and enhance model learning efficiency. A typical CNN architecture consists of two primary components: the convolutional layer, which includes multiple convolution kernels for feature extraction as defined by equation (1), and the pooling layer, which reduces the high-dimensional feature space generated by convolutional operations. This layered structure enables CNNs to effectively process diverse data types, making them highly versatile for a broad range of applications (Wenjie Lu et al.).

$$l_t = tanh(x_t * k_t + b_t) \quad (1)$$

Where l_t represents the output value after convolution, $tanh$ is the activation function, x_t is the input vector, k_t is the weight of the convolution kernel, and b_t is the bias of the convolution kernel.

In parallel to CNNs, Long Short-Term Memory (LSTM) networks, a prominent type of Recurrent Neural Network (RNN) architecture introduced by Hochreiter and Schmidhuber in 1997, have gained significant relevance in deep learning and sequential data analysis. LSTMs were developed to address the vanishing gradient problem that hindered traditional RNNs. Their core strength lies in the ability to capture long-range dependencies and retain information over extended sequences, making them particularly suitable for time series analysis, natural language processing, and speech recognition. The LSTM architecture includes specialized memory cells and gating mechanisms, as shown in Fig. 1: input gate (i_t), output gate (o_t), and forget gate (f_t), which enable the selective storage and retrieval of information across different time steps (Joshi et al., 2022). This capability has driven their widespread adoption in tasks ranging from stock price prediction to machine translation.

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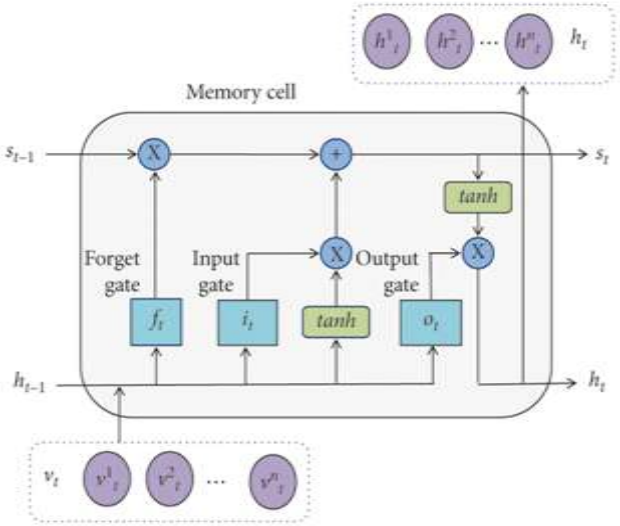

Figure 1. The structure of Long Short-Term Memory (LSTM)

Source: based on Yang et al. (2022)

The forget gate f_t uses x_t and h_{t-1}as input to compute the information to be preserved in c_{t-1} using a sigmoid activation. The input gate i_t takes x_t and h_{t-1} to compute the value of c_t The output gate o_t performs regulation on the output of an LSTM cell by considering c_t and applying both sigmoid and tanh layers.

Building on the capabilities of traditional LSTMs, Bidirectional Long Short-Term Memory (BiLSTM) networks extend the architecture to capture dependencies in sequential data from both past and future contexts. Unlike unidirectional LSTMs that process sequences in a single direction, BiLSTMs employ two sets of hidden states: one that moves forward in time and another that moves backward. This bidirectional approach allows the model to utilize the full context when making predictions, significantly enhancing performance in applications such as named entity recognition, sentiment analysis, and speech recognition. By combining forward and backward information flows, BiLSTMs have proven to be a powerful enhancement for modeling complex patterns in sequential data, solidifying their role in modern deep learning frameworks.

The following equations are used in gates updating (Joshi et al., 2022):

$$f_t = \sigma_g\left(W_{xf}U_t + V_{hf}h_{t-1} + b_f\right) \quad (2)$$

$$i_t = \sigma_g(W_{xi}U_t + V_{hi}h_{t-1} + b_i) \quad (3)$$

$$o_t = \sigma_g(W_{xo}U_t + V_{ho}h_{t-1} + b_o) \quad (4)$$

$$\dot{C}_t = tanh(W_{xc}U_t + V_{hc}h_{t-1} + b_c) \quad (5)$$

$$C_t = f_t * C_{t-1} + i_t * \dot{C}_t \quad (6)$$

$$h_t = o_t * tanh(C_t) \quad (7)$$

U_t= input at time t, h_{t-1}= previous hidden state, h_t= hidden state at time t.

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C_t= memory cell output, $\dot{C}_t$= intermediate cell output.

b_f, b_i, b_o, and b_c= bias vectors.

V_{hf}, V_{hi}, V_{ho}, and V_{hc}= three gates and weight matrices that link the output state of the preceding cell to the input cell state.

W_{xf}, W_{xi}, W_{xo}, and W_{xc}= weight matrices are used to calculate the hidden layer input to three gates, as well as the state of the input cell.

σ_g= gate activation function, $tanh$ = state activation function.

An output vector is generated by the BiLSTM layer - y_t:

$$\overrightarrow{h_t} = \sigma_h\left(W_{x\vec{h}}U_t + W_{\vec{h}\vec{h}}\overrightarrow{h_{t-1}} + b_{\vec{h}}\right) \quad (8)$$

$$h_t^{\leftarrow} = \sigma_h(W_{xh^{\leftarrow}}U_t + W_{h^{\leftarrow}h^{\leftarrow}}h_{t-1}^{\leftarrow} + b_{h^{\leftarrow}})) \quad (9)$$

$$y_t = W_{\overrightarrow{hy}}\vec{h}_t + W_{hy^{\leftarrow}}\vec{h^{\leftarrow}}_t + b_y \quad (10)$$

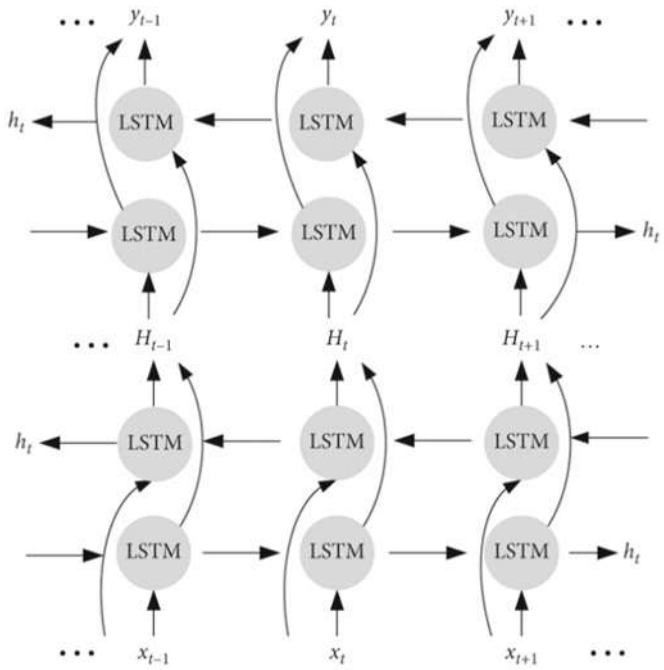

Figure 2. The network structure of Bidirectional Long Short-Term Memory (BiLSTM)
Source: based on Peng et al. (2021)

Proposed Methodology

This proposed method has been based on Multivariate Multi-step convolutional neural network - Bidirectional Long Short-Term Memory (Multivariate Multi-step CNN-BiLSTM) networks to be employed for forecasting stock prices of three of the significant maritime transport organizations. This method is comprised of Convolutional Neural Networks (CNN) and Bidirectional Long Short-Term Memory (BiLSTM). CNN is utilized for feature extraction

from the input data, while BiLSTM utilizes the extracted feature data to forecast the closing stock price for the upcoming five days.

This study employs deep learning techniques, specifically Multivariate Multi-step CNN-BiLSTM, Multi-step LSTM, and Multi-step Gated recurrent unit (GRU), with the aim of predicting stock prices for three prominent shipping companies: Evergreen, Yang Ming, and COSCO. To effectively evaluate the models' performance, the study follows a structured procedure, encompassing the following steps: (1) the collection of historical data for Evergreen, Yang Ming, and COSCO; (2) exploratory data visualization; (3) dividing each dataset into separate test and training datasets; (4) conducting model training for the three distinct types (Multivariate Multi-step CNN-BiLSTM, Multi-step LSTM, and Multi-step GRU); (5) testing the models; and (6) a comprehensive comparison of each model's performance.

To validate the efficacy of the Multivariate Multi-step CNN-BiLSTM model, we conducted a comparative analysis with the Multi-step LSTM and Multi-step GRU using same training and test datasets under the same operating environment. These experiments were carried out using Python 3.9.7, along with essential libraries such as Pandas, NumPy, scikit-learn, Keras, and Matplotlib. The model training and testing processes were conducted on a machine equipped with an i7-6500U Intel Core CPU, running at 2.50 GHz, with 12 GB of RAM. The implementation was executed using Python 3.9.7 and various core libraries, using Jupyter Notebook Server 6.4.5. The datasets employed in this experiment encompassed stock prices for Evergreen, Yang Ming, and COSCO, spanning from January 1, 2018, to May 1, 2023, covering a five-year period. These datasets were solicited from Yahoo Finance's website, and Table 1 provides an overview of the parameter specifications used in the analysis.

Data preprocessing techniques are applied to the stock price data to prepare them for deep learning. Handling missing data is the initial step, where rows are validated for null values, and it is confirmed that the Open, High, Low, Close, Adj, and Volume columns have no missing data. The data is processed to align with the CNN-BiLSTM model requirements. It is transformed into time steps, with a specific step value of 50 chosen. Subsequently, the training data is restructured to fit the intended CNN-BiLSTM model, and this reshaping process involves three parameters: the sample size, the time step (set at 50), and the number of features.

Table 1. Dataset specifications

Parameter	Description	Data Type
Date	Date of the observation.	Date
Open	Daily opening price of the selected stock.	Number
High	Daily high price of the selected stock.	Number
Low	Daily low price of the selected stock.	Number
Close	Daily closing price of the selected stock.	Number
Close Adj Close	Daily Adjusted close price of the selected stock.	Number

Source: based on Phumudzo Lloyd Seabee et al. (2023)

For algorithm based on the Multivariate Multi-step CNN-BiLSTM, the size of the sample corresponds to the number of rows in the training set, amounting to 1211. Given the utilization

of the Open, High, Low, Close, and Volume columns, the data feature size is set at 5. Feature scaling is performed to standardize the data using StandardScaler from the sklearn preprocessing library. This method transforms the data distribution by subtracting the mean and dividing by the standard deviation, resulting in features centered around zero with a standard deviation of one. Standardization is particularly useful when features have varying scales, as it helps stabilize gradients and weight updates during training. This process preserves the shape of the original distribution while improving the optimization of the model, often leading to faster and more reliable convergence. The following equation yields the transformation:

$$x' = \frac{x-\mu}{\sigma} \tag{11}$$

where X is an original value, x' represents the scaled value, μ is the mean of the feature's values, and σ is the standard deviation of the feature's values. (Rashmi et al. 2024).

As the process progresses, the data are divided into training and testing sets. The dataset is divided in such a way that the last 20 records are assigned for testing data, while the rest constitute the training data. Figure 3 presents a line plot illustrating the progression of Evergreen, Yang Ming, and COSCO stock prices from January 2018 to May 2023, providing a visual representation of their trends over time.

The prediction of stock prices involves building the Multivariate Multi-step CNN-BiLSTM model in a sequential process. This model consists of five layers, which have been determined as the optimal number to achieve accurate predictions while avoiding overfitting, based on empirical tuning and evaluation. The initial layer is Conv1D, with an input shape of (50, 5) signifying a time-step of (50) and (5) feature columns. The 50-time steps are chosen to capture sufficient historical context, while the 5 features represent key stock indicators. The layer has (32) filters, a kernel size of (1), allowing the model to learn feature-level patterns without temporal aggregation. padding set to 'same' to preserve the input dimensions, and the Tanh activation function is used due to its non-linear nature, zero-centered output, and relatively stronger gradients compared to sigmoid, which together enable the model to learn complex patterns more efficiently and converge faster. Subsequently, a Pooling layer with a pool size of (1), followed by a BiLSTM layer with (100) cells and another BiLSTM layer with a shape of (50) and employs the Tanh activation function for both, the cell sizes (100 and 50) balance model complexity and training time, while the use of kernel_regularizer=L2(0.01) helps prevent overfitting by penalizing overly complex models. Representing the number of days to be predicted, the final layer is a dense layer with a shape of (5).

The model is an integration of the Adam optimizer due to its adaptive learning rate, ease of implementation, low memory requirements, and strong performance across diverse models, making it a widely adopted and reliable optimizer, and the mean squared error loss function, which enables faster convergence in scenarios where the error values are relatively small and consistent.

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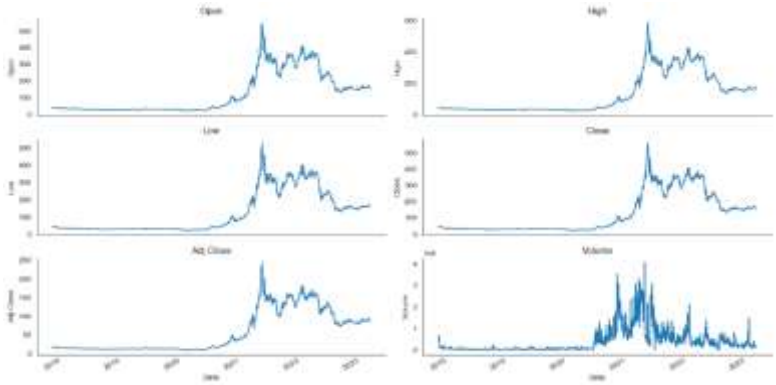
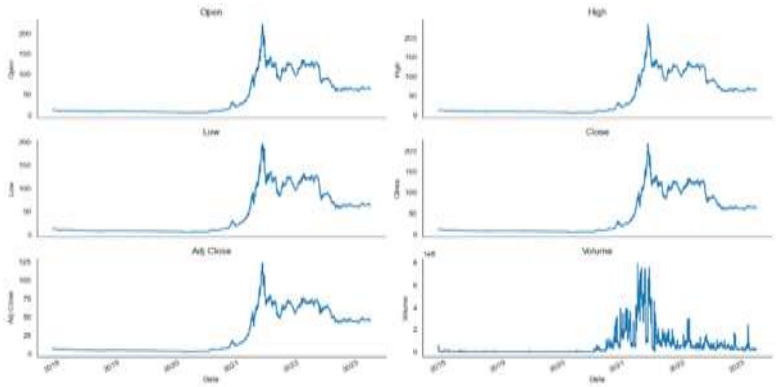
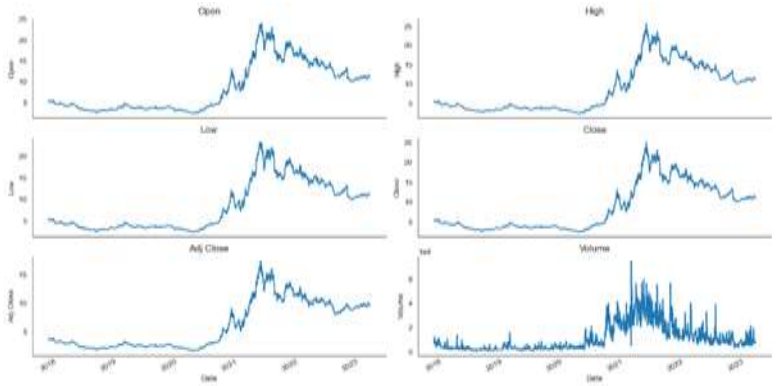


Evergreen stock prices



Yang Ming stock prices



COSCO stock prices

Figure 3. Value of Evergreen, Yang Ming, COSCO stocks price over 5 years

Source: authors own study

A batch size of 5 was selected to provide a fine-grained gradient update per step, which is particularly useful when training on small or volatile datasets Training is conducted for 100 epochs, and EarlyStopping is implemented with patience = 10 and restore_best_weights = True to monitor the test set and halt training once performance ceases to improve, effectively reducing overfitting and improving generalization (Gerritzen et al., 2024). during training, exhibiting the data processed in batches of 5 and passed through the CNN-BiLSTM model 100

times. After training, the model predicts data that needs to be normalized back to the original scale using the inverse transform() function. Comparing the inverse-scaled data with the original data allows for assessing the performance of the model, typically measured by using MAPE (Mean Absolute Percentage Error).

Results

For stock price prediction and performance evaluation, both training and test data are utilized. The proposed algorithm's accuracy is validated using a set of metrics, including Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), Median Absolute Percentage Error (MDAPE), and Mean Absolute Percentage Error (MAPE). The smaller the values of MAE, RMSE, MDAPE, and MAPE are, the closer the predicted values are to the real values, indicating higher forecasting accuracy.

The formula for calculating MAE is as follows:

$$MAE = \frac{1}{n}\sum_{1}^{n} |X_t - X_t'| \quad (12)$$

The formula to calculate RMSE is as follows:

$$RMSE = \sqrt{\frac{1}{n}\sum_{1}^{n} (X_t - X_t')^2} \quad (13)$$

The formula for calculating MDAPE is as follows (Xin Wen et.al, 2022):

$$MDAPE = median\left(\left|\frac{X_t - X_t'}{X_t}\right|\right) \quad (14)$$

The formula for calculating MAPE is as follows:

$$MAPE = \frac{1}{n}\sum_{1}^{n} \left|\frac{X_t - X_t}{X_t}\right| \quad (15)$$

Where X_t is the actual value, X_t' is the forecast value, and n is sample size.

The Multivariate Multi-step CNN-BiLSTM model achieved an average Mean Absolute Percentage Error (MAPE) of 3.07 on the training data and 2.78 on the test data, demonstrating accuracy levels of 96.93% and 97.22% on training and testing data, respectively. To further illustrate the accuracy of the model, Figure 4 displays the stock price on a specific date alongside the forecasted stock price, while Table 2 provides a tabulated comparison. The model's predictions reveal exceptional accuracy, as evidenced by the high overlap between actual and predicted stock prices.

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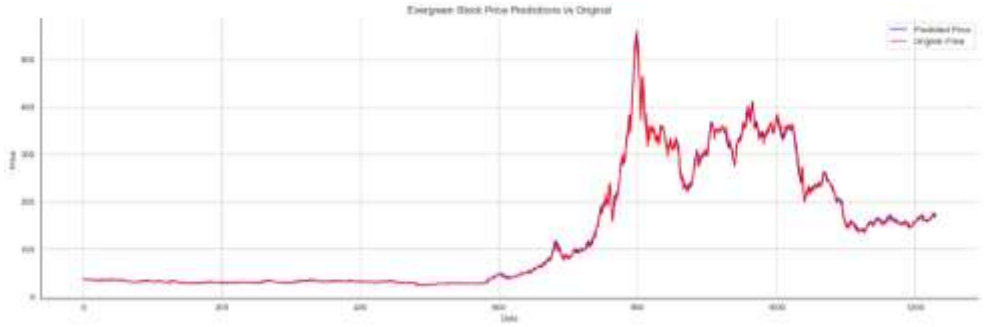
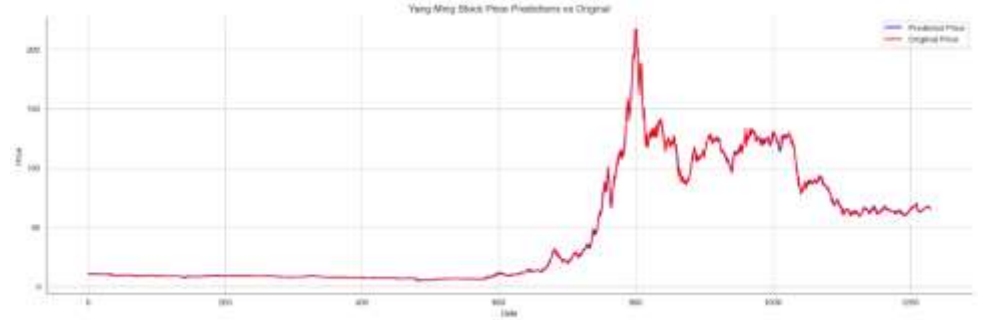
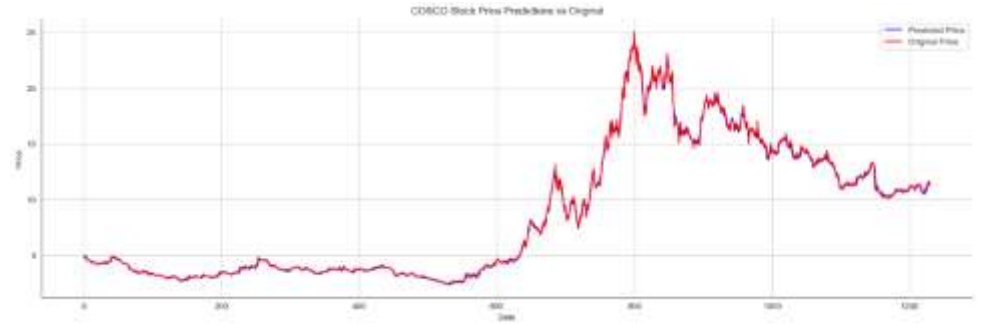


Evergreen stock price Prediction vs Original



Yang Ming stock price Prediction vs Original



COSCO stock price Prediction vs Original

Figure 4. Original and predicted values for Evergreen, Yang Ming, COSCO stocks price

Source: authors own study

Table 2. Comparison of the original stock price with the predicted stock price for Evergreen, Yang Ming, and COSCO

Evergreen		**Yang Ming**		**COSCO**	
Original	*predicted*	*Original*	*predicted*	*Original*	*predicted*
171.0	171.39905	67.5	70.55099	11.09000015	11.298306
167.0	169.87651	66.5	71.03494	11.10999966	11.316631
159.5	170.1119	64.69999695	69.911064	11.09000015	11.2541275
162.0	169.02843	65.40000153	69.03856	11.06000042	11.215194
162.0	166.94925	65.80000305	67.51167	11.10000038	11.224907

Source: authors own study

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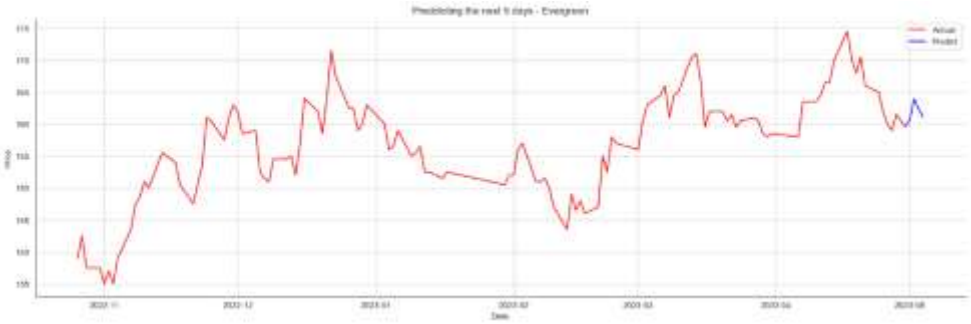
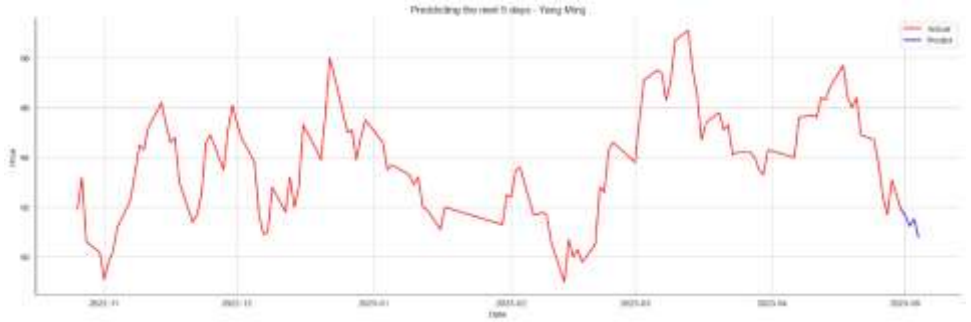
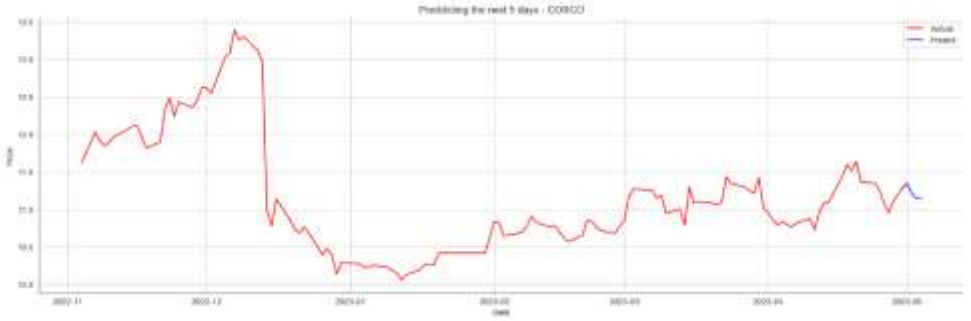
Subsequently, I will generate forecasts for the upcoming five days by inputting the stock prices from the preceding 30 trading days into the model. The model's predictions are depicted in Figure 5 and summarized in Table 3 for the respective companies (Evergreen, Yang Ming, and COSCO).



Predict the next 5 days – Evergreen



Predict the next 5 days – Yang Ming



Predict the next 5 days – COSCO

Figure 5. Original and predicted values for Evergreen, Yang Ming, COSCO stocks price

Source: authors own study

Table 3. Predicted values for 5 days for Evergreen, Yang Ming, and COSCO

Evergreen	Yang Ming	COSCO
159.593216	61.932083	11.295383
160.682785	61.668739	11.346975
163.941849	61.237114	11.207294
162.387161	61.524155	11.150970
161.097946	60.798306	11.143347

Source: authors own study

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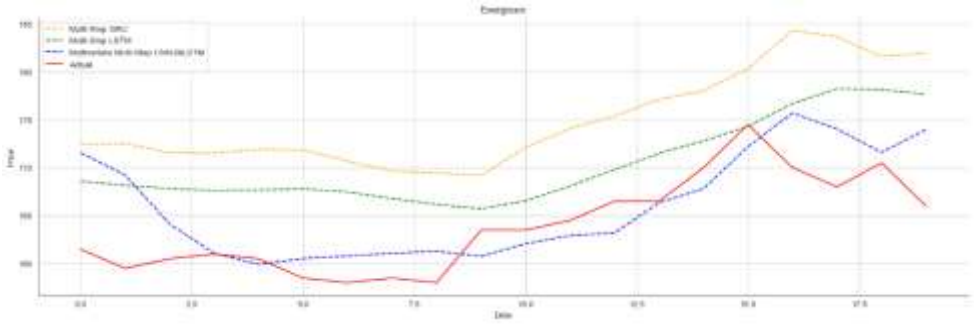
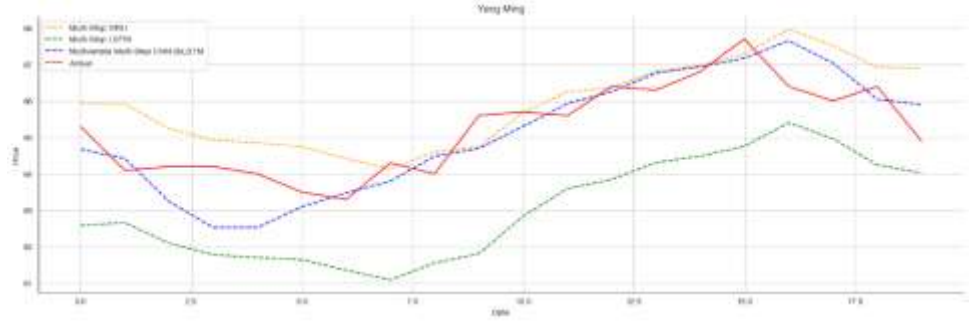
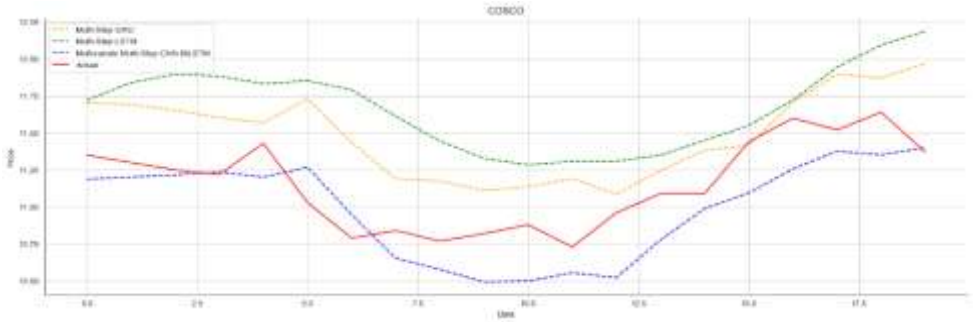
The model's projection suggested that sea shipping prices would remain relatively stable with minimal downward movement, potentially benefiting the industry by cost optimization practices. However, forecasting stock prices, especially for transportation and shipping companies, presents a formidable challenge due to the myriads of variables influencing stock values. These variables combine political and logistical intricacies, internal corporate conflicts, and external factors such as geopolitical conflicts and natural disasters, such as pandemics.



Comparison between predicted value and actual value for Multi-step GRU COSCO, Multi-step LSTM, and Multivariate Multi-step BiLSTM Evergreen



Comparison between predicted value and actual value for Multi-step GRU COSCO, Multi-step LSTM, and Multivariate Multi-step BiLSTM Yang Ming



Comparison between predicted value and actual value for Multi-step GRU COSCO, Multi-step LSTM, and Multivariate Multi-step BiLSTM COSCO

Figure 6. Comparison of the predicted value and the real value for Multi-step GRU, Multi-step LSTM, and Multivariate Multi-step BiLSTM on Evergreen, Yang Ming, COSCO test data

Source: authors own study

Given the volatile nature of these factors, the COVID-19 pandemic actively underscored the significant fluctuations in the stock values of transportation and shipping firms, making long-term stock price predictions a daunting task. In order to assess the effectiveness of the proposed model, I compared it to other models, including Multi-step LSTM and Multi-step GRU, utilizing three distinct stock datasets (Evergreen, Yang Ming, and COSCO). After training the Multivariate Multi-step CNN-BiLSTM, Multi-step LSTM, and Multi-step GRU models with the processed training data, I applied these models to predict the test dataset. Figure 6 illustrates the comparison between the actual values and the predicted values.

Figure 6 exhibits the degree of fit proportionality between actual values and predictions for the Multivariate Multi-step CNN-BiLSTM, Multi-step LSTM, and Multi-step GRU, among the three prediction algorithms Notably, the Multivariate Multi-step CNN-BiLSTM model exhibits a substantial overlap between the actual and predicted values. For further deeper evaluation of each method's performance, I calculate the respective evaluation metrics, for both predicted and real values. Table 4 below exhibits a summary of the comparative results of these three methods:

Table 4. Forecast errors of different network models

Evergreen				
	MAE	**RMSE**	**MDAPE**	**MAPE**
Multi-Step GRU	6.94	8.07	4.27	4.24
Multi-Step LSTM	6.07	7.22	3.64	3.71
Multivariate Multi-Step CNN-BiLSTM	4.5	5.93	2.24	2.75
Yang Ming				
	MAE	**RMSE**	**MDAPE**	**MAPE**
Multi-Step GRU	2.45	3.05	2.9	3.79
Multi-Step LSTM	1.82	2.21	2.89	2.81
Multivariate Multi-Step CNN-BiLSTM	0.96	1.3	1.18	1.49
COSCO				
	MAE	**RMSE**	**MDAPE**	**MAPE**
Multi-Step GRU	0.49	0.61	3.45	4.45
Multi-Step LSTM	0.48	0.55	4.09	4.31
Multivariate Multi-Step CNN-BiLSTM	0.46	0.57	3.29	4.08

Source: authors own study

Table 4 exhibits that Multi-Step GRU shows the highest values for MAE, RMSE, MDAPE, and MAPE, while Multivariate Multi-step CNN-BiLSTM boasts the lowest values for these metrics. These results establish the superior performance of Multivariate Multi-step CNN-BiLSTM over the other two methods. Notably, in terms of prediction accuracy, Multivariate Multi-step CNN-BiLSTM achieves the lowest and most accurate scores among the three prediction models.

Limitations and Future Work

The limitations of this research can be summed up in several perspectives:

- Technical: Applying such prediction methods and models requires a high-level buy-in and sufficient technical infrastructure to utilize the potential positive impacts of the proposed prediction accuracy.
- Data limitation: Due to lack, unavailable standardized data sources to feed in the model to reach higher percentages of prediction accuracy.
- Time limitation: It addressed the performance of stocks of specific companies in a limited and exceptional period of time.
- Applicability limitation: Lack of the clear correlations between the shipping sector and other economic sectors based on comprehensive empirical research might make policy makers reluctant to adopt the proposed methods that might positively or adversely impact the economies at the macro and micro levels.
- Future work: Further research work is required to look into more robust combinations of similar models, and further invetigate potential correlations with other sectors.

Conclusions

This research paper introduces a novel and progressive approach to stock price prediction by using a Multivariate Multi-step CNN-BiLSTM model optimized with Adam. The methodology involves partitioning normalized time series data into time steps to establish past-future value relationships for accurate predictions. The Multivariate Multi-step CNN-BiLSTM model achieves a prediction accuracy of 97.22% on the testing dataset and 96.93% on the training dataset. It exhibits an average error percentage of 2.78% on the testing data and 3.07% on the training data, signifying highly precise forecasts. A five-day forward forecast suggests price stability with minimal downward movement, potentially benefiting sea shipping with lower prices. Comparative analysis against two other methods, Multi-step GRU and Multi-step LSTM, affirms that Multivariate Multi-step CNN-BiLSTM surpasses them in performance. It consistently records the lowest and most accurate scores for prediction accuracy metrics, including MAE, RMSE, MDAPE, and MAPE, among the three models. This research has been confined by certain limitations: Time constraints: It focuses on datasets relevant to the COVID-19 period's duration; Scope limitations: It does not incorporate external variables like political and logistical issues or investor opinions and sentiments; Feasibility: The model predicts stock closing prices for only the next five days, offering limited utility for investors seeking longer-term predictions.

Future research should attempt to enhance prediction accuracy by integrating the Multivariate Multi-step CNN-BiLSTM model with other deep learning technologies and incorporating a wider range of quantitative and qualitative variables as inputs for the prediction model. Additionally, the integration of an attention mechanism (AM) technology could further improve the model's ability to capture complex patterns and relationships within the data. The

attention mechanism, in particular, helps reduce noise and can improve performance on sequence-based tasks, thereby contributing to more robust and accurate forecasts. These conclusions can be utilized by the active economic players, policy makers, corporations, and individuals to have better outlooks in relation to their economic predictions, opportunities and costs, and consumer behavior, leading to better insights in relation to GDP, economic growth, inflation, unemployment, and economic outputs of economies and individuals.

Data Availability

The data presented in this study are available on request from the corresponding author due to restrictions privacy.

Conflicts of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this paper.

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References

Ahmed, D. M., Hassan, M. M., & Mstafa, R. J. (2022). A review on deep sequential models for forecasting time series data. *Applied Computational Intelligence and Soft Computing*, *2022*. https://doi.org/10.1155/2022/6596397

Chen, Y., Fang, R., Liang, T., Sha**,** Z., Li, S., Yi, Y., Zhou, W., & Song, H. (2021). Stock price forecast based on CNN-BiLSTM-ECA model. *Scientific Programming*, *2021*. https://doi.org/10.1155/2021/2446543

Gerritzen, J., Hornig, A., Winkler, P., & Gude, M. (2024). A methodology for direct parameter identification for experimental results using machine learning - Real world application to the highly non-linear deformation behavior of FRP. *Computational Materials Science*, *244*. https://doi.org/10.1016/j.commatsci.2024.113274

He, Z., Zhou, J., Dai, H.-N., & Wang, H. (2019). Gold price forecast based on LSTM-CNN model. In *2019 IEEE International Conference on Dependable, Autonomic and Secure Computing; Pervasive Intelligence and Computing; Cloud and Big Data Computing; Cyber Science and Technology Congress (DASC/PiCom/CBDCom/CyberSciTech)* (pp. 1046-1053). Fukuoka, Japan. https://doi.org/10.1109/DASC/PiCom/CBDCom/CyberSciTech.2019.00188

Hochreiter, S., & Schmidhuber, J. (1997). Long short-term memory. *Neural Computation*, *9*(8), 1735–1780. https://doi.org/10.1162/neco.1997.9.8.1735

Joshi, V. M., Ghongade, R. B., Joshi, A. M., & Kulkarni, R. V. (2022). Deep BiLSTM neural network model for emotion detection using cross-dataset approach. *Biomedical Signal Processing and Control*, *73*. https://doi.org/10.1016/j.bspc.2021.103407

LeCun, Y., Bottou, L., Bengio, Y., & Haffner, P. (1998). Gradient-based learning applied to document recognition. *Proceedings of the IEEE*, *86*(11), 2278–2324. https://doi.org/10.1109/5.726791

Lu, W., Li, J., Li, Y., Sun, A., & Wang, J. (2020). A CNN-LSTM-based model to forecast stock prices. *Complexity*, *2020*. https://doi.org/10.1155/2020/6622927

Md, A. Q., Kapoor, S., Junni, C. A. V., Sivaraman, A. K., Tee, K. F., Sabireen, H., & Janakiraman, N. (2023). Novel optimization approach for stock price forecasting using multi-layered sequential LSTM. *Applied Soft Computing*, *134*. https://doi.org/10.1016/j.asoc.2022.109830

Peng, Y., Han, Q., Su, F., He, X., & Feng, X. (2021). Meteorological satellite operation prediction using a BiLSTM deep learning model. *Security and Communication Networks*, *2021*. https://doi.org/10.1155/2021/9916461

Rashmi, C. R., & Shantala, C. P. (2024). Evaluating deep learning with different feature scaling techniques for EEG-based music entrainment brain computer interface. *e-Prime - Advances in Electrical Engineering, Electronics and Energy*, *7*. https://doi.org/10.1016/j.prime.2024.100448

Seabe, P. L., Moutsinga, C. R. B., & Pindza, E. (2023). Forecasting cryptocurrency prices using LSTM, GRU, and bi-directional LSTM: A deep learning approach. *Fractal and Fractional*, *7*(2), 203. https://doi.org/10.3390/fractalfract7020203

Tok, V., & Ece, N. J. (2022). The impact of COVID-19 on maritime trade and transportation: An estimation of the maritime trade post-COVID-19. *Mersin University Journal of Maritime Faculty*, *4*(2), 18–30. https://doi.org/10.47512/meujmaf.1200009

United Nations Conference on Trade and Development. (2021, November). *Freight rates, maritime transport costs and their impact on prices*. https://unctad.org/system/files/official-document/rmt2021ch3_en.pdf

Wang, H., Wang, J., Cao, L., Li, Y., Sun, Q., & Wang, J. (2021). A stock closing price prediction model based on CNN-BiSLSTM. *Complexity*, *2021*. https://doi.org/10.1155/2021/5360828

Wen, X., Jaxa-Rozen, M., & Trutnevyte, E. (2022). Accuracy indicators for evaluating retrospective performance of energy system models. *Applied Energy*, *325*. https://doi.org/10.1016/j.apenergy.2022.119906

Widiputra, H., Mailangkay, A., & Gautama, E. (2021). Multivariate CNN-LSTM model for multiple parallel financial time-series prediction. *Complexity*, *2021*. https://doi.org/10.1155/2021/9903518

World Health Organization. (2021). *An implementation guide for the management of COVID-19 on board cargo ships and fishing vessels*. https://iris.who.int/bitstream/handle/10665/350941/WHO-2019-nCoV-Non-passenger_ships-2021.1-eng.pdf

Yang, C., Zhai, J., & Tao, G. (2020). Deep learning for price movement prediction using convolutional neural network and long short-term memory. *Mathematical Problems in Engineering*, *2020*. https://doi.org/10.1155/2020/2746845

Yang, C.-H., & Chang, P.-Y. (2020). Forecasting the demand for container throughput using a mixed-precision neural architecture based on CNN–LSTM. *Mathematics*, *8*(10), 178. https://doi.org/10.3390/math8101784

Yang, M., & Wang, J. (2022). Adaptability of financial time series prediction based on BiLSTM. *Procedia Computer Science*, *199*, 1–8. https://doi.org/10.1016/j.procs.2022.01.003

Zain, Z. M., & Alturki, N. M. (2021). COVID-19 pandemic forecasting using CNN-LSTM: A hybrid approach. *Journal of Control Science and Engineering*, *2021*. https://doi.org/10.1155/2021/8785636

Zhang, J., Ye, L., & Lai, Y. (2023). Stock price prediction using CNN-BiLSTM-Attention model. *Mathematics*, *11*(9). https://doi.org/10.3390/math11091985

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ANTIFRAGILITY MODEL DEVELOPMENT FOR BUSINESSES IN THE COSMETICS INDUSTRY

Iulia IVAȘCENCO*[1]

Abstract: *This paper explores how antifragility principles can be applied in the cosmetics industry to turn uncertainty and crises into opportunities for growth, innovation, and long-term resilience. Unlike traditional risk management, which focuses on minimizing disruption, antifragile business models thrive under volatility by embracing proactive adaptation, decentralized supply chains, sustainable innovation, and digital transformation. Drawing on case studies from leading firms such as L'Oréal, Estée Lauder, Shiseido, P&G, and Coty, the study identifies key decision-making approaches - including scenario planning, agile strategy shifts, and crisis response mechanisms - that support business agility in uncertain environments. Extending the analysis to emerging economies, particularly Moldova and Eastern Europe, the research examines how firms facing limited capital, regulatory uncertainty, and market constraints can adapt global antifragility strategies to their local contexts. The findings emphasize the importance of supply chain diversification, digitalization, and sustainability-focused consumer engagement in enhancing competitiveness. By offering a structured framework grounded in industry practices and secondary data, this study contributes to the literature on resilience, crisis management, and business strategy. Future research should validate these findings through empirical studies and comparative analyses. Ultimately, the paper argues that antifragile firms are not only more adaptive, but also better positioned for sustainable success in a complex global economy.*

Keywords: *antifragility, resilience, crisis management, cosmetics industry, digital transformation, sustainability, emerging markets.*

JEL Code: *L10, M10, O30, F61, Q56.*

UDC: *[687.55:005.334]:004*

Introduction

The cosmetics industry is one of the most competitive and rapidly evolving global markets, driven by changing consumer preferences, technological advancements, and economic fluctuations. With a market size exceeding $300 billion in 2023 and a projected annual growth rate of 3.96% through 2030, the sector continuously adapts to economic crises, regulatory changes, and digital transformations (Euromonitor International, 2023; Statista, 2025). Traditional risk management approaches that focus solely on resilience are often insufficient, as companies that merely endure disruptions without evolving risk losing market share and stagnating in the long term.

The concept of antifragility, introduced by Taleb (2012), offers a strategic alternative by proposing that businesses can improve and expand when exposed to volatility. Rather than resisting uncertainty, antifragile companies use crises as opportunities to innovate, diversify, and strengthen their market position. The COVID-19 pandemic provided a strong example of antifragility in the cosmetics industry (Ivașcenco, 2022). While some brands suffered supply

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chain disruptions and decreased in-store sales, L'Oréal, Estée Lauder, and Shiseido capitalized on the crisis by expanding e-commerce, offering virtual beauty consultations, and adopting AI-driven product personalization (Estée Lauder, 2022; L'Oréal, 2022; Shiseido, 2022). Their ability to turn disruption into opportunity underscores the necessity of antifragile strategies in today's volatile business environment.

For emerging economies, antifragility is even more critical, as businesses often operate in unstable regulatory, financial, and political environments (Ivașcenco, 2023b, 2024). Companies in India and Brazil have demonstrated that antifragile strategies - such as market diversification, digital transformation, and sustainability-driven innovation - can drive growth despite economic challenges (Hindustan Unilever Limited - Subsidiary Companies, 2022; Nykaa, 2022; O Boticário, 2022). By drawing insights from these cases, this study examines how cosmetics firms in Moldova and Eastern Europe can implement antifragility principles to navigate uncertainty and sustain long-term growth.

This research explores three key questions: first, what defines an antifragile business model in the cosmetics industry? Understanding the fundamental characteristics of antifragility can provide insights into how businesses can thrive under uncertainty (Hamel & Zanini, 2020). Second, how do leading cosmetics companies apply antifragility in practice? Global firms such as L'Oréal, Procter & Gamble, and Unilever have successfully embraced sustainability, digitalization, and portfolio diversification to manage risk and expand into new markets (L'Oréal, 2022; Procter & Gamble, 2022; Unilever, 2021). Examining their strategic responses provides a framework for decision-making under uncertainty. Lastly, this research asks how Moldovan and Eastern European firms can adapt global antifragile strategies to their unique economic conditions, where financial constraints and regulatory shifts pose additional challenges (BNP Paribas, 2025; International Monetary Fund, 2024; World Bank, 2024).

This paper contributes to both academic and business strategy discussions by combining theoretical insights with real-world industry applications. It provides a structured framework for identifying antifragile business principles, offering practical recommendations for firms operating in uncertain environments. The study is structured as follows: the second chapter outlines the research methodology, the third chapter examines the literature on antifragility and its application in business, and the fourth chapter presents key findings on antifragile strategies in the cosmetics sector. The fifth chapter extends this analysis to developing economies, and the final chapter summarizes key insights and highlights directions for future research.

By integrating antifragility theory, industry case studies, and strategic decision-making models, this research aims to demonstrate how cosmetics businesses can move beyond resilience to actively benefit from economic and market volatility.

Methodology

This study employs a systematic literature review (SLR) methodology, following established academic protocols for transparency, reproducibility, and comprehensiveness

(Nightingale, 2009). The goal of this SLR is to synthesize existing research on antifragility in the cosmetics industry, particularly with regard to resilience, crisis management, and strategic business adaptation. The interdisciplinary nature of antifragility necessitates a diverse approach to literature and industry analysis, integrating insights from organizational theory, strategic management, digital transformation, and sustainability studies (Furr, Nathan, Harmon Furr, & Susannah, 2022).

Step 1: Research Design and Database Selection

Relevant academic databases - Google Scholar, Scopus, Web of Science, and SSRN - were selected for their comprehensive coverage of peer-reviewed journals and working papers. The search strategy employed Boolean operators and combinations of keywords including: "antifragility", "resilience", "cosmetics industry", "crisis management", "business model innovation", "supply chain diversification", and "digital transformation".

Step 2: Inclusion and Exclusion Criteria

Only publications from 2010–2024 were considered. Inclusion criteria focused on peer-reviewed journal articles, industry reports, and case studies that explicitly addressed antifragility-related concepts in business strategy or operations. Excluded were articles lacking empirical or theoretical rigor, and those unrelated to strategic responses to uncertainty.

Step 3: Source Triangulation

To ensure a balanced view, data were triangulated using academic literature and practitioner sources such as industry whitepapers, consulting firm analyses (e.g., McKinsey & Company, Boston Consulting Group, Deloitte), and annual reports from companies operating in the cosmetics sector (e.g., L'Oréal, Estée Lauder, Shiseido, Coty, Natura & Co).

Step 4: Thematic Analysis

A four-step thematic coding procedure was used to identify core themes. First, sources were imported into a spreadsheet and labeled by topic. Second, key strategies, patterns, and frameworks were extracted through content analysis. Third, codes were grouped into categories such as "digital transformation", "supply chain agility", "sustainability", and "consumer-centric resilience". Finally, these categories were synthesized into a conceptual framework for antifragile business models.

Step 5: Model Development

Findings from the thematic analysis were used to construct a conceptual model presented in Table 1. This model maps ten strategic components of antifragility and links them to real-world examples from the cosmetics industry.

Limitations

The study does not include primary data collection, such as interviews, surveys, or firm-level financial modeling. This limits empirical validation of the conceptual framework. Additionally, reliance on publicly available secondary data may not reflect unpublished innovations or confidential strategic responses (Euromonitor International, 2023). Future

research should address these gaps through longitudinal case studies or comparative analyses of antifragile and non-antifragile firms.

Despite these limitations, this methodology ensures a rigorous, multi-source synthesis of antifragility strategies in the global cosmetics sector, offering actionable insights for both academic and industry audiences.

Literature Review

1. The Concept of Antifragility

The concept of antifragility, introduced by Nassim Nicholas Taleb (2012) in *Antifragile: Things That Gain from Disorder*, extends his earlier work on risk, uncertainty, and randomness. Unlike traditional risk management, which focuses on resilience - the ability to withstand crises without fundamental change - antifragility suggests that some systems improve and strengthen when exposed to volatility, stress, and uncertainty. This idea challenges conventional business strategies by proposing that companies should not only endure instability but also use it as a mechanism for growth and innovation.

A fundamental distinction Taleb makes is between fragility, resilience, and antifragility. A fragile system is vulnerable to shocks, such as a business that collapses under financial crisis or supply chain disruptions. Resilience, while an improvement, merely allows a system to absorb shocks and return to its previous state without significant evolution. Antifragility, however, enables an organization to gain strength from challenges, much like muscles growing through resistance training or biological systems adapting to environmental stressors (Taleb, 2012).

In business, antifragility is reflected in companies that use uncertainty as a driver of innovation and market expansion. Unlike firms that avoid risk, antifragile companies actively engage with volatility to refine their strategies, enhance operational efficiency, and develop new competitive advantages. This is particularly relevant in industries with high competition and rapid shifts, such as the cosmetics sector, where firms must navigate changing consumer preferences, regulatory updates, and technological disruptions. Businesses that embrace antifragility view uncertainty as an opportunity for transformation rather than a threat.

Historical evidence supports this approach. During the 2008 financial crisis, companies that prioritized adaptability and diversification outperformed those with rigid, risk-averse strategies. Similarly, in the cosmetics industry, firms that leveraged e-commerce and digital transformation during the COVID-19 pandemic rebounded quickly, while brands reliant on brick-and-mortar retail struggled to recover (Estée Lauder, 2022; Euromonitor International, 2023; L'Oréal, 2022; Shiseido, 2022).

Antifragility is increasingly relevant in today's global economy, where digital disruption, supply chain instability, and economic uncertainty demand flexible and responsive business models. Research highlights that organizations fostering a culture of experimentation, decentralization, and redundancy are better equipped to adapt swiftly to market fluctuations (Hamel & Zanini, 2020). This distinction between resilience and antifragility is crucial for

strategic decision-making. While resilient firms prepare for crises by maintaining financial reserves and diversifying supply chains, antifragile companies seek asymmetric opportunities that allow them to benefit from volatility (Ramezani & Camarinha-Matos, 2020).

For example, leading cosmetics brands are investing in AI-driven personalization, blockchain for supply chain transparency, and sustainability initiatives, positioning themselves for long-term success despite market instability. By understanding the core principles of antifragility, businesses can develop strategic frameworks that transform uncertainty into a competitive advantage.

2. Business Applications of Antifragility

The concept of antifragility has become increasingly relevant in business strategy, particularly as organizations seek to navigate uncertainty and volatility in competitive markets. Unlike traditional approaches that emphasize stability and risk minimization, antifragility proposes that companies can benefit from disorder, using crises as opportunities for innovation and transformation. Management literature highlights key antifragile principles, such as decentralization, redundancy, and optionality, which improve an organization's ability to adapt to unpredictable challenges (Taleb, 2012). While conventional risk management focuses on mitigating negative impacts, antifragility-oriented strategies actively leverage crises to drive growth.

Theoretical models suggest that uncertainty can serve as a catalyst for strategic evolution. Research indicates that antifragile firms embrace experimentation and adaptability, enabling them to develop competitive advantages in volatile environments (Hamel & Zanini, 2020). This perspective aligns with real options theory, which argues that businesses maintaining flexibility in decision-making are better prepared for market shifts (Settembre-Blundo, González-Sánchez, Medina-Salgado, & García-Muiña, 2021). Many antifragile firms structure themselves modularly and decentral, allowing them to respond rapidly to changes without overhauling their entire business model. These organizations focus on continuous innovation, ensuring they evolve in response to market disruptions rather than merely recovering from them.

The difference between resilience and antifragility is crucial in understanding how firms react to crises. Resilient companies withstand shocks and recover, often returning to pre-crisis conditions. They emphasize risk mitigation strategies, such as financial reserves, supply chain diversification, and crisis management protocols. However, resilience does not inherently lead to long-term improvement. Antifragile companies, by contrast, emerge stronger from volatility, treating market shocks as triggers for transformation and expansion (Estée Lauder, 2022; L'Oréal, 2022; Shiseido, 2022).

Case studies illustrate how different industries have successfully applied antifragile principles. The technology sector is a notable example, where companies like Amazon, Google, and Tesla leverage uncertainty to refine their business models and expand aggressively. Rather than adopting defensive postures, these firms thrive by iterating products, decentralizing decision-making, and embracing rapid innovation cycles. Similarly, the financial sector,

particularly hedge funds using barbell strategies, balances low-risk assets with high-reward opportunities, ensuring adaptability in volatile markets (Taleb, 2012).

The cosmetics industry has also demonstrated antifragility, particularly during the COVID-19 pandemic, when traditional retail models faced severe disruption. L'Oréal, Estée Lauder, and Shiseido rapidly accelerated digital transformation efforts, using AI-driven personalization, virtual consultations, and direct-to-consumer e-commerce to compensate for declining in-store sales (Estée Lauder, 2022; Euromonitor International, 2023; L'Oréal, 2022; Shiseido, 2022). Instead of merely surviving the downturn, these firms expanded their digital presence and redefined consumer engagement, strengthening their market positions. The shift toward omnichannel retailing and supply chain diversification illustrates how antifragile businesses capitalize on volatility rather than simply endure it.

A similar pattern can be observed in the automotive industry, where firms that embraced electric vehicle (EV) innovation during market downturns positioned themselves as long-term industry leaders. Companies like Tesla and BYD used regulatory changes, supply chain crises, and shifting consumer preferences to expand market share, rather than seeing these challenges as obstacles. Their ability to exploit market uncertainties to drive industry-wide transformations is a hallmark of antifragile strategy.

Antifragility is also evident in healthcare and biotechnology, where R&D-driven firms have leveraged crisis-driven demand shifts. The rapid development of mRNA vaccines by Pfizer and Moderna during the COVID-19 pandemic exemplifies how businesses that integrate adaptive innovation and decentralized production into their core strategies thrive under extreme uncertainty (Groth, 2023). By investing in pre-existing research and flexible production networks, these firms did not just recover from the crisis but strengthened their long-term market dominance.

While resilience remains a critical aspect of business strategy, today's economic landscape increasingly rewards organizations that move beyond resilience and leverage uncertainty as a competitive advantage. Companies fostering an antifragile culture invest in decentralized decision-making, flexible systems, and adaptive innovation. Understanding how different industries have successfully integrated antifragility allows businesses in the cosmetics sector to adopt similar approaches, ensuring they do not merely withstand disruptions but emerge stronger and more competitive in the process.

3. Antifragility in the Cosmetics Industry

The cosmetics industry is highly dynamic, shaped by changing consumer preferences, technological advancements, regulatory shifts, and macroeconomic fluctuations. Companies in this sector must navigate instability while maintaining a competitive edge, making antifragility a crucial factor for long-term success. Unlike businesses that focus solely on resilience, antifragile firms leverage crises and volatility as catalysts for innovation and expansion. Leading global brands such as L'Oréal, Estée Lauder, Shiseido, Procter & Gamble, and Coty have successfully incorporated digital transformation, diversification, and sustainable

innovation into their business models, allowing them to emerge stronger from crises such as the COVID-19 pandemic and economic downturns (Coty, 2022; Estée Lauder, 2022; L'Oréal, 2022; Procter & Gamble, 2022; Shiseido, 2022).

The COVID-19 crisis significantly disrupted traditional brick-and-mortar retail, forcing cosmetics companies to accelerate their digital transformation. L'Oréal expanded its direct-to-consumer (DTC) platforms, integrating AI-powered virtual beauty consultations, AR makeup try-on tools, and AI-driven skin diagnostics to maintain customer engagement despite store closures (L'Oréal, 2022). Estée Lauder adopted a similar strategy, enhancing its online sales channels and AI-driven personalization while adjusting its product offerings to reflect growing demand for skincare and self-care during lockdowns (Estée Lauder, 2022; Euromonitor International, 2023). Shiseido, a leader in the Asian beauty market, strengthened its e-commerce capabilities and expanded into health and wellness products, recognizing the increasing consumer preference for holistic beauty solutions (Shiseido, 2022).

Procter & Gamble leveraged its diversified portfolio and supply chain resilience to navigate economic downturns. Its broad range of beauty, skincare, and household products provided a natural hedge against market fluctuations. By utilizing real-time consumer analytics, Procter & Gamble optimized production and marketing strategies, ensuring it could rapidly adapt to shifting consumer demands while maintaining supply chain agility (Procter & Gamble, 2022). Coty, which faced significant declines in fragrance sales during the pandemic, pivoted towards digital commerce and influencer marketing, forming strategic partnerships with high-profile influencers and celebrities to engage younger consumers on social media platforms like Instagram and TikTok (Coty, 2023).

The antifragility of these companies is evident in three key strategic initiatives: digital transformation, diversification, and sustainability-driven innovation. The integration of AI, AR, and machine learning has allowed brands to enhance customer experiences, optimize supply chains, and improve demand forecasting. Companies that had already adopted omnichannel retailing and direct-to-consumer models capitalized on changing consumer behaviors during economic disruptions.

Diversification also played a pivotal role in antifragility. Firms reliant on a single product category or distribution channel faced greater risks during crises. In contrast, L'Oréal, Estée Lauder, and Shiseido expanded into skincare, haircare, fragrances, and wellness products, mitigating risks associated with shifts in individual product segments (L'Oréal, 2022; Shiseido, 2022). This ability to expand into adjacent markets allowed them to capture new revenue streams and strengthen their resilience.

Sustainability has emerged as another pillar of antifragility. Companies that proactively adopt eco-friendly formulations, ethical sourcing, and carbon-neutral initiatives strengthen their long-term market positioning while meeting rising consumer expectations and regulatory standards. L'Oréal aims to achieve carbon neutrality across all its production sites by 2025, while Shiseido continues investing in biodegradable and cruelty-free cosmetics (Coty, 2022;

L'Oréal, 2022). Sustainability-driven innovation enhances brand loyalty and ensures compliance with evolving environmental regulations.

The cosmetics industry illustrates that antifragility is not just about survival but about strategic evolution. By embracing digital transformation, product diversification, and sustainability, leading brands have transformed crises into opportunities for growth. These strategic shifts not only enabled companies to navigate short-term disruptions but also positioned them for long-term success in an increasingly volatile global market.

4. Antifragility in Emerging Markets

Emerging markets pose distinct challenges and opportunities for businesses navigating economic instability, regulatory fluctuations, and evolving consumer preferences. Unlike developed economies, where institutional support provides stability, companies in emerging markets must adopt antifragile strategies to ensure long-term growth. The cosmetics industries in India and Brazil provide compelling examples of how businesses leverage uncertainty, transform operations, and capitalize on market dynamics to strengthen their market position.

The Indian cosmetics industry has experienced rapid growth, driven by rising consumer spending, digitalization, and demand for locally produced beauty products. Despite economic disruptions, brands such as Nykaa, Lakmé, and Himalaya Herbals have demonstrated remarkable adaptability. Nykaa, an e-commerce beauty retailer, exemplifies antifragility by integrating digital innovation and consumer-centric marketing. When COVID-19 lockdowns disrupted traditional retail, Nykaa accelerated its investment in online platforms, expanded its in-house beauty brands, and leveraged influencer marketing, securing a larger market share despite economic downturns (Euromonitor International, 2023; Nykaa, 2022).

Similarly, Lakmé, a dominant domestic brand, has strengthened its antifragility through multi-channel distribution, direct-to-consumer models, and exclusive brand stores (Hindustan Unilever Limited - Subsidiary Companies, 2022). This strategy allowed it to remain competitive during economic downturns while investing in sustainable beauty innovation. The brand's ability to anticipate consumer trends and quickly adjust its product offerings underscores the importance of strategic flexibility in antifragile business models.

The Brazilian cosmetics industry, one of Latin America's largest, also demonstrates antifragility through sustainability and omnichannel retailing. Companies such as Natura & Co, O Boticário, and Grupo Boticário have turned economic volatility into opportunities for innovation. Natura & Co, for example, leveraged crises to reinforce its commitment to sustainability and ethical sourcing. By integrating eco-friendly practices and expanding direct sales, it built a business model resilient to market disruptions and supply chain volatility (Natura & Co, 2022).

O Boticário, facing declining in-store traffic during economic slowdowns, enhanced its online presence, introduced virtual consultations, and invested in AI-driven personalization. These initiatives strengthened customer engagement and brand loyalty despite economic contractions (O Boticário, 2022). Similarly, Grupo Boticário has

capitalized on Brazil's biodiversity and consumer preference for natural beauty, investing in sustainable sourcing of Amazonian ingredients. This differentiation not only bolstered its brand positioning but also insulated it from economic volatility, aligning with the global shift toward ethical and organic beauty products.

The strategies of Indian and Brazilian cosmetics firms demonstrate that antifragility is a practical necessity in volatile environments. By embracing digital transformation, revenue diversification, and sustainability, these companies turned market disruptions into growth opportunities. Their approaches offer valuable insights for businesses in other emerging markets, including Eastern Europe, where similar adaptive strategies can ensure resilience and long-term success.

5. Antifragility in Moldova and Eastern Europe

The concept of antifragility is particularly relevant in small-market economies such as Moldova and Eastern Europe, where businesses face economic volatility, political uncertainty, and supply chain disruptions. Unlike larger, diversified economies, these countries are more vulnerable to global financial instability due to limited industrial capacity, reliance on external markets, and dependence on remittances. While resilience focuses on recovery, antifragility emphasizes leveraging crises for growth and innovation, making it a more effective long-term strategy.

A major challenge in Moldova is restricted access to capital, which limits SMEs' ability to invest in innovation, technology, and expansion (World Bank, 2024). Many firms operate in import-dependent industries, making them highly susceptible to currency fluctuations and trade restrictions. To counteract this, companies can adopt antifragile strategies such as revenue diversification, digital transformation, and flexible supply chain models to mitigate external risks.

Another critical issue is brain drain, where skilled professionals migrate to Western Europe for better opportunities. This talent shortage hinders business scalability and competitiveness. However, antifragile companies adapt by implementing remote work models, automation, and workforce upskilling programs to retain talent. Businesses that embrace flexible working conditions and digital solutions are better positioned to attract and retain professionals despite demographic challenges (Boc, 2020).

Several strategic adaptations can enhance antifragility for Moldovan firms. Digital transformation and e-commerce allow businesses to reduce dependence on physical infrastructure and access international markets. AI-driven marketing, online marketplaces, and digital payments help companies expand beyond domestic limitations. In the cosmetics sector, brands leveraging direct-to-consumer platforms and personalized digital marketing are more resilient than those dependent on traditional retail channels (Ivașcenco, 2023a).

Another critical factor is market diversification, ensuring businesses do not over-rely on a single sector or export market. Many Moldovan firms remain highly concentrated in specific trade relationships, increasing their exposure to regional economic fluctuations. Companies that establish cross-industry partnerships, alternative revenue streams, and flexible product lines can

better absorb shocks. Expanding regional trade networks and value-added services creates additional buffers against economic crises while unlocking growth potential (Otarinia, 2024).

Sustainability-driven business models are also crucial for antifragility. The global shift toward green technologies, ethical sourcing, and circular economies presents opportunities for Moldovan businesses. With a strong agricultural sector, companies can adopt eco-friendly production, renewable energy, and ethical sourcing to align with EU sustainability trends, strengthening competitiveness in export markets. The demand for sustainable cosmetics and personal care products continues to grow, making it a viable strategy for long-term success (Statista, 2025).

Agile supply chain strategies further reinforce antifragility in Moldova and Eastern Europe. Many companies face logistical constraints due to geographic isolation and import dependency. Firms that develop local supplier networks, nearshoring opportunities, and AI-powered logistics solutions gain flexibility in managing disruptions. Blockchain transparency and real-time supply chain analytics provide businesses with adaptive capabilities to respond to trade and transportation challenges (Ezzat & Aiman, 2023).

Ultimately, embracing antifragility in Moldova requires a shift in mindset, moving from crisis avoidance to leveraging uncertainty as a strategic advantage. Companies that integrate digitalization, diversified revenue models, sustainability initiatives, and supply chain agility will thrive despite economic instability. As Moldova strengthens its economic ties with European and global markets, businesses that proactively adopt antifragile strategies will be well-positioned for sustained growth and market expansion.

Findings: The Antifragility Model for the Cosmetics Industry

1. Key Principles of an Antifragile Business Model

The cosmetics industry operates in a highly volatile environment, shaped by consumer trends, regulatory shifts, and technological advancements. Companies that adopt an antifragile approach do not merely withstand disruptions but use them as opportunities for growth. The development of an antifragile business model relies on *proactive adaptation, decentralized supply chains, sustainable innovation, and digital transformation.* These principles help firms capitalize on uncertainty, minimize risks, and gain a competitive edge in an industry where agility is crucial for long-term success (Estée Lauder, 2022; L'Oréal, 2022; Shiseido, 2022).

Proactive adaptation allows businesses to anticipate disruptions rather than react to them. Cosmetics companies that monitor emerging trends and regulatory shifts can quickly adapt, turning potential threats into opportunities. For instance, L'Oréal and Estée Lauder incorporated sustainable packaging and clean beauty formulations in response to rising consumer demand for eco-friendly products. By acting before regulatory mandates, these firms gained an early-mover advantage and strengthened their market position (Estée Lauder, 2022; Euromonitor International, 2023; L'Oréal, 2022). Dynamic pricing, agile marketing,

and diversified sourcing strategies further enhance flexibility, enabling firms to respond swiftly to market fluctuations.

Decentralization and redundancy are critical for supply chain resilience. The cosmetics industry relies on global supply networks, making companies vulnerable to trade restrictions, geopolitical risks, and pandemics. Traditional cost-efficient supply chains have proven fragile, as seen during COVID-19 disruptions. Companies like Shiseido have diversified production across multiple regions, ensuring that local disruptions do not cripple global operations (Shiseido, 2022). Multi-supplier sourcing and regional manufacturing hubs further reduce dependency on single supply chains, enabling firms to adapt when primary suppliers face constraints.

Sustainable innovation is another pillar of antifragility. As regulatory requirements and consumer preferences evolve, investing in green chemistry, bio-based formulations, and ethical sourcing helps future-proof businesses. Companies such as Natura & Co and The Body Shop have incorporated biodegradable packaging and carbon-neutral production, aligning with global sustainability trends (Natura & Co, 2022; Warsita & Indriastuti, 2021). Beyond risk mitigation, these initiatives create new revenue streams, appeal to eco-conscious consumers, and reduce exposure to volatile commodity markets. Sustainability also enhances brand equity, as consumers increasingly prioritize ethical business practices (Ezzat & Aiman, 2023).

Digital transformation is essential for consumer engagement, operational efficiency, and market expansion. AI, AR, blockchain, and big data analytics enhance antifragility by allowing companies to personalize consumer experiences and optimize supply chains. AI-driven personalization enables brands to offer customized product recommendations, predictive trend analysis, and targeted marketing, strengthening customer loyalty. Companies like Estée Lauder and Sephora use AI-powered skincare diagnostics and virtual makeup try-on tools, allowing consumers to shop despite physical store closures (Estée Lauder, 2022; Sephora, 2021).

Blockchain technology further enhances antifragility by ensuring supply chain transparency and counterfeit prevention. Counterfeit cosmetics pose significant brand risks, especially in markets with high fraud levels. Blockchain-based authentication helps trace raw material origins, verify ethical sourcing, and prevent counterfeit sales, reinforcing consumer trust (Bai & Sarkis, 2020).

Augmented reality strengthens antifragility by offering immersive digital shopping experiences. With the decline of in-store testing during COVID-19, AR-powered tools allowed customers to virtually apply makeup, experiment with shades, and receive online beauty consultations. This shift redefined omnichannel retail strategies, ensuring brands remain resilient to evolving consumer behavior (Euromonitor International, 2023).

Building on the theoretical framework discussed, Table 1 presents a structured conceptual model outlining the key components of antifragile business models in the cosmetics industry, integrating insights from existing research and industry practices.

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Table 1. Conceptual Model of Antifragility in the Cosmetics Industry

Key component	Function	Implementation Strategies	Examples from the Cosmetics Industry
Proactive adaptation	Anticipating and responding to consumer trends, regulatory changes, and market disruptions before they occur.	- Continuous market research and trend forecasting - Agile product innovation - Regulatory foresight and compliance planning	- L'Oréal's early adoption of clean beauty trends before regulatory mandates - Estée Lauder's pivot to skincare-focused products during COVID-19 lockdowns
Decentralized supply chains	Reducing reliance on a single supplier or region, increasing flexibility to respond to disruptions.	- Multi-supplier sourcing strategies - Regional manufacturing hubs - AI-powered supply chain analytics	- Shiseido's regionalized production hubs to minimize global supply chain risks - P&G's nearshoring approach to reduce logistics disruptions
Sustainability-driven innovation	Ensuring long-term business resilience by integrating environmental and ethical considerations into core business models.	- Investment in biodegradable and eco-friendly packaging - Carbon-neutral production initiatives - Ethical sourcing and cruelty-free certification	- Natura & Co's investment in carbon-neutral operations and biodegradable packaging - The Body Shop's commitment to cruelty-free formulations
Digital transformation	Enhancing operational efficiency and consumer engagement through technology adoption.	- AI-driven product personalization - Blockchain for supply chain transparency - Augmented reality for virtual product trials	- Estée Lauder's AI-driven personalization and virtual beauty consultations - Sephora's AR-powered Virtual Artist tool for makeup try-ons
Decision-making under uncertainty	Developing agility in business strategy through scenario planning and risk management.	- AI-powered predictive analytics for demand forecasting - Dynamic pricing models - Crisis management playbooks	- P&G's scenario-based forecasting for adapting to economic downturns - L'Oréal's dynamic pricing model based on consumer demand fluctuations
Revenue diversification	Reducing dependence on a single product line or market segment to ensure financial stability.	- Expansion into adjacent product categories - Omnichannel sales approach (physical and digital retail) - Subscription-based business models	- Coty's expansion into digital commerce and influencer-driven marketing - L'Oréal's entry into dermatological skincare and active cosmetics
Consumer-centric resilience	Strengthening brand loyalty and market adaptability through direct consumer engagement and community-driven strategies.	- Direct-to-consumer (DTC) sales models - Data-driven customer segmentation - Personalized loyalty programs and digital engagement	- Sephora's Beauty Insider loyalty program enhancing repeat purchases - Estée Lauder's AI-driven consumer behavior analysis for targeted marketing
Financial agility and risk mitigation	Ensuring liquidity and operational flexibility during economic downturns.	- Maintaining financial reserves and low debt ratios - Flexible budgeting for crisis response - Strategic M&A to	- L'Oréal's acquisition of emerging clean beauty brands to strengthen market position - P&G's diversified portfolio balancing premium and mass-market segments

Key component	Function	Implementation Strategies	Examples from the Cosmetics Industry
		capitalize on distressed assets	
Market expansion and global adaptation	Adapting business models for emerging markets and new consumer segments to mitigate risk exposure.	- Localization of product offerings - Strategic partnerships with regional retailers - Influencer marketing tailored to cultural preferences	- Shiseido's expansion into Southeast Asia with region-specific product formulations - Nykaa's use of local influencers in India to drive online beauty sales
Crisis response and recovery mechanisms	Turning disruptions into opportunities for market repositioning and innovation.	- Rapid shifts to digital-first business models - Agile workforce and remote operations strategies - Investment in crisis-proof supply chains	- Estée Lauder's digital pivot and virtual consultations during COVID-19 - Sephora's ability to quickly shift marketing to self-care trends during lockdowns

Source: elaborated by the author.

The antifragility model in cosmetics relies on proactive adaptation, decentralized supply chains, sustainable R&D, and digital innovation. Companies that integrate these principles do not merely survive crises but emerge stronger and more competitive. Future-proofing the cosmetics sector requires continuous investment in innovation and agility, ensuring businesses remain adaptable amid uncertainty.

2. Decision-Making Under Uncertainty

In the cosmetics industry, decision-making under uncertainty is crucial for long-term success. Global supply chain disruptions, shifting consumer preferences, and economic crises have shown that traditional risk mitigation is insufficient. Instead, antifragile decision-making - which enables businesses to improve through disruptions - offers a more effective strategy. The key components of this approach include *risk management and scenario planning, agile strategy adjustments, and crisis response mechanisms.* These elements help companies proactively navigate volatility and turn challenges into growth opportunities.

Risk management and scenario planning form the foundation of antifragile decision-making. Unlike conventional strategies that focus on minimizing damage, antifragile firms identify strategic opportunities in volatile markets. Leading brands such as L'Oréal, Estée Lauder, and Shiseido use data analytics, AI-driven forecasting, and scenario modeling to anticipate economic downturns, supply chain risks, and changes in consumer demand (Estée Lauder, 2022; L'Oréal, 2022; Shiseido, 2022). The COVID-19 pandemic underscored the value of scenario planning, as companies that had invested in digital infrastructure and e-commerce quickly pivoted to online sales, while brands reliant on traditional retail suffered losses (Euromonitor International, 2023).

Agile strategy adjustments are another essential element of antifragile decision-making. Unlike rigid long-term planning, agile organizations continuously adapt to market changes. This flexibility is evident in product innovation, where companies that rapidly adjust formulations, packaging, and marketing stay ahead of trends. Natura & Co and Coty, for

example, swiftly embraced clean beauty and sustainability, realigning their supply chains and R&D to meet evolving consumer expectations (Coty, 2022; Natura & Co, 2022). Their ability to fast-track product development and streamline manufacturing helped them gain market share while competitors struggled with slow adaptation.

Crisis response mechanisms further strengthen antifragile decision-making. While many companies prepare contingency plans, true antifragility involves transforming crises into opportunities. This is particularly relevant in supply chain management, where firms that decentralized supplier networks and built redundancy were better equipped to handle geopolitical tensions, shipping delays, and material shortages. The adoption of blockchain technology and real-time logistics tracking has enhanced crisis response, ensuring supply chain visibility and optimized distribution channels (Ezzat & Aiman, 2023).

Consumer engagement is another critical aspect of crisis response. The way a company communicates and adapts to disruptions impacts brand trust and loyalty. During COVID-19, Sephora and Estée Lauder launched virtual beauty consultations and AI-powered personalization tools to maintain consumer engagement despite store closures (Estée Lauder, 2022; Sephora, 2021). These digital innovations not only prevented revenue loss but expanded customer bases by offering tailored online experiences.

Ultimately, decision-making under uncertainty must be driven by risk intelligence, strategic agility, and proactive crisis management. Businesses that view uncertainty as an opportunity rather than a threat are more likely to adapt, innovate, and grow. By continuously investing in data-driven insights, digital transformation, and consumer engagement, companies can ensure long-term success in an unpredictable industry.

3. Long-Term Strategies for Antifragility

In the fast-changing cosmetics industry, companies that adopt long-term antifragility strategies ensure sustained growth and adaptability in uncertain conditions. Unlike firms that rely on short-term crisis management, antifragile companies proactively position themselves for resilience and expansion. Key strategies include *diversified revenue streams, sustainability-driven consumer engagement, and market expansion through digitalization.* These elements reduce exposure to economic volatility while enabling continuous evolution in response to external shocks.

A diversified revenue model ensures stability across product categories, markets, and sales channels. Leading firms like L'Oréal mitigate risk by expanding beyond traditional skincare and makeup into dermatological treatments, haircare, and active cosmetics, creating a balanced revenue structure that buffers against downturns in any one sector (Euromonitor International, 2023). Estée Lauder similarly hedges risks by maintaining a presence in both luxury and mass-market segments, ensuring financial resilience despite changing consumer behaviors (Estée Lauder, 2022). This approach allows brands to sustain growth despite economic instability or regional regulatory shifts.

Sustainability and consumer-centric business models further enhance antifragility. As environmental and ethical concerns shape purchasing decisions, brands that integrate sustainability into core strategies position themselves for long-term success. Natura & Co and The Body Shop, for example, invest in biodegradable packaging, carbon-neutral operations, and cruelty-free formulations, aligning with rising consumer expectations and regulatory trends (Ezzat & Aiman, 2023; Natura & Co, 2022; Warsita & Indriastuti, 2021). Sustainability-driven models enhance brand loyalty, reduce reputational risks, and future-proof businesses as younger generations prioritize ethical consumption.

Market expansion and digitalization offer another pillar of antifragility. The growth of e-commerce, direct-to-consumer platforms, and AI-driven personalization has transformed consumer engagement. Brands like Sephora and Estée Lauder have used AR and AI-powered skincare consultations to maintain engagement, even as physical retail declined (Estée Lauder, 2022; Sephora, 2021). Shiseido has successfully expanded into Southeast Asia and Latin America, localizing product formulations, marketing, and distribution to match regional preferences and climate conditions (Shiseido, 2022). This reduces overdependence on mature Western markets, distributing risks across diverse economies and ensuring long-term stability.

By integrating diversified revenue models, sustainability-driven engagement, and digital expansion, cosmetics firms move beyond mere survival to long-term growth. Instead of reacting to industry disruptions, brands that embed antifragility into their strategic vision create self-reinforcing cycles of innovation and market expansion. The ability to operate across multiple revenue streams, align with ethical consumption trends, and scale digitally ensures beauty brands remain competitive and thrive in an unpredictable global market.

4. Building Antifragile Business Models in Moldova and Eastern Europe

While much of the focus has been on large multinational corporations, the Antifragility concept is equally critical for small-market economies such as Moldova and other Eastern European nations. Businesses in these regions face persistent challenges, including limited access to capital, dependence on external markets, and workforce migration. Unlike firms in developed economies, businesses in Eastern Europe must operate with heightened uncertainty, making antifragility not just an advantage but a necessity (International Monetary Fund, 2024). Drawing on global case studies, it is possible to identify how companies in Moldova and the broader region can develop strategies to navigate economic volatility and ensure long-term sustainability.

The global cosmetics industry has provided valuable insights into how firms successfully integrate antifragile principles. Companies like L'Oréal, Estée Lauder, and Shiseido have used economic crises, supply chain disruptions, and shifting consumer preferences as catalysts for transformation rather than obstacles. *One of the most significant lessons from these firms is the importance of digital transformation.* Businesses that embraced e-commerce, AI-driven marketing, and virtual consultation services were far better positioned to maintain consumer engagement despite disruptions to traditional retail channels (Estée Lauder, 2022; L'Oréal, 2022; Shiseido, 2022). This approach offers a model for companies in Moldova, where reliance

on physical retail can be a limitation. A digital-first strategy can allow businesses to reach international markets, circumventing domestic economic constraints.

Another key lesson from international case studies is the role of supply chain resilience in mitigating risks. Firms that diversified their supplier base, regionalized manufacturing, and built agile distribution networks fared better during periods of crisis. Natura & Co in Brazil and Coty in the United States provide examples of how businesses can develop robust supply chains by strengthening relationships with local suppliers, investing in flexible logistics, and using real-time data analytics to track production risks (Coty, 2022; Natura & Co, 2022). This model is particularly relevant for Moldova, where heavy reliance on imported raw materials exposes businesses to fluctuations in currency values, trade restrictions, and geopolitical instability (World Bank, 2024). Establishing regional partnerships with suppliers in Romania, Poland, and across the European Union could enhance supply chain resilience and mitigate disruptions.

Sustainability has also emerged as a core element of antifragility. Companies such as The Body Shop and Lush have successfully positioned themselves as leaders in ethical and environmentally responsible business practices. Their commitment to biodegradable packaging, cruelty-free formulations, and sustainable sourcing has not only differentiated their brands but also ensured long-term viability in a market increasingly shaped by regulatory changes and shifting consumer expectations (Ezzat & Aiman, 2023).

For Moldova and other Eastern European economies, where regulatory frameworks are aligning with EU sustainability policies, integrating environmentally responsible practices can serve both as a compliance mechanism and as a competitive advantage in export markets. Businesses that emphasize sustainable production, organic ingredients, and environmentally conscious branding can carve out a niche within the growing demand for ethical beauty products.

During the COVID-19 pandemic, the cosmetics company *Viorica* demonstrated notable antifragility (Ivașcenco, 2022). Rather than halting operations, the firm transformed its business model by scaling up disinfectant production, launching an e-commerce platform, and investing in R&D to develop new product lines like *Viorica Vie*. The company leveraged its own eco-plantation (*VioPark*) and collaborated with international research laboratories to innovate sustainably. As a result, Viorica increased its sales volume by 181% in 2020 compared to 2019 and returned to profitability after several years of loss. This case illustrates how a Moldovan firm used digital tools, sustainability, and strategic agility to thrive during crisis conditions.

Adopting antifragility principles in Moldova requires more than simply copying global best practices; strategies must be adapted to the realities of local economic structures and market conditions. Digital transformation is an essential component of this adaptation, particularly in enabling businesses to reduce their reliance on physical retail and expand internationally. While multinational corporations already have established omnichannel strategies, Moldovan firms can leapfrog certain traditional barriers to entry by investing in direct-to-consumer models and leveraging cross-border e-commerce platforms (Ivașcenco, 2023a). The increasing availability of digital payment solutions, third-party logistics providers,

and AI-powered marketing tools presents a significant opportunity for local businesses to modernize without requiring extensive capital investment.

Supply chain diversification is another critical factor in enhancing antifragility in Moldova. Unlike multinational companies that can operate multiple manufacturing plants across different regions, Moldovan businesses need to focus on regional collaboration to build supply chain resilience. Strengthening trade relationships with neighboring countries such as Romania and Poland can reduce dependency on a single market and create alternative sourcing options. This approach would not only mitigate supply risks but also allow firms to scale production more efficiently and align with EU trade regulations (World Bank, 2024).

Sustainability-driven innovation provides a competitive advantage for Moldovan cosmetics companies seeking to differentiate themselves in an increasingly crowded market. Unlike mass-market brands that compete on cost and volume, Moldovan firms can focus on producing niche, eco-friendly beauty products using locally sourced ingredients. Moldova's strong agricultural sector offers opportunities for developing organic skincare lines, herbal formulations, and sustainable packaging solutions. Aligning with European consumer preferences for ethical and sustainable beauty products can open doors to broader export opportunities while fostering long-term resilience (Euromonitor International, 2023).

For businesses in Moldova and other Eastern European economies to build antifragility, they must integrate multiple strategies, combining digitalization, supply chain optimization, sustainability, and market expansion. Digital infrastructure is one of the most immediate opportunities, allowing local brands to compete beyond national borders and establish stronger brand identities through direct-to-consumer sales. Companies that invest in strong brand narratives, influencer marketing, and AI-driven consumer insights will be better positioned to compete on global e-commerce platforms.

Another crucial step for Moldovan firms is developing export-oriented business models that align with European market standards. Many companies in Eastern Europe struggle to integrate into global value chains due to regulatory misalignment. Investing in EU-compliant certifications, sustainable sourcing practices, and transparent supply chains will facilitate long-term access to Western consumer markets. This shift will not only make Moldovan products more attractive to international buyers but will also enhance resilience by reducing dependence on a limited domestic market.

Local production capabilities and circular economy initiatives should also be prioritized. As global supply chains continue to face disruptions, businesses that shorten their supply chains, develop in-house production capabilities, and establish regional collaborations will be better equipped to withstand future crises. The incorporation of recycling programs, zero-waste initiatives, and eco-friendly formulations will not only reduce operational risks but also strengthen consumer trust and brand value among sustainability-conscious demographics (Ezzat & Aiman, 2023).

While Moldova and other Eastern European economies face structural challenges, businesses that embrace antifragility strategies will be better positioned to navigate

uncertainty and drive long-term growth. By focusing on digital transformation, regional supply chain cooperation, sustainability, and export expansion, companies in the cosmetics sector can transform economic volatility into a strategic advantage. Rather than merely surviving market fluctuations, firms that integrate antifragile business models can thrive in an increasingly unpredictable global landscape.

Conclusions

This study underscores that in an increasingly volatile global economy, firms in the cosmetics industry must go beyond resilience. Antifragile businesses actively use disruption as a catalyst for growth, innovation, and competitive advantage. Drawing on global case studies, the research identifies four core principles of antifragility: proactive adaptation, supply chain decentralization, sustainability-driven innovation, and digital transformation. Companies such as L'Oréal, Estée Lauder, and Shiseido illustrate how these strategies help navigate economic shocks, shifting consumer preferences, and operational uncertainties.

For emerging economies like Moldova and those in Eastern Europe, the findings are especially relevant. Limited access to capital, supply chain vulnerabilities, and regulatory shifts require tailored antifragile strategies. The Moldovan case study shows that digitalization, sustainability, and market diversification can turn structural limitations into growth opportunities. Firms that prioritize ethical production, export readiness, and omnichannel distribution are better positioned to align with EU standards and integrate into global value chains.

Theoretically, this research extends Taleb's concept of antifragility from financial systems to corporate operations and consumer-driven markets. It also examines decision-making under uncertainty, emphasizing the role of scenario planning, dynamic pricing, and agile strategies. However, no empirical decision-making model was applied - an area that presents a valuable direction for future studies. Similarly, while comparative analysis of antifragile and non-antifragile firms is discussed conceptually, it was not conducted and should be pursued in future longitudinal research.

Despite its contributions, the study is limited by its reliance on secondary data. Future research could benefit from primary data collection, empirical model testing, and industry-specific comparative analyses. Expanding the scope to include sectors like fashion, food, or luxury goods, or exploring supportive government policies - such as investment in digital infrastructure and sustainability incentives - would further deepen understanding of antifragility.

Ultimately, this study demonstrates that uncertainty can be transformed into strategic advantage. Firms that embrace innovation, sustainability, and agility are not only more likely to survive crises but to thrive through them. For companies in Moldova and beyond, embedding antifragile principles into core business models may be the key to enduring success in an unpredictable world.

References

Bai, C., & Sarkis, J. (2020). A supply chain transparency and sustainability technology appraisal model for blockchain technology. *International Journal of Production Research, 58*(7), 2142-2162. https://doi.org/10.1080/00207543.2019.1708989

BNP Paribas. (2025). *Central and Eastern Europe: going for growth*. https://cib.bnpparibas/central-and-eastern-europe-going-for-growth/

Boc, E. (2020). Opinion of the European Committee of the Regions—Brain Drain in the EU: addressing the challenge at all levels (2020/C 141/08). *Official Journal of the European Union. https://eur-lex. europa.eu/legal-content/EN/TXT/PDF*

Boticário, O. (2022). *Annual Impact Report.* https://www.grupoboticario.com.br/wp-content/uploads/2022/07/RA_Boticario_2021_v4_ING.pdf

Coty. (2022). *Annual Report 2022 (Form 10-K).* https://s23.q4cdn.com/980953510/files/doc_financials/2022/ar/COTY-Annual-Report-2022.pdf

Coty. (2023). *Annual Report 2023 (Form 10-K).* https://s23.q4cdn.com/980953510/files/doc_financials/2023/ar/coty-annual-report-2023_f.pdf

Estée Lauder. (2022). *Annual Report (Form 10-K).* https://otp.tools.investis.com/clients/us/estee_lauder4/SEC/sec-show.aspx?FilingId=16037879&Cik=0001001250&Type=PDF&hasPdf=1

Euromonitor International. (2023). *World Market for Beauty and Personal Care.* https://www.euromonitor.com/world-market-for-beauty-and-personal-care/report

Ezzat, Aiman. (2023). *The future of business is digital and sustainable. Here's why.* https://www.weforum.org/stories/2023/01/the-future-of-business-digital-sustainable-davos2023/

Furr, Nathan, & Furr, Susannah Harmon. (2022). *How to Navigate and Thrive Through Uncertainty*. https://hbr.org/webinar/2022/07/how-to-navigate-and-thrive-through-uncertainty

Groth, O., Esposito, M. & Tse, T. (2023). The Great Remobilization: Strategies and Designs for a Smarter Global Future: *MIT Press*. https://mitpress.mit.edu/9780262047937/the-great-remobilization/

Hamel, G., & Zanini, M. (2020). *Humanocracy: Creating organizations as amazing as the people inside them*: Harvard Business Press.

Hindustan Unilever Limited - Subsidiary Companies. (2022). *Annual Report 2021-22.* https://www.hul.co.in/files/92ui5egz/production/c12285a9a7713006308894d21364591395b975b9.pdf

International Monetary Fund. (2024). *Regional Economic Outlook. Europe. October 2024.* https://www.imf.org/en/Publications/REO/EU/Issues/2024/10/24/regional-economic-outlook-Europe-october-2024

Ivașcenco, I. (2022). Rising and Thriving in the Post COVID-19 Era: The Case of Antifragility in a Cosmetics Company. In *Conferința științifică internațională Strategii și politici de management în economia contemporană*, 9-10 iunie 2022. (Ed. a 7-a, pp. 122-128). ASEM.

Ivașcenco, I. (2023a). Antifragility and Business Model Innovation in the Age of Digital Transformation: Strategies and Ethical Implications. *Review of Economic Studies and Research Virgil Madgearu, 16*(1), 45-56. https://doi.org/10.24193/RVM.2023.16.98

Ivașcenco, I. (2023b). Building Supply Chain Resilience and Antifragility: Strategies and Technologies for Mitigating Disruptions. *Eastern European Journal for Regional Studies (EEJRS), 9*(1), 70-76. https://doi.org/10.53486/cike2023.03

Ivașcenco, I. (2024). Antifragility in Leadership: Framework and Cases From the Developing World. *Review of Economic Studies and Research Virgil Madgearu*, *17*(2), 55-78.

L'Oréal. (2022). *2021 Annual Report.* https://www.loreal-finance.com/en/annual-report-2021/?utm_source=mynews&utm_medium=referral&utm_content=oa_brde_ra21_text_aw&utm_campaign=oa_brde_ra21_launch

L'Oréal. (2022). *L'Oréal 2021 Annual Report.* https://www.loreal-finance.com/system/files/2022-03/LOREAL_2021_Annual_Report_0.pdf

Natura & Co. (2022). *Annual Report* 2021. https://ri.naturaeco.com/en/esg/annual-reports/

Nightingale, A. (2009). A guide to systematic literature reviews. *Surgery (Oxford)*, *27*(9), 381-384.

Nykaa. (2022). *Annual Report 2021-2022.* https://www.nykaa.com/media/wysiwyg/2021/Investors-Relations/pdfs/annual-report/21-22/annual-report-2021-22.pdf

Otarinia, M. A. (2024). The impact of E-commerce and foreign investment on economic growth in developing countries. *Creative Economy and New Business Management Approaches*, 18-59.

Procter & Gamble. (2022). *Annual Report 2022 (Form 10-K).* https://s1.q4cdn.com/695946674/files/doc_financials/2022/ar/1a1b8ef0-7de1-4b8e-be29-46b22c2dd110.pdf

Ramezani, J., & Camarinha-Matos, L. M. (2020). Approaches for resilience and antifragility in collaborative business ecosystems. *Technological Forecasting and Social Change*, *151*, 119846.

Sephora. (2021). *Virtual Artist.* https://www.sephora.sg/pages/virtual-artist?srsltid=AfmBOopAjpm53XuFUDKle13p9QGmb8TG9KZzhaORnFkT4pphbo5ktujp

Settembre-Blundo, D., González-Sánchez, R., Medina-Salgado, S., & García-Muiña, F. E. (2021). Flexibility and resilience in corporate decision making: a new sustainability-based risk management system in uncertain times. *Global Journal of Flexible Systems Management*, *22*(Suppl 2), 107-132.

Shiseido. (2022). *Integrated Report 2021*. https://corp.shiseido.com/report/en/2021/

Statista. (2025). *Cosmetics - Worldwide*. https://www.statista.com/outlook/cmo/beauty-personal-care/cosmetics/worldwide

Taleb, N. N. (2012). *Antifragile: Things that gain from disorder* (Vol. 3). Random House.

Unilever. (2021). *Unilever Annual Report and Accounts 2021.* https://www.unilever.com/files/92ui5egz/production/75f31d18a2219004f4afe03e37ccd2a3b383472f.pdf

Warsita, M., & Indriastuti, H. (2021). The Influence of Corporate Social Responsibility Towards Brand Image and Corporate Reputation on the Study of the Body Shop" Forever Againts Animal Testing" Campaign. *International Journal of Economics, Business and Accounting Research (IJEBAR)*, *5*(2). https://doi.org/10.29040/ijebar.v5i2.2334

World Bank. (2024). *Moldova Overview: Development news, research, data.* https://www.worldbank.org/en/country/moldova/overview

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PERFORMANCE IN ACCESSING FUNDING THROUGH DIGITAL EUROPE PROGRAMME

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Abstract: *The digital transformation of the European Union is a strategic priority, and the Digital Europe Programme (DIGITAL) is an essential mechanism to strengthen the digital infrastructure, improve technological innovation, and develop digital skills. This study aims to assess the role of DIGITAL in supporting the European Digital Agenda and to evaluate Romania's performance in accessing this funding instrument. The research addresses the question: 'To what extent does the DIGITAL serve as a catalyst for the EU's digital transformation, and how effectively has Romania accessed and utilized the funding opportunities provided by this initiative?' This study employed a qualitative and descriptive approach, based on the analysis of official EU regulations, policy documents, and data available through the DIGITAL Dashboard. Findings indicate that Romania has secured a relatively small share of DIGITAL funding, with disparities in allocations across beneficiary types and regions. While this instrument has generated benefits in Romania, current funding remains insufficient to bridge the digital divide and challenges persist. The study suggests that strengthening the role of European Digital Innovation Hubs and National Contact Points could support fund absorption and project implementation, ensuring Romania's alignment with EU digitalization objectives and enhancing its economic competitiveness. It also highlights the importance of integrating DIGITAL with other instruments, such as the National Recovery and Resilience Plan and Horizon Europe. This research contributes to understanding how DIGITAL is operationalized at national level, identifying both opportunities and structural challenges in Romania's current digital funding landscape, and offering recommendations to improve strategic alignment and implementation.*

Keywords: *Digital transformation, Digital Europe Programme, Romania's performance, European technological sovereignty, Cyber security, Digital skills development, European Digital Innovation Hubs, Artificial Intelligence.*

JEL Code: *O33, O38, L86.*

UDC: *339.727.22:[005.8:004](4EU+498)*

Introduction

Over the past two decades, the European Union has pursued a comprehensive digital transformation strategy. The Lisbon Strategy initially set the foundation for the EU's digital ambitions, emphasizing the role of information and communication technologies (ICTs) in achieving economic growth and social progress. Building upon this, the Digital Agenda for Europe (European Commission, 2010) formally recognized ICTs as key enablers for the EU's strategic objectives, driving digitalization across sectors. Furthermore, the Digital Single Market Strategy (European Commission, 2015) aimed to improve access to digital goods and services, create an integrated digital market, and enhance the growth potential of Europe's

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digital economy. By 2020, the EU introduced the "Shaping Europe's Digital Future" strategy (European Commission, 2020), emphasizing the development of people-centric technologies, economic competitiveness, and democratic digital governance. In 2021, the Digital Compass outlined four key digital targets for 2030 - focusing on digital skills, e-government, digital business transformation, and resilient digital infrastructure - to ensure Europe's leadership in the global digital landscape (European Commission, 2021).

A key strategic priority on the European Union (EU) agenda is digital transformation, which serves as a fundamental driver for sustainable growth, enhanced global competitiveness, and social inclusion. Recent efforts underline the critical role of digital infrastructure in strengthening economic and social resilience. The EU has allocated substantial financial resources, particularly through its long-term budget for 2021–2027 and the NextGenerationEU initiative, to accelerate digitalization, thus demonstrating a strong commitment to advancing digital transformation.

In this context, the Digital Europe Programme (DIGITAL) was launched as a key funding mechanism to consolidate digital infrastructure, promote the uptake of emerging technologies, and develop digital skills needed for the transition to a digitalized environment (European Commission, n.d.).

Romania, as a member state of the European Union, is facing significant challenges in the field of digitalization, as highlighted by its constant ranking in the Digital Economy and Society Index (DESI) (European Commission, n.d.). However, the funding available through DIGITAL represents a major opportunity to bridge the digital divide with other member states and accelerate the deployment of advanced technological solutions.

The objective of this paper is twofold: to assess the role of the Digital Europe Programme as a catalyst for the EU's digital transformation; and to evaluate how effectively Romania has accessed and utilized the funding instruments provided through DIGITAL. To address these aims, the following research question is formulated: 'To what extent does the Digital Europe Programme serve as a catalyst for the European Union's digital transformation, and how effectively has Romania accessed and utilized the funding opportunities provided by this initiative?'

The study has both academic and practical significance, as it provides insights into the operationalization of DIGITAL at national level, and identifies highlighting both opportunities and structural challenges in the current funding landscape.

This paper includes a literature review focused on key concepts and recent developments in EU digital policy and funding instruments. It then outlines the research design and methodology, including the formulation of hypotheses and data sources. The core of the article analyzes the Digital Europe Programme as a strategic framework and examines Romania's performance in accessing and using the program's funding. The article concludes with key findings and conclusion.

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Literature Review

Strategic Priorities and Conceptual Foundations of the Digital Europe Programme

The literature underlines that DIGITAL is a strategic tool of the EU to accelerate the digital transformation, increase global competitiveness, and strengthen European technological sovereignty. Bıçakcı (2024) highlights that DIGITAL is not just a funding mechanism, but a transformative project that led to socioeconomic changes through investments in essential technologies such as artificial intelligence (AI), cloud computing, cyber security, digital infrastructure, and digital single market.

Burinskienė and Nalivaikė (2024) argue that development of digital infrastructure, such as broadband Internet access and cloud services, which are foundational to establishing a cohesive digital single market, vital for maintaining competitiveness within the global economy.

Mărcuț (2020) offers a perspective on the EU's global digital policy stance, highlighting the "Brussels Effect," which transforms EU norms into global benchmark for data protection, digital content regulation, and internet governance. This aligns with the EU's aspiration for technological sovereignty, wherein DIGITAL plays a vital enabling role.

Moreover, literature highlights that the post-pandemic economic recovery in the EU was built on three key pillars: green transition, digitalization and economic and social resilience. Miron et al. (2022) analyze in detail the strategies and financial instruments implemented through the Multiannual Financial Framework (MFF) 2021-2027 and NextGenerationEU (NGEU), with accent on the Recovery and Resilience Facility and highlighting difficulty of efficiently accessing European funds, especially in countries such as Romania, which faces challenges in implementing digital reforms and ensuring a coherent framework for funding absorption.

Positioning digitalization as a strategic priority of the EU and underlying the allocation of substantial financial resources through mechanisms such as RRF, Horizon Europe, Digital Europe, are also addressed by Miron et al. (2024), with accent on the relationship between budgetary allocations for digital transformation and its prioritization within the EU agenda.

Enhancing Economic Competitiveness through Digital Investment

DIGITAL's initiatives are designed to drive economic competitiveness by fostering innovation and developing digital skills across the EU. This strategic focus is essential for sustaining economic growth and creating new opportunities for member states while the integration of digital technologies across various sectors reflects the program's commitment to enhancing the EU's position in the global digital economy (Miron et al., 2024; Maurer, 2021). By supporting these initiatives, DIGITAL contributes significantly to the economic competitiveness.

Ogrean et al. (2024) provide a micro-level perspective from Central Region of Romania, where sectors like smart manufacturing, e-health, and smart cities show digital divide. The study that many organizations are at the early stages of transformation, constrained by a lack of digital skills and limited access to finance. Their findings reinforce the importance of targeted support mechanisms in translating macro-level strategies into actionable improvements.

Promoting Technological Sovereignty

The role of DIGITAL in fostering technological sovereignty is multi-dimensional. Bormane and Blaus (2024) to the EU's strategy for achieving technological sovereignty, ensuring that Europe can independently develop and deploy digital technologies without reliance on external entities, while López-Nores et al. (2022) highlight the importance of establishing a European data economy and digital single market to to safeguard the interests of the EU and maintain control over data and technology. Bicakci (2024) frames this sovereignty as essential for EU resilience and competitiveness. This strategic approach is crucial for preserving the autonomy and integrity of the EU's digital landscape, for strengthening its technological trajectory and reduce vulnerability to external actors.

Adressing Challenges and Barriers

Despite its strategic objectives, the program faces challenges that need to be addressed to achieve its objectives fully. The digital divide and cybersecurity concerns remain significant barriers to the successful implementation of DIGITAL initiatives, as Garau et al. (2023) highlight. Ensuring equitable access to digital technologies and secure digital environments across all member states is essential for realizing the program's goals. Furthermore, harmonizing digital standards and regulations within the EU is crucial for facilitating cross-border collaboration and technological advancements (Savitska, 2025). Overcoming these barriers is key to unlocking the full potential of the Digital Europe Programme and enhancing the technological sovereignty and competitiveness of the European Union.

Similarly, Tiganasu and Lupu (2023) show that institutional quality and administrative capacity directly influence the absorption of EU funds. Their research on Central and Eastern Europe reveals that stronger institutions with high levels of digitalization had a better capacity to attract and use European funds efficiently, thus facilitating economic convergence. However, administrative barriers, institutional bottlenecks, excessive bureaucracy, and corruption are identified as major obstacles to the absorption of European funds, limiting their capacity to generate spillover effects on the economy.

In Romania, Coban (2023) illustrates how low adoption rates of cloud computing (11%), big data analytics (5–6%), and AI (1%) signal insufficient digital maturity. Copăceanu and Mazăre (2023) further emphasize that bureaucracy and lack of experience in managing European-funded, challenges in addressing the requirements for projects, lack of technical assistance undermine Romania’s capacity to implement DIGITAL-funded projects effectively.

Stoican and Chirieac (2021) stress the need for integrated approaches to the twin transition (digital and green), their interconnection and underly the obstacles in Achieving a Digital and Green Europe. In this context, mechanisms such as NextGenerationEU and the Recovery and Resilience Facility direct significant resources toward digitalization, infrastructure strengthening, and technological innovation, contributing to the objectives of climate neutrality and economic competitiveness.

The Role of Intermediaries (EDIHs) and Skills Development

The European Digital Innovation Hubs (EDIHs) play an essential role in a variety of forms of institutional work at organizational, network, and ecosystem levels and support the uptake of digital technologies, by bridging the gap between organizations and new technologies, creating collaborative structures and influencing regulations to facilitate digitalization (Colovic et al., 2024). EDIHs serve as institutional intermediaries by offering technical, regulatory, and coordination support in creating the necessary conditions for the success of digital projects.

Coban (2023) and Ogrean et al. (2024) highlight the relevance of services such as technology pre-testing, digital skills development, and support in accessing finance - all critical functions typically provided by EDIHs. Although not always explicitly named, these intermediaries are particularly valuable in underdeveloped regions. However, significant disparities in regional uptake and digital maturity remain pronounced.

Furthermore, human capital constraints significantly affect implementation. Rathod et al. (2024) and Pirinen et al. (2024) highlight acute shortages in cybersecurity professionals and the role of the European Cybersecurity Skills Framework (ECSF) in addressing these gaps. The European Cybersecurity Skills Framework (ECSF) is once again seen as a tool that aims to align skills and facilitate collaboration between higher education institutions, industry, and public authorities. Projects like CyberSecPro and NERO demonstrate how European financial instruments support upskilling and reskilling initiatives tailored to market needs.

Research Gaps and Study Contribution

The reviewed literature collectively establishes the strategic importance of DIGITAL but exposes several gaps. First, empirical insights at the national level remain limited, particularly regarding fund absorption mechanisms and institutional performance. Second, there is limited exploration of how DIGITAL interacts with other instruments (e.g., RRF, Horizon Europe) in practice. Third, implementation asymmetries among EU Member States are not sufficiently addressed.

This study addresses these gaps by providing a Romania-focused analysis of the implementation of DIGITAL. It contributes to understanding the national-level operationalization of the program, identifies structural challenges and opportunities within the current digital funding landscape, and proposes recommendations to enhance strategic alignment and implementation.

Data and Methodology

A qualitative and descriptive research design was adopted to answer the research question and assess three hypotheses regarding the role and impact of the Digital Europe Programme (DIGITAL) at EU and national level. The study follows a deductive logic and relies on

documentary analysis and the interpretation of secondary data from official sources, including EU strategic documents, reports, and statistical dashboards (e.g., DESI, DIGITAL Dashboard).

The first hypothesis (H1) assumes that DIGITAL reflects the EU's commitment to digital transformation, as defined in the Multiannual Financial Framework (MFF) 2021–2027, with significant implications for European technological sovereignty and competitiveness (H1). The second hypothesis (H2) explores the limited performance of Romania in accessing DIGITAL funds, with regional and typological disparities. Building on these findings, the third hypothesis (H3) assesses the contribution of DIGITAL-funded projects in Romania to bridging the digital divide.

The methodology consists of two main stages. First, a documentary analysis of official EU policy and programming documents is used to assess the strategic positioning of DIGITAL (H1). Second, the study applies descriptive statistical analysis to data from public sources (e.g., Digital Dashboard, DESI, official reports) to evaluate Romania's performance (H2) and the scope of funded interventions (H3).

The use of quantitative indicators (e.g., volume of financing, success rate of proposals, regional allocation, typology of beneficiaries) serves to the analysis of the hypotheses through a structured, theory-informed and deductive research approach. The analysis relies on publicly available and verifiable data, ensuring transparency and replicability.

The Model and Findings

The Digital Europe Programme - a strategic framework for the EU digital transformation

The Digital Europe Programme (DIGITAL) represents a strategic initiative of the European Union designed to accelerate the digital transformation of the European economy, public sector and society. The EU's digital agenda includes multiple funding instruments, dedicating significant resources to digitalization through initiatives such as Digital Europe, Horizon Europe, and the Connecting Europe Facility, among others (Figure 1). As part of Multiannual Financial Framework (MFF) 2021-2027, the Digital Europe Programme aims to strengthen the strategic autonomy of the EU, enhance cyber security resilience and the deployment of digital technologies in various industries. By supporting innovation and increasing European competitivity in the global digital economy, DIGITAL provides a structured framework to bridge the technological gaps and promote sustainable digital development.

The figure 2 illustrates DIGITAL's six key strategic objectives (SO), each of them targeting a fundamental area of digital transformation across the European Union. DIGITAL aims to develop and deploy the digital capacities essential for the economic growth and strategic autonomy of the EU. Among its key proprieties, High Performance Computing (HPC) plays on essential role in advancing scientific research, industrial applications and digitalization of public administration.

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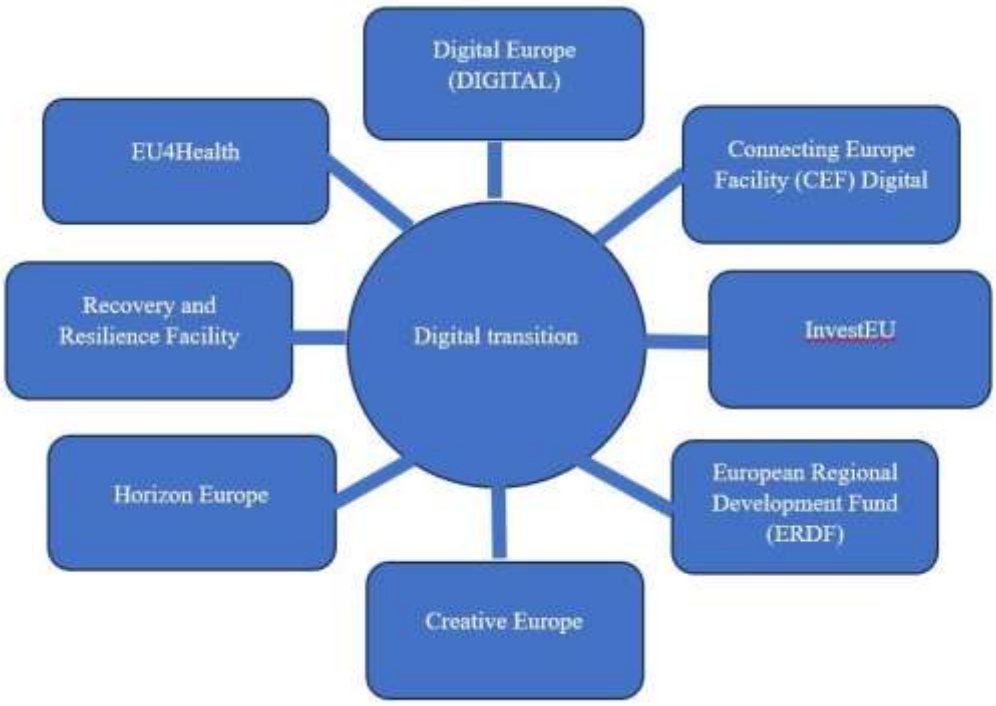

Figure 1. EU funding opportunities available for the 2021-2027 fostering digital transformation

Source: Miron et al. (2024)

A significant art of the funding envisages the supercomputing infrastructures, with a particular focus on the EuroHPC Joint Initiative, that support progress in artificial intelligence (AI), climate modelling and big data analytics. Another key pillar of DIGITAL is artificial intelligence, cloud computing and data space, which facilitate cross-border digital integration and support the digitalization of public services and businesses.

In the global context marked by geopolitical risks and an increase in cyber-attacks, DIGITAL focusses on cyber security and digital trust. The European Cybersecurity Competence Centre (ECCC) was established to coordinate initiatives in this field and support the implementation of cyber security policies at Member States level. DIGITAL also facilitates the cross-border cooperation in the digital security field, contributing to an integrated and efficient European framework in addressing emerging cyber threats. In addition to technological and security infrastructure, this instrument has as a priority the development of advanced digital skills, allocating funds to specialized training programs. These initiatives are essential to address the increasingly demand for digital competences in various sectors and ensure that the European workforce is prepared for the digital transition.

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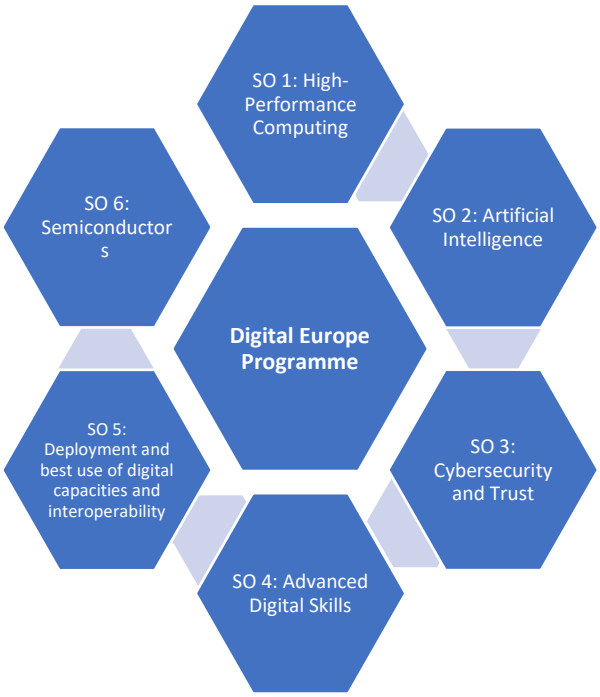

Figure 2. The objectives of the Digital Europe Programme

Source: Author's compilation based on data available on https://digital-strategy.ec.europa.eu/en/activities/digital-programme

To accelerate the adoption of digital technologies, DIGITAL includes a specific component dedicated to digital deployment and best practices, through the European Digital Innovation Hubs (EDIHs). These hubs play an essential role in supporting small and medium size enterprises (SMEs), industrial entities and public institutions in their process of digitalization. In addition, in response to the global crisis of semiconductor, in September 2023, DIGITAL introduced a dedicated initiative, under the Chips Act, with the aim of strengthening the position of Europe in microelectronics and semiconductors production, reducing the dependency of non-European markets.

The financial framework of DIGITAL reflects its strategic importance. Initially, a budget of EUR 7588 million was allocated for 2021-2027, with the aim of supporting the projects in the five key priorities. Subsequently, with the adoption of Chips Act, an additional EUR 800 million was allocated to address the shortage of semiconductors. However, after some relocations to the Secure Connectivity Programme and other budgetary adjustments to strengthen the role of European agencies such as the European Union Agency for Cybersecurity (ENISA), the financial programming increased with 6% compared to its initial allocation, up to 8178.7 million, highlighting the EU commitment to digital development and economic resilience (Figure 3).

In terms of the management mechanism, DIGITAL uses direct and indirect management to ensure an efficient allocation of funds. Under direct management, the European Commission supervises all financial operations, including launching calls for proposals, evaluating

proposals and monitoring projects implementation. This management type represents around 20% of the total EU budget allocated for 2021-2027. By contrast, indirect management the budgetary and operational responsibilities are transferred to partner institution, national agency, international organizations and specialized EU bodies. This approach allows EU to benefit from the external expertise and to ensure that financial resources are distributed in an efficient and transparent manner.

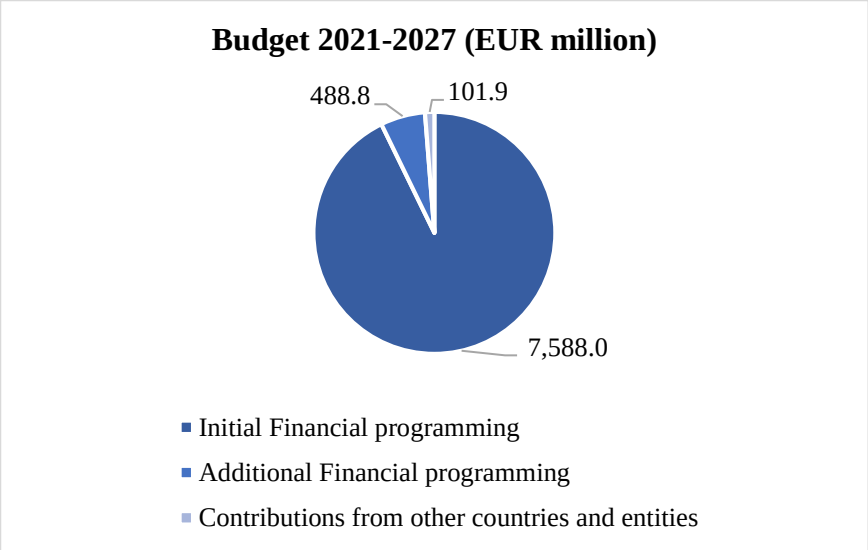

Figure 3. The budget of the Digital Europe Programme

Source: Author's compilation based on data available on https://digital-strategy.ec.europa.eu/en/activities/digital-programme

DIGITAL is open for international cooperation, providing financing opportunities also for non-EU countries. While participation is mainly targeted at EU Member States, several associated countries, including Norway, Iceland, Liechtenstein, Ukraine, Moldova, the Wester Balkan and Turkey, are also eligible for financing. In addition, Switzerland will be able to participate from 1 January 2025, subject to transitional arrangements. Given the strategic sensitivity of some digital investments, participation in projects in cyber security area is conditioned by some specific security requirements, as set out in Art. 12.5 and 12.6 of the Digital Europe Programme Regulation (EU) 2021/694. These provisions are intended to protect the EU's digital infrastructure and ensure the security of European digital ecosystem.

Given the strategic importance of the Digital Decade Strategy 2030, DIGITAL plays a key role in shaping the Europe's digital future. By allocating financial resources to essential digital technologies, strengthening cyber security and supporting digitalization of public and private sectors, DIGITAL actively contributes to enhancing EU competitiveness in the global digital economy. With a well-structured financial and operational framework, it represents a driver of the European technological autonomy, ensuring sustainable and inclusive digital development.

The budgetary implementation of DIGITAL reflects a moderate implementation rate, highlighting both its strategic commitments and the challenges inherent in implementing large scale digital investments. At the end of 2023, the implementation rate of commitments was 46.5 %. However, the payment implementation rate remains significantly lower, at only 20.6 %. This discrepancy between commitments and payments suggests possible delays in project implementation, administrative bottlenecks or the complexity of allocating funds to technology initiatives. There is a progressive increase in commitments and payments in 2023 compared with 2021, highlighting an acceleration in the use of funds, probably due to the maturity of projects and increased absorption capacity. However, the low rate of payments underlines the need to improve administrative efficiency, simplify procurement procedures and strengthen monitoring mechanisms to optimize financial execution and ensure the achievement of digital transformation objectives within the foreseen timeframe. The inclusion of the Chips Act in DIGITAL adds an additional layer of complexity, requiring more agile financial management to support Europe's strategic autonomy objectives in the field of semiconductor technologies.

The implementation of DIGITAL reflects a clearly targeted allocation to the digital transition, with a total contribution of 3.7 billion EUR over the period 2021-2023, which represents 100% of the budget committed for these years. This budget implementation confirms the strategic role of strengthening the European Union's digital capacities, accelerating the development of digital infrastructures, cybersecurity and the uptake of emerging technologies. Unlike the green transition, where the cumulative contribution amounts to only 336.3 million EUR (around 4% of the 2021-2027 budget), the digital transition benefits from full funding, highlighting the EU's commitment to bridge the technological divide and boost European digital competitiveness. Overall, DIGITAL is an example of the efficient implementation of EU funds for digitalization, with significant implications for European technological autonomy and increasing economic resilience in an increasingly competitive global landscape.

Accessing funds through DIGITAL in Romania

DIGITAL is a key initiative of the EU aiming to support the digital transformation of Member States' economies and societies. According to the data available in the dashboard of the Digital Europe Programme, the total costs of the selected projects under DIGITAL is 3.17 billion, with an EU contribution in amount of 1.81 billion. From the total of participation, considered as acts of involvement of legal entities in grant agreements, 22.47% are SME participation (Table 1).

Table 1. Significant figures of DIGITAL and Romania's participation

Country	Total Cost		EU Contribution		Signed Grants		Participation	
All countries	3.17 billion €	100%	1.81 billion €	100%	549	100%	6133	100%
Romania	88.08 million €	2.77%	48.44 million €	2.68%	73	13.3%	217	3.54%

Source: Author's compilation based on data from the DIGITAL Dashboard

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Romania, as Member State, benefits from funding opportunities through this instrument, to develop digital infrastructure, enhance digital skills and consolidate cyber security. Its participation in DIGITAL reflects both specific needs for digital development and the country's commitment to achieve the objectives set at European level. Romania ranks 9 in the top of Member States and associated countries, considering the number of its participations, 217. With total costs of the selected projects of 88.08 million EUR and EU contribution of 48.44 million EUR, it represents around 2.7% from the total costs and contribution registered for the entire program. The number of grants that have been signed represents a proportion of 13.30% from the total number of grants signed within DIGITAL.

The success rate of its proposals, scoring 50.62%, is slightly above the average rate of Member States and of DIGITAL as a whole, indicating a good capacity to elaborate projects in line with requirements of financing authority. However, the success rate in accessing funds is not equivalent with maximizing their economic and technological impact, given that the absolute envelope of the fundings remains relatively reduced compared to other Member States.

Compared to advanced economies in the EU, such as Germany, which ranks 1st with 239.99 million EUR EU contribution, France, 2nd place with 181.29 million EUR and Italy, 3rd place with 169.60 million EUR, Romania benefits from a more modest EU contribution, but compared to other countries in the region, it is in a competitive position. It is important to notice that the first six countries situated in the top as receiving the higher the EU contribution, namely Germany, France, Italy, Belgium, Spain and Greece concentrate 53% of the total EU contribution in DIGITAL (Figure 4).

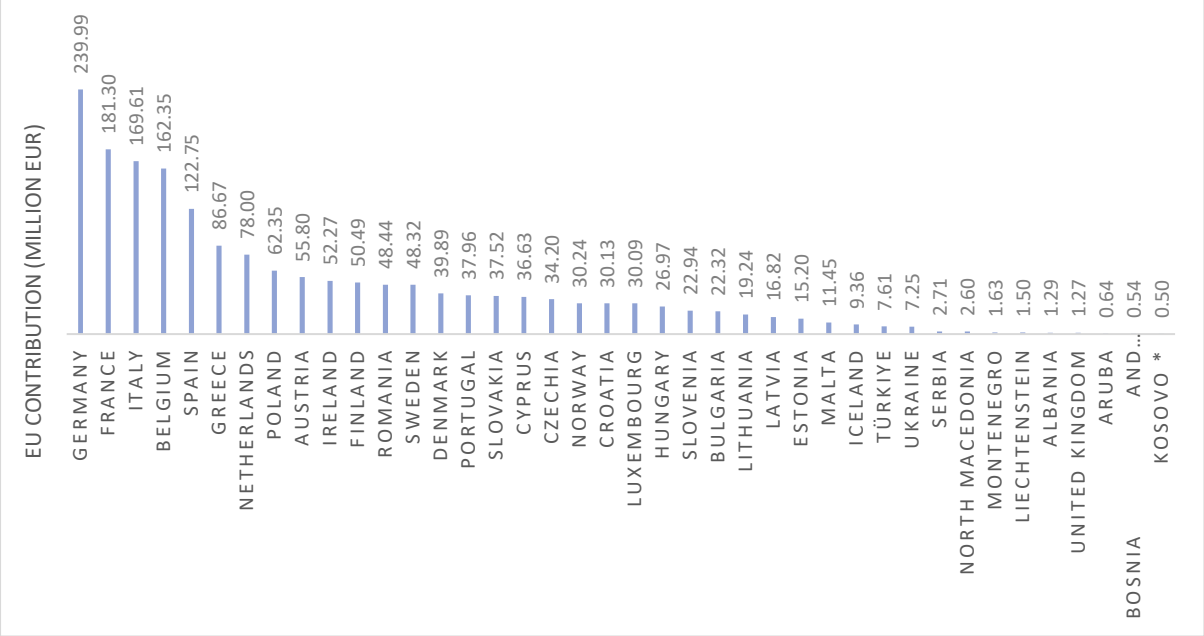

Figure 4. Overview of EU contribution by country

Source: Author's compilation based on data from the DIGITAL Dashboard

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The distribution of funds at major socio-economic regions (NUTS1) shows a significant concentration in "*Macroregiunea trei*", which absorbed more than a half of the total funds allocated to Romania, followed by "*Macroregiunea unu*" and "*Macroregiunea doi*", with similar allocations. By contrast, "*Macroregiunea patru*" received only 4.9% of the funds. This uneven distribution highlights a polarization of access to financial resources, with a predominance of regions benefiting from more developed digital infrastructure and those hosting innovation and research centers integrated into European networks.

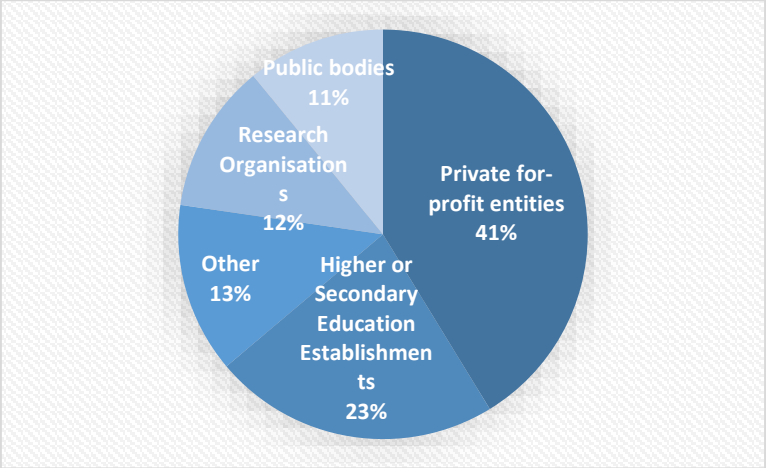

Figure 5. Distribution according to organization type

Source: Author's compilation based on data from the DIGITAL Dashboard

The main organizations benefiting from European Funds in Romania include IT companies, prestigious academic institutions, research organizations and public bodies, as shown in Figure 4. The most significant funds were allocated to the Romanian National Cyber Security Directorate, Expertware SRL, National University of Science and Technology Politehnica Bucharest and Eviden SRL. This distribution highlights a concentration of funds in strategic sectors such as cyber security, digitalization of education and IT infrastructure development. The first 12 organizations register 50% from the total EU contribution accessed in Romania through DIGITAL (Figure 6).

An important aspect of Romania's participation in the DIGITAL is the implication of small and medium-sized enterprises (SMEs), which play a key role in technological innovation and development of digital infrastructure. While SMEs applied for European funding in amount of 139 million EUR, they obtained only 15.15 million EUR, representing 31.28% from the total EU contribution to Romania under DIGITAL. Although this percentage is significantly higher than the average recorded for the entire program, the absolute value of funding received compared to the requested amount suggests that despite active participation of SMEs, there are difficulties in obtaining funds, either due to high competition or due to challenges in project elaboration. In total, 56 Romanian SMEs participated in the program and EXPERTWARE SRL, EXIMPROD ENGINEERING, I-ENERGYLINK SRL are among the most important beneficiaries.

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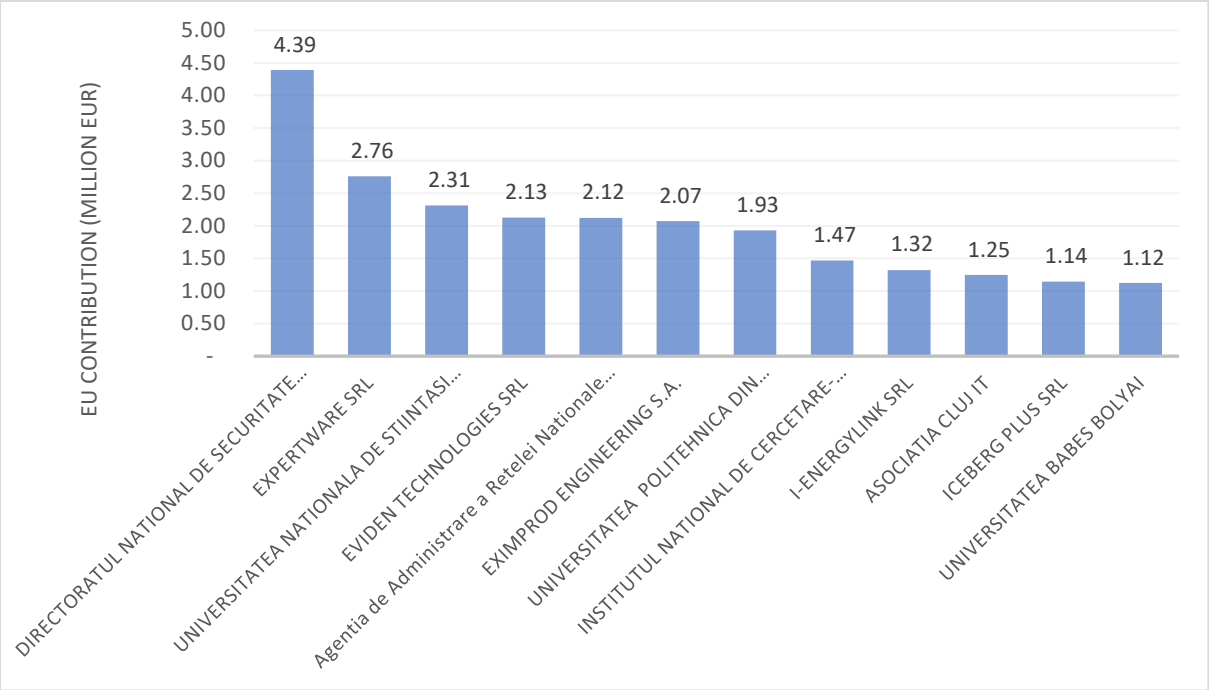

Figure 6. Top 12 organizations in Romania based on EU contribution

Source: Author's compilation based on data from the DIGITAL Dashboard

Under the Digital Europe, Romania has been involved in several large-scale projects, with a total EU contribution of 378.4 million EUR. The most significant projects include Genomic Data Infrastructure (GDI) and Digital Innovation Zone EDIH (eDIH-DIZ), as part of initiatives dedicated to the development of digital infrastructure in healthcare system. Another major project is AgriDataSpace, that received EU financing to create a European framework for data management in agriculture, demonstrating a strategic interest for the digitalisation of this sector. Regional Digital Innovation Hubs, such as Wallachia eHub (WeH) and Transilvania Digital Innovation Hub (TDIH) highlight the focus on creating regional digital ecosystems to facilitate the deployment of emerging technologies in economy. The MERIT project represents a relevant academic initiative to train specialists smart, secure and interconnected technologies and contribute to reducing the shortage of high qualified workforce in digital sector.

Another important element of Romania's participating under DIGTAL is the extensive network of international collaborations, demonstrating an active integration into the European digital ecosystem. The most significant partnerships were established with Spain, Greece, Italy, Germany, Belgium, Sweden and France. This distribution of collaborations indicates a well-defined strategy of integration into European research and innovation consortia, given that partner states are recognized for the technologic advancement and expertise in digitalization field. The active participation in these cooperation networks can facilitate the knowledge transfer, access to advanced technologies and strengthen of Romania's position in the European digital ecosystem.

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The analysis of factors influencing the access and absorption of funds from the DIGITAL highlights a series of administrative, economic, technological, and strategic challenges that impact the efficiency of funding (Table 2).

Table 2. Factors, obstacles, and improvement measures for accessing DIGITAL funding

Factors	Obstacles	Improvement Measures
Administrative and Institutional Factors	Excessive bureaucracy in public institution.	Optimize the existing procedures for accessing European funds.
	Limited administrative capacity – lack the expertise of applicants in accessing funds.	Develop training programs to improve capacity for accessing DIGITAL funding.
	Institutional bottlenecks and lack of inter-institutional coordination.	Develop training programs for public officials and project managers to improve capacity for managing DIGITAL projects.
Regional Disparities and Fund Absorption Capacity	Digital infrastructure gaps – Less developed regions struggle to implement projects due to inadequate digital infrastructure.	Allocate dedicated funding for infrastructure development in underfunded regions to ensure equitable digital growth.
	Lack of digital skills – Insufficient digital literacy in certain regions reduces fund absorption rates.	Strengthen digital training programs and facilitate collaborations between educational institutions and businesses.
Economic and Technological Factors	Limited co-financing access – SMEs and startups face difficulties securing co-financing for projects.	Introduce flexible co-financing schemes with EU-backed guarantees to ease financial constraints.
	Degree of digitalization of the economy – More digitalized economies access funds more easily, benefiting from existing infrastructure.	Foster international public-private partnerships to encourage digital innovation and strengthen digital ecosystems at national and European levels.
	Regulatory and interoperability challenges – Divergent national regulations hinder cross-border digital projects.	Promote the adoption of harmonized EU regulations to ensure seamless integration of digital solutions.
EU Strategy and Political Priorities	Conditionalities imposed related to cofinancing and security restrictions.	Transparency and cooperation with national authorities to identify additional sources for cofinancing.
Awareness and Access to Information	Low awareness of funding opportunities – Many eligible beneficiaries are unaware of DIGITAL financing mechanisms.	Enhance promotional efforts through webinars, training sessions, and collaboration with National Contact Points (NCPs).
	Difficulty in forming European consortia – Many organizations struggle to identify and connect with suitable partners.	Strengthen the role of European Digital Innovation Hubs (EDIHs) and NCPs to facilitate networking and international partnerships.

Source: Author's compilation

Administrative and institutional barriers, such as excessive bureaucracy and limited public sector capacity, slow down the funding process and reduce the accessibility of financial resources. Additionally, regional disparities in digital infrastructure further exacerbate inequalities in fund absorption. From an economic and technological perspective, the lack of co-financing opportunities for SMEs and startups, along with regulatory fragmentation across EU Member States, restricts participation in transnational digital

projects. Furthermore, at the EU strategy level, stringent funding conditions create uncertainty for applicants. A major obstacle remains the lack of awareness and access to information, as many potential beneficiaries are not sufficiently informed about funding opportunities or struggle to form international consortia.

To address these challenges, several improvement measures can be recommended, including strengthening the role of European Digital Innovation Hubs (EDIHs) and National Contact Points (NCPs) as essential for facilitating partnerships and providing technical assistance to applicants. By implementing these strategic measures, Romania could significantly improve its participation in the program and accelerate its digital transformation.

Conclusions

This study set out to evaluate the contribution of the Digital Europe Programme (DIGITAL) to the EU's digital transformation and to assess Romania's performance in accessing and utilizing this funding. Guided by three hypotheses and relying on documentary analysis and descriptive statistical evaluation, the research contributes to a deeper understanding of how DIGITAL is operationalized at the national level.

The findings confirm the first hypothesis (H1): DIGITAL is a strategic, well-structured funding mechanism embedded in the Multiannual Financial Framework 2021–2027, reflecting the EU's commitment to technological sovereignty and global competitiveness through investments in infrastructure, cybersecurity, and digital skills. These conclusions align with prior literature highlighting the EU's shift toward strategic digital autonomy (e.g., Bıçakçı, 2024; Bormane & Blaus, 2024; López-Nores et al., 2022).

The second hypothesis (H2) is also validated. The analysis of Romania's participation reveals that the country has secured a relatively small share of the total funding, with significant disparities - both regionally and institutionally - with higher education institutions and private firms absorbing most of the funding, while public institutions and some regions remain underrepresented.

The findings of the research also test the third hypothesis (H3). DIGITAL-funded projects in Romania have a positive impact on digital infrastructure and skill development, but their scale and distribution remain insufficient to significantly reduce the digital divide with other EU Member States. Persistent barriers such as bureaucratic complexity, limited awareness among stakeholders, and limited co-financing opportunities for SMEs constrain Romania's capacity to fully leverage DIGITAL support.

Building on insights from the literature (Garau et al., 2023; Savitska, 2025; Tiganasu & Lupu, 2023) and the current analysis, several actionable measures can be proposed to improve Romania's absorption rate and alignment with EU priorities:

- Strengthening institutional capacity for managing DIGITAL-related projects;
- Enhancing support for SMEs and start-ups through co-financing mechanisms and advisory services;

- Expanding the role of European Digital Innovation Hubs (EDIHs) as regional enablers of innovation and technical assistance (Colovic et al., 2024; Coban, 2023; Ogrean et al., 2024);
- Increasing the visibility and functionality of National Contact Points (NCPs) to better guide beneficiaries;
- Establishing a national monitoring framework to track the effectiveness of DIGITAL-funded initiatives.

While DIGITAL is an essential funding mechanism it cannot alone address Romania's digitalization challenges. A coordinated approach leveraging complementary funding sources - such as the National Recovery and Resilience Plan (NRRP) and Horizon Europe or other program, as well as private investments - is necessary to bridge the digital divide and create a sustainable digital ecosystem. The NRRP provides substantial allocations for digital infrastructure and skills development, while Horizon Europe offers funding for digital research and technological innovation, offering long-term competitiveness through international collaboration. A strategic integration of these mechanisms would enable Romania to accelerate digital transformation, strengthen its technological landscape, and close the gap with more digitally advanced EU Member States.

By offering an assessment of DIGITAL implementation in Romania, this study contributes empirically and conceptually to understanding how EU digital funding mechanisms function at the national level. In practical terms, it offers actionable recommendations for policymakers, funding authorities, and innovation intermediaries seeking to improve fund absorption, institutional coordination, and alignment with EU digital objectives.

This research provides valuable insights, but some limitations must be acknowledged. The analysis relies on quantitative data from official EU sources, which, while highly reliable, do not fully capture the qualitative aspects of digital transformation, such as governance efficiency, and project impact assessments. Moreover, the lack of comparative analysis with other Central and Eastern European (CEE) countries limits the ability to identify regional best practices.

Future research could address these gaps by exploring comparative case studies across CEE countries, investigating the role of institutional ecosystems in fund absorption, or analyzing synergies between DIGITAL, NRRP, and Horizon Europe. Such studies could provide a more integrated perspective on EU digital funding and its capacity to support convergence and strategic autonomy across the Union.

In conclusion, the Digital Europe Programme offers unprecedented opportunities for accelerating the digital transformation of the European Union. However, its full potential remains underutilized in Romania due to structural inefficiencies, administrative challenges, and regional funding disparities. To maximize the economic and technological impact of DIGITAL funding, Romania must implement a strategic, integrated, and results-driven approach, focusing on administrative efficiency, institutional capacity-building, and diversified access to EU digital financing instruments.

References

Bıçakçı, A. S. (2024). Digital Europe Program: Nurturing technological sovereignty for a resilient European digital ecosphere. *Ankara Avrupa Çalışmaları Dergisi, 23*(Özel Sayı-Future of Europe: Reflections from Türkiye), 135-174. https://doi.org/10.32450/aacd.1439811

Bormane, S., & Blaus, E. (2024). Artificial intelligence in the context of digital marketing communication. *Frontiers in Communication*, 9. https://doi.org/10.3389/fcomm.2024.1411226

Burinskienė, A., & Nalivaikė, J. (2024). Digital and sustainable (twin) transformations: A case of SMEs in the European Union. *Sustainability*, *16*(4), 1533. https://doi.org/10.3390/su16041533

Coban, M. (2023). The role of digital technology in the development of enterprises in the European Union. *Eastern European Journal of Regional Studies*, *9*(2), 142–155. https://doi.org/10.53486/2537-6179.9-2.10

Colovic, A., Caloffi, A., Rossi, F., & Russo, M. (2024). Institutionalising the digital transition: The role of digital innovation intermediaries. *Research Policy*, *54*(1), 105146. https://doi.org/10.1016/j.respol.2024.105146

Copăceanu, C., & Mazăre, S. (2023). Management of European funds: Case study: Neamț and Constanța counties, Romania. *Eastern European Journal for Regional Studies, 9*(2), 82–95. https://doi.org/10.53486/2537-6179.9-2.06

Garau, C., Desogus, G., & Stratigea, A. (2023). Digitalisation process and sustainable development of vulnerable territories: Assessment of equity potentials of major Mediterranean islands. *TeMA - Journal of Land Use, Mobility and Environment*, *16*(3), 565–594. https://doi.org/10.6093/1970-9870/9910

López-Nores, M., Pazos-Arias, J. J., Gölcü, A., & Kavrar, Ö. (2022). Digital Technology in Managing Erasmus+ Mobilities: Efficiency Gains and Impact Analysis from Spanish, Italian, and Turkish Universities. *Applied Sciences*, *12*(19), 9804. https://doi.org/10.3390/app12199804

Maurer, F. (2021). Business intelligence and innovation: A European digital innovation hub to increase system interaction and value co-creation within and among service systems. In *Proceedings of the 10th International Conference on Operations Research and Enterprise Systems (ICORES)* (pp. 208–217). https://doi.org/10.5220/0010255602080217

Mărcuț, M. (2020). Evaluating the EU's role as a global actor in the digital space. *Romanian Journal of European Affairs*, *20*(2), 79-91. https://www.researchgate.net/publication/346570197

Miron, D., Strat, V., Marinaș, C. V., & Marinaș, L. E. (2022). *Redresarea economică post-pandemie. Oportunități pentru România pe termen mediu și lung.* Institutul European din România. http://ier.gov.ro/publication-category/studii-spos-2021/

Miron, D., Ionel, E. S., & Belciu, A. C. (2024). An analysis of the digital resilience challenge for implementing EU programs and instruments. In *Proceedings of the 18th International Conference on Business Excellence (ICBE 2024)* (pp. 321-334). https://doi.org/10.2478/picbe-2024-0028

European Commission. (2010). *A digital agenda for Europe* (COM/2010/0245 final). https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A52010DC0245

European Commission. (2015). *A digital single market strategy for Europe* (COM/2015/0192 final). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52015DC0192

European Commission. (2020). *Shaping Europe's digital future* (COM/2020/0067 final). https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52020DC0067

European Commission. (2021). *2030 Digital Compass: The European way for the Digital Decade* (COM/2021/0118 final). https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52021DC0118

European Commission. (n.d.). *The Digital Europe Programme*. https://digital-strategy.ec.europa.eu/en/activities/digital-programme

European Commission. (n.d.). *The DIGITAL Dashboard*. https://dashboard.tech.ec.europa.eu/qs_digit_dashboard_mt/public/extensions/CNECT_DIGITAL_dashboard/CNECT_DIGITAL_dashboard.html

European Commission. (n.d.). *The Digital Economy and Society Index (DESI)*. https://digital-strategy.ec.europa.eu/en/policies/desi

Ogrean, C., Pîrvu, B. C., & Herciu, M. (2024). Exploring digital needs in the Centru Region, Romania: A comparative cross-sectoral study. *Studies in Business and Economics, 19*(3), 348–368. https://doi.org/10.2478/sbe-2024-0060

Pirinen, R., Rathod, P., Gugliandolo, E., Fleming, K., & Polemi, N. (2024). Towards the harmonization of cybersecurity education and training in the European Union through innovation projects. In *2024 IEEE Global Engineering Education Conference (EDUCON)* (pp. 1-9). . https://doi.org/10.1109/EDUCON60312.2024.10578867

Rathod, P., Kioskli, K., Polemi, N., Wessels, J., & Lehto, M. (2024). Leveraging the European Cybersecurity Skills Framework (ECSF) in EU innovation projects: Workforce development through skilling, upskilling, and reskilling. In *2024 IEEE Global Engineering Education Conference (EDUCON)* (pp. 1-9). https://doi.org/10.1109/EDUCON60312.2024.10578846

Savitska, V. (2025). Digitalisation of the public administration system in the context of economic and legal areas of European integration. *Baltic Journal of Economic Studies*, 11(1), 270-280. https://doi.org/10.30525/2256-0742/2025-11-1-270-280

Stoican, A., & Chirieac, R. (2021). The New Direction of the EU: the Creation of a Digital Europe. In *Resilience and Economic Intelligence Through Digitalization and Big Data Analytics* (pp. 479-491). https://doi.org/10.2478/9788366675704

Tiganasu, R., & Lupu, D. (2023). Institutional quality and digitalization: Drivers in accessing European funds at regional level. *Socio-Economic Planning Sciences, 90*, 101738. https://doi.org/10.1016/j.seps.2023.101738

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SUSTAINABLE DEVELOPMENT: FROM EARLY CONCEPTS TO 21ST CENTURY ACHIEVEMENTS

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Abstract: *This article examines the historical evolution and theoretical foundations of sustainable development as a guiding economic and policy principle from the early 20th century to contemporary global frameworks. The primary research question is: how have significant historical milestones and theoretical contributions influenced the conceptual development and practical implementation of sustainable development? Employing a historical-analytical methodology, the paper reviews critical documents and events, including The Limits to Growth (1972), the Brundtland Report (1987), the Rio Earth Summit (1992), the Kyoto Protocol (1997), and the adoption of the Sustainable Development Goals (2015). The data analysis highlights the progressive integration of sustainable principles into global policy agendas and institutional frameworks, emphasizing an increasing global commitment to environmental protection and social equity. Key findings suggest that international cooperation, policy integration, and continued innovation in sustainability frameworks remain essential. The article concludes with recommendations for future research, emphasizing the need to investigate the effectiveness of recent policies, such as the Paris Agreement, and explore innovative approaches to addressing key challenges in the practical implementation of sustainability principles, such as limited resources, regulatory gaps, and political inertia.*

Keywords*: Sustainable Development, Economic Sustainability, Environmental Policy, Social Equity, Global Cooperation, Sustainable Development Goals, International Agreements.*

JEL Classification*: O44, Q56, Q58*

UDC: *339.97:504.03*

Introduction

In the face of accelerating environmental degradation, growing socio-economic inequalities, and mounting global policy challenges, the concept of Sustainable Development has emerged as a central paradigm for reconciling economic progress with environmental and social responsibility.

Among the modern approaches to global economic development, we identify a unifying paradigm – Sustainable Development – which integrates several interrelated components: Green Economy, Circular Economy, Corporate Social Responsibility (CSR), and Inclusive Development**.** These concepts are not separate paradigms but represent strategic directions within the broader Sustainable Development Paradigm (SDP)**,** as they share common principles such as environmental responsibility, social equity, and long-term economic viability.

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This approach aligns with recent academic literature, such as Z. Shishcan (2018), which analyzes the internal coherence and evolution of the SDP, situating Green and Circular Economies as essential models within its structure.

Understanding the theoretical foundations and historical evolution of the Sustainable Development paradigm is essential for identifying the origin of key concepts, recognizing how global priorities have shifted over time, and clarifying the policy-making context in which current sustainability frameworks operate. This perspective helps to reveal not only the depth of the paradigm but also the strategic rationale behind international environmental cooperation and the formulation of global goals.

Data and Methodology

This research is based on a qualitative, descriptive, and historical analysis of the evolution of the sustainable development concept. The methodology does not involve empirical modeling or statistical calculations but instead traces the theoretical, institutional, and policy-related progression of the idea over the last century.

Approach:

The study uses a literature-based analytical framework to explore how sustainable development has evolved through successive economic, ecological, and policy-based perspectives into a globally adopted paradigm, addressing environmental, economic, and social dimensions.

A key methodological tool is the construction of an evolutionary model, dividing the development of the concept into five major historical phases:

1. Early Economic Ideas (1920–1970);
2. Recognition щf Environmental Impact (1960–1980);
3. The Definition щf Sustainable Development (1980–1990);
4. The Institutionalization Of Sustainable Development (1992–2000);
5. Global Transformation Through Sustainable Development (2000–present).

This phased model is used to organize findings and track the integration of sustainability into global governance and development discourse.

Data Sources:

The analysis draws on secondary data and official documents from:

- International organizations (UN, World Bank, Club of Rome, OECD, IPCC);
- Seminal reports and frameworks (e.g., Our Common Future, Agenda 21, The Limits to Growth, Paris Agreement, SDGs);
- Academic works by scholars such as Herman Daly, Kate Raworth, Jeffrey Sachs, and Amartya Sen.

Research Techniques:

- Content analysis of documents and academic literature;
- Comparative review of sustainability milestones and global frameworks;

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- Thematic categorization of sustainability approaches across historical periods.

The Model and Findings

The five historical stages were identified through a comparative review of academic and institutional sources. This classification reflects the conceptual, political, and institutional milestones that have shaped the evolution of Sustainable Development from early economic theories to a multidimensional global framework.

Stage 1. (1920-1970): Early Economic Ideas

Research on Sustainable Development began to take shape in economic literature in the 1920s, with studies by renowned economists such as Léon Walras, John R. Hicks, Paul Samuelson, Abraham Wald, and others. These researchers focused on analyzing the general equilibrium of the market - an economic theory that examines how different markets within an economy interact to reach a common equilibrium point where supply and demand for all goods and services are balanced. This theory, developed by Léon Walras (1874) and later refined by economists such as Kenneth Arrow and Gérard Debreu, demonstrated that an economic system could reach a stable equilibrium when all markets operate simultaneously in harmony (Hicks, 1939).

Market equilibrium was analyzed based on the conditions of perfect competition - a theoretical market model in which there are a large number of buyers and sellers, and no single participant has the power to influence prices. The price of each good or service is determined solely by the interaction between supply and demand. These economists highlighted that market development and its sustainability depend on economic processes at all stages of the economic cycle, including production, distribution, and consumption. The importance of these studies laid the foundation for a fundamental concept in economic theory, influencing modern strategies for sustainable economic growth – a process that ensures long-term economic stability, promotes efficient allocation of natural resources and waste reduction, and supports sustainable economic policies by integrating ecological and social aspects.

During the 1950s and 1960s, the rapid expansion of the industrial economy led to unprecedented environmental issues, such as pollution, deforestation, and the depletion of natural resources. These challenges contributed to shaping a new aspect of the Sustainable Development concept, centered on recognizing environmental impact.

Stage 2. (1960-1980): Recognition of Environmental Impact

Between the 1960s and 1980s, the paradigm of Sustainable Development was consolidated, closely linked to the efforts of most countries to promote development with minimal environmental impact. During this period, scholars began formulating the first concerns about environmental issues and the impact of human activities on nature.

The most important publications on this subject during this period came from researchers in the United States, the United Kingdom, and France.

1. Rachel Carson's scientific publication *Silent Spring* (Carson, 1962) – a landmark work that raised awareness about the effects of pesticides and sparked the global environmental movement at world level.

2. *The Economics of the Coming Spaceship Earth* by Kenneth E. Boulding (Boulding, 1966) – a study in which the American economist and sociologist warned about the limits of economic growth (the concept that unlimited economic development is not possible due to constraints imposed by finite planetary resources, the regenerative capacity of ecosystems, and the impact of human activities on the environment).
3. *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind* (Meadows et al., 1972), published by a team of researchers from the Massachusetts Institute of Technology (MIT) under the coordination of Donella Meadows, analyzed the long-term consequences of economic growth on planetary resources and the environment. Commissioned by the Club of Rome - an international think tank focused on global challenges - the report became one of the earliest comprehensive studies to warn about the dangers of unchecked economic expansion and excessive resource consumption. It was later updated in 1992 and 2004 through the volumes *Beyond the Limits* and *Limits to Growth: The 30-Year Update*. The report had a profound influence on the development of the concepts of Sustainable Development and Sustainability, emphasizing the need for systems capable of maintaining long-term functionality without compromising the resource needs of future generations.

   Key conclusions of the report:

   - Exponential economic growth cannot be sustained in the long term without severe ecological consequences;
   - Excessive resource consumption and pollution threaten the planet's ecological balance;
   - Without sustainable policies, there is a risk of economic and social collapse;
   - Proposed solution: Balanced development that limits negative environmental impacts.

The report's contribution to modernizing the concept of Sustainable Development:

- Raised global awareness (one of the first documents to scientifically demonstrate that planetary resources are finite);
- Influenced international policy (laid the foundation for later environmental policies and sustainable development strategies);
- Stimulated research in ecological economics (helped integrate ecological dimensions into economic models);
- Influenced UN conferences on sustainable development, including the Stockholm Summit (1972) and the Rio Earth Summit (1992).

4. *Only One Earth* by Barbara Ward (1972) – a British economist who promoted the concept of equity between developed and developing countries and argued that economic development should be inclusive and sustainable.

5. Also, a contribution to the formulation and finalization of the concept of Sustainable Development can be found in the works of Edward Goldsmith (1928-2009), founder of Political Ecology and the journal *The Ecologist* (Goldsmith, various issues). He advocated that economic models should be compatible with Earth's natural cycles, influenced biodiversity protection policies (a set of strategies, regulations, and measures adopted at local, national, and international levels for the conservation and sustainable use of ecosystems, species, and genetic resources), and promoted an economic model in harmony with nature.

The year 1972 was a pivotal moment in shaping the theoretical and methodological foundation of the Sustainable Development concept. The United Nations Conference on the Human Environment in Stockholm (June 5-16, 1972) (United Nations, 1972), the first global meeting dedicated to environmental issues, marked the official recognition of the need to integrate environmental protection into economic development strategies.

Key Outcomes of the Stockholm Declaration:

- Recognition of the right to a healthy environment (the environment is essential for human well-being and must be protected; economic development must not compromise ecological balance);
- Establishment of the principle of common responsibility (states must cooperate to protect natural resources; each country has sovereign rights over its resources but also a responsibility to prevent environmental damage);
- Creation of the United Nations Environment Programme (UNEP) (this agency became the main international body responsible for coordinating environmental and sustainable development policies);
- The “Polluter Pays” Principle (states and companies are responsible for the costs of remediating environmental damage).

Foundation for future Sustainable Development Summits, including the Rio Earth Summit (1992), the Johannesburg Summit (2002), and the Paris Agreement (2015).

A brief overview of the Stockholm Declaration’s Impact on Sustainable Development:

- Integrated environmental concerns into economic decision-making (it was the first document to demonstrate that economic development must consider environmental protection);
- Established a foundation for global environmental legislation (influenced the adoption of international environmental regulations, including treaties on pollution and climate change);
- Shifted perspectives on economic growth (contributed to the transition from an economy focused solely on growth to one that incorporates long-term sustainability);
- Initiated international environmental cooperation (marked the beginning of global environmental diplomacy, paving the way for future sustainability collaborations).

The Stockholm Declaration (1972) played a crucial role in defining and developing the concept of Sustainable Development, establishing fundamental principles for environmental protection and integrating sustainability into global economic strategies. It represented the

starting point for all future international initiatives aimed at balancing development with natural resource protection.

Between 1960 and 1980, the concept of Sustainable Development was shaped by contributions from economists, ecologists, and political scientists who demonstrated the link between economy, environment, and society. Their research laid the groundwork for modern sustainability strategies, influencing international policies such as the Stockholm Declaration (1972), the Rio Earth Summit (1992), and the 2030 Agenda.

Stage 3 (1980-1990): The Definition of Sustainable Development

During this period, the concept of Sustainable Development was formalized and strengthened at the international level.

1. **The Brundtland Report** – *Our Common Future* (World Commission on Environment and Development [WCED], 1987). The report was developed under the leadership of Gro Harlem Brundtland , former Prime Minister of Norway and Chair of the World Commission on Environment and Development (WCED). She was the first woman to hold the position of Prime Minister of Norway, serving multiple terms (1981, 1986–1989, 1990–1996), and is recognized as the "Mother of Sustainable Development." This report marked a turning point in global thinking about development and environmental protection. Official definition of sustainable development (Brundtland Report, 1987): "Development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs."

Key Themes of the Brundtland Report – Our Common Future:

- Interdependence between the economy, environment, and society (economic growth must consider natural resources and social equity);
- Limiting human impact on the environment (reducing pollution, protecting biodiversity, and using resources efficiently);
- Global responsibility (sustainable development must be implemented through international cooperation);
- The need for political and economic reforms (economic policies must account for ecological and social costs).

Impact of the Brundtland Report – Our Common Future:

- Influenced the adoption of *Agenda 21* and the *Rio Declaration* at the Earth Summit (Rio de Janeiro, 1992);
- Provided the foundation for the Sustainable Development Goals (SDGs) adopted by the UN in the *2030 Agenda*;
- Transformed the global perspective on economic growth, emphasizing the need for a balance between the economy, environment, and society.

2. **State of the World** (Brown, 1984) by Lester R. Brown. Lester R. Brown, founder of the Worldwatch Institute, was a leading analyst of global environmental issues, natural resources, soil degradation, and climate change. In *State of the World*, he:

highlighted the relationship between sustainable agriculture, water resources, and food security; advocated for a transition to renewable energy and responsible economic policies; provided one of the first global analyses of environmental problems and sustainable solutions. This work remains a key reference in sustainability discussions and policy-making.

3. **The I = PAT Model**

Developed by American biologist Paul R. Ehrlich and American scientist John P. Holdren (Ehrlich & Holdren, 1971), who later served as a research and technology advisor to former U.S. President Barack Obama, this model describes the environmental impact of human activities.

Formula:

$$I = P \times A \times T, \quad (1)$$

where:

I - *Environmental Impact;*

P - *Population;*

A - *Affluence (consumption per capita);*

T - *Technology used.*

Significance of the I = PAT Model

It demonstrates how population growth, consumption patterns, and technology choices influence environmental sustainability. Suggests that solutions for sustainable development must focus on reducing excessive consumption and improving eco-friendly technologies. Is widely used in public policy, ecology, economics, and sustainability planning. Remains a fundamental tool for analyzing human environmental impact and developing sustainability strategies today.

4. **Scientific Contributions of American Economists Edward Barbier** (Barbier, various works) and Amory Lovins (Lovins,1999). Edward Barbier was one of the first scholars to make significant contributions to the development and definition of the Green Economy concept. He promoted the transition to a sustainable economic model that reduces environmental impact and emphasized the role of investments in renewable energy, pollution reduction, and biodiversity protection. Amory Lovins, an energy researcher and founder of the Rocky Mountain Institute, advocated for renewable energy and energy efficiency as key solutions for sustainable development. He demonstrated that an economy based on energy efficiency is more profitable and sustainable, influencing carbon emission reduction policies and the global transition to green energy.

The period 1980–1990 marks the shift from local environmental concerns to global recognition of the need for sustainable development. During this time, Sustainable Development became a strategic international goal, integrated into the economic and environmental policies of states and international organizations. These initiatives paved the

way for concrete actions, culminating in the Earth Summit in Rio (1992), which strengthened global commitments to sustainability.

Stage 4. (1990–2000): The Institutionalization Of Sustainable Development

During the 1990s and early 2000s, sustainable development was officially integrated into global and national policies, becoming a strategic objective for international organizations and governments. This stage marked the transition from theory to practice, with the adoption of agreements, strategies, and concrete measures for environmental protection and economic-social balance. This period was marked by two mutually reinforcing dynamics: conceptual elaboration by leading scholars and the formalization of sustainability principles at the international institutional level.

Academic contributions and scientific works

Among the scholars who contributed to the promotion of this concept, and conferences/summits organized, we can highlight:

1. Two works by Herman Daly, American economist-ecologist, founder of Ecological Economics and promoter of the concept of Sustainable Economy: *Steady-State Economics: The Economics of Biophysical Equilibrium and Moral Growth* (Daly, 1991). In this work, Daly introduces the concept of the steady-state economy, which assumes economic growth limited by the capacity of natural resources to regenerate; and *Beyond Growth: The Economics of Sustainable Development* (Daly, 1996). Daly criticizes the traditional model of infinite economic growth and emphasizes the need for a sustainable economic model. He stresses the importance of natural capital and maintaining a balance between the economy and the environment. In his works, the author promoted the idea that the economy must function within the limits of ecosystems and advocated the transition to an economy based on natural capital and the sustainable use of resources. He argued that GDP is not a sufficient indicator of economic progress and proposed indicators of ecological and social well-being (alternative indicators to GDP, such as the Index of Sustainable Economic Well-being – ISEW) and contributed to global policies on renewable resources and green energy.
2. *The Value of the World's Ecosystem Services and Natural Capital* (Costanza et al., 1997), published in the journal *Nature*, represents a pivotal moment in the development of ecological economics. Robert Costanza and his colleagues quantified the economic value of ecosystem services globally, estimating it at approximately $33 trillion per year (a value significantly higher than the global GDP at the time). It demonstrated that natural systems provide essential economic benefits – such as water purification, pollination, climate regulation, and soil protection. This publication influenced the integration of the concept of natural capital into economic policies and sustainability strategies and is considered the cornerstone of ecological economics. It has served as a basis for numerous environmental protection policies.
3. *Development as Freedom* (Sen, 1999) by Amartya Sen is a monograph in which the author expanded the concept of Sustainable Development through the perspective of

human development and social equity. The Indian economist and Nobel Prize laureate in Economics (1998) highlighted the link between poverty, economic well-being, and sustainability. He argued that development should not be measured solely by economic growth, but by the ability of individuals to improve their lives. Namely, he introduces the concept of fundamental freedoms, arguing that sustainable development must ensure:

- Equitable access to resources;
- Poverty reduction;
- Education and health;
- Democratic participation.

This vision influenced the development of the Human Development Index (HDI) and global strategies for reducing inequalities.

4. Paul Hawken, author of *The Ecology of Commerce* (Hawken, 1993), proposed a regenerative economic model. He emphasized the importance of the circular economy and corporate responsibility in sustainable development. He analyzed the destructive impact of business on the environment and proposed a model of a regenerative economy, in which companies must operate in harmony with ecosystems. *The Ecology of Commerce* is considered one of the most influential works in the field of Sustainable Development and ecological economics, highlighting the need to transform business into a regenerative force for the environment.

International institutional breakthroughs

Alongside theoretical progress, this decade also witnessed major international political and institutional developments that translated the sustainability paradigm into concrete global commitments.

5. The Earth Summit in Rio de Janeiro (1992) was a key moment in the history of Sustainable Development, establishing fundamental principles for the integration of environmental protection into global economic and social strategies (United Nations, 1992). It brought together over 178 states, world leaders, international organizations, and civil society, generating a strategic framework for economic, social, and ecological integration.

Key documents and agreements adopted:

- *Agenda 21* – A global plan for sustainable development (strategic document that provides an action plan for sustainable development at local, national, and international levels; it has influenced public policies on natural resource management, poverty reduction, and environmental protection).
- *Rio Declaration on Environment and Development* – Comprises 27 fundamental principles for integrating environmental protection into economic and social processes; promoted the polluter pays principle and the right of each nation to sustainable development.
- *United Nations Framework Convention on Climate Change (UNFCCC)* – Laid the foundations for subsequent agreements, such as the Kyoto Protocol (1997) and the Paris Agreement (2015), to reduce greenhouse gas emissions.

- *Convention on Biological Diversity (CBD)* – Established international strategies for protecting ecosystems, species, and genetic resources.
- *Declaration of Forest Principles* – The first international document to recognize the importance of forests in sustainable development.

Impact on international and national policies of the Earth Summit in Rio de Janeiro

Globally:

- Stimulated the adoption of the Millennium Development Goals (2000–2015) and subsequently the Sustainable Development Goals (2015–2030);
- Created the basis for subsequent climate change conferences (COPs).

Nationally:

- Governments began to integrate the principles of sustainable development into economic and environmental policies;
- Laws and regulations were adopted to protect biodiversity and natural resources.

Kyoto Protocol (United Nations, 1997) – An international agreement on the reduction of greenhouse gas emissions, signed at the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC). It aimed to reduce greenhouse gas (GHG) emissions to combat global climate change. From a Sustainable Development perspective, the Kyoto Protocol represented an important step in aligning economic and environmental policies by imposing clear emission reduction targets for developed countries, which are the largest emitters of GHG. It emphasized the need for a balance between economic growth, environmental protection, and global equity, promoting the transition to a greener and more sustainable economy. At the same time, the Protocol encouraged investments in clean technologies and innovative solutions to support emerging economies and sustainable development at a global level.

Taken together, the intellectual contributions and international agreements of this period consolidated the Sustainable Development paradigm. They marked a critical shift from theoretical discourse to institutionalization, embedding sustainability into political frameworks, economic models, and legal commitments at both global and national levels.

Stage 5. (2000–Present) – Global Transformation Through Sustainable Development

The scientists who fundamentally contributed to the development and consolidation of the concept of Sustainable Development during this period include the following leading figures:

1. *Johan Rockström and the Stockholm Resilience Centre team – Planetary Boundaries* (Rockström et al., 2009). Introduced the concept of "planetary boundaries," identifying 9 essential *biophysical* processes for Earth's stability (e.g., climate change, biodiversity loss, nitrogen cycle).
2. *Jeffrey Sachs – The Age of Sustainable Development* (Sachs, 2015). One of the most influential sustainability economists. Contributed to the formulation of the Sustainable Development Goals (SDGs) and the promotion of *integrated* global strategies to eradicate poverty, reduce inequality, and support sustainable economic growth. His work strengthened the link between development economics and sustainability governance.

3. *Kate Raworth – Doughnut Economics* **(**Raworth, 2017). Proposed a new economic model based on the balance between social needs and ecological limits. The "Doughnut Model" offers an alternative vision to unlimited economic growth by defining a *"safe and just space for humanity."* Her approach is widely used by cities and institutions aiming to implement sustainability at local levels.

Key Events

Johannesburg Agreement (2002) – World Summit on Sustainable Development:

- Continuation of the commitments established by the Earth Summit in Rio (1992);
- Focus on combating poverty and protecting the environment;
- Launch of partnerships between governments, the private sector, and civil society.

Adoption of the Sustainable Development Goals (United Nations, 2015):

- The UN launched the 2030 Agenda with 17 Sustainable Development Goals (SDGs);
- These goals aim to eradicate poverty, combat climate change, and promote social equity;
- The SDGs represent a global policy consensus on sustainability and inclusiveness.

Paris Agreement (United Nations, 2015) – Combatting Climate Change:

- Signed by 196 countries, this agreement aims to limit global warming to below 2°C, ideally to 1.5°C;
- Nations committed to reducing greenhouse gas emissions and investing in renewable energy;
- Marked a shift toward legally binding global climate cooperation and adaptive strategies.

European Green Deal (2019):

- The European Union launched an ambitious plan to achieve climate neutrality by 2050;
- Focus on transitioning to green energy, reducing pollution, and developing the circular economy;
- Positioned the EU as a leader in global sustainable development policy.

COP26 (2021) – Glasgow Climate Summit:

- Strengthening commitments to reduce emissions;
- Global agreement to reduce coal usage and increase funding for developing countries;
- Reaffirmed the urgency of coordinated climate action in light of increasing environmental risks.

This phase represents the global operationalization of sustainable development. Through both groundbreaking scientific contributions and international policy frameworks, sustainability has become embedded in development planning, environmental law, economic restructuring, and institutional governance. The continuous evolution of tools, models, and agreements in this phase reflects the complexity and interconnectedness of global sustainability challenges.

These five stages illustrate the progressive integration of sustainability principles across different disciplines and sectors. The conceptual foundation laid by early economists evolved

into an interdisciplinary paradigm, with each phase contributing new dimensions - environmental, institutional, and policy-based - to Sustainable Development's current form.

Conclusion

In the 20th and 21st centuries, the paradigm of Sustainable Development has gradually evolved, beginning with the recognition of the need to reconcile economic growth with environmental protection. Key contributions came from economists and ecologists who emphasized the importance of responsibly using natural resources.

The following table presents a synthesis of key intellectual contributions that directly shaped the formal development and institutionalization of the Sustainable Development Paradigm, particularly in its mature phases (Phases 3–5). Earlier conceptual foundations - addressed in Phases 1 and 2 - are discussed in the main text but are intentionally not included in the table, as they served as theoretical premises rather than formalized paradigm stages.

Table 1. Consolidated Contributions to the Sustainable Development Paradigm (Phases 3–5)

Author	**Work/Contribution**	**Main Idea**	**Year**	**Field**	**Global Impact**
Gro Harlem Brundtland	Our Common Future	Defining sustainable development as a balance between needs and resources	1987	Politics, Environment	Influenced Agenda 21 and the UN SDGs
Amartya Sen	Development as Freedom	Sustainable development includes human rights and freedom	1999	Economics, Ethics	Contributed to sustainable economic policies
Jeffrey Sachs	The Age of Sustainable Development	Global strategies for eradicating poverty and sustainability	2015	Economics, Global Development	Contributed to the formulation of the Sustainable Development Goals (SDGs)
Kate Raworth	Doughnut Economics	Economic model based on social and ecological balance	2017	Ecological Economics	Adopted by cities and institutions for sustainable planning
Herman Daly	Steady-State Economics	Sustainable economy based on limiting resource consumption	1977	Economics, Ecology	Influenced circular economy policies
Paul Hawken	Drawdown	Practical solutions for reducing CO_2 emissions	2017	Business, Ecology	Sparked green corporate initiatives
Donella Meadows & The Club of Rome	The Limits to Growth	Warning about overconsumption and resource depletion	1972	Systems Modeling, Ecology	Sparked global debates about economic growth
Johan Rockström	Planetary Boundaries	The concept of "planetary boundaries" to maintain stability	2009	Science, Climatology	Used by the UN and EU for climate policies

Source: elaborated by the authors

The evolution of Sustainable Development has been shaped by key milestones across different stages, from its early economic theories in the 1920s to its current global transformation. The initial research in economic equilibrium and market efficiency laid the groundwork for understanding the importance of sustainable growth. However, it was the recognition of environmental impacts in the 1960s and 1970s - highlighted by works such as *Silent Spring* and *The Limits to Growth* - that marked a critical turning point, emphasizing the need to integrate ecological considerations into economic models.

The formalization of Sustainable Development in the 1980s through the Brundtland Report reinforced the imperative to balance economic growth, environmental protection, and social equity. This foundation enabled the adoption of global frameworks like *Agenda 21* and the *Rio Declaration*, which continue to shape international environmental policy. The 1990s brought institutionalization, marked by the *Earth Summit* and *Kyoto Protocol*, which embedded sustainability into policy and climate action.

The 21st century introduced a global transformation, led by frameworks like the UN *Sustainable Development Goals*, the *Paris Agreement*, and the *European Green Deal*. These initiatives advanced the international commitment to reducing emissions, combating inequality, and promoting a just transition to sustainable economic systems.

Implications of the analysis

The progression of Sustainable Development reveals how interdisciplinary collaboration - combining economic, ecological, and ethical perspectives - has resulted in a more holistic understanding of global challenges. The inclusion of planetary boundaries, social equity, and circular economic principles has significantly broadened the concept's scope and applicability.

Shortcomings of the research

While the historical and theoretical evolution has been mapped, this analysis does not include quantitative validation of policy impact at the national or regional levels. Additionally, the study does not assess implementation gaps between international agreements and real-world practices. Another limitation is the reliance on secondary sources without incorporating primary empirical data.

Directions for future research

Further research should explore how Sustainable Development principles are operationalized in national policy frameworks across diverse economic contexts. A comparative analysis of SDG implementation across regions, as well as case studies of successful and failed strategies, would offer valuable insights. Moreover, future studies should evaluate the effectiveness of alternative economic models - such as Doughnut Economics or Steady-State Economics - in real-world applications, and investigate measurable outcomes of sustainability metrics beyond GDP.

Sustainable Development remains a central force in shaping global agendas. Moving forward, it must remain adaptive, evidence-based, and inclusive - responding to emergent crises such as climate displacement, geopolitical resource tensions, and socio-economic disruptions.

Only through continuous critical evaluation and policy innovation can Sustainable Development fulfill its promise for future generations.

References

Barbier, E. B. (2010). *A Global Green New Deal: Rethinking the Economic Recovery*. Cambridge University Press. https://doi.org/10.1017/CBO9780511761743

Boulding, K. E. (1966). The economics of the coming spaceship Earth. In Jarrett, H. (Ed.). *Environmental quality in a growing economy* (pp. 3–14). http://www.zo.utexas.edu/courses/thoc/Boulding_SpaceshipEarth.pdf

Brown, L. R. (1984). *State of the world*. W.W. Norton & Company. https://scpd.gov.kw/Englishbooks/State%20Of%20The%20World%20.pdf

Brundtland, G. H. (1987). *Our common future*. Oxford University Press. https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf

Carson, R. (1962). *Silent spring*. Houghton Mifflin. https://library.uniteddiversity.coop/More_Books_and_Reports/Silent_Spring-Rachel_Carson-1962.pdf

Costanza, R., d'Arge, R., de Groot, R. *et al.* The value of the world's ecosystem services and natural capital. *Nature* 387, 253–260 (1997). https://doi.org/10.1038/387253a0

Daly, H. E. (1991). *Steady-state economics: The economics of biophysical equilibrium and moral growth.* (Rev. ed.). W.H. Freeman and Company. http://gesd.free.fr/pvictor.pdf

Ehrlich, P. R., & Holdren, J. P. (1971). Impact of population growth. In *The Environmental Future*. Thomas Y. Crowell.

Goldsmith, E. (1972). A blueprint for survival. *The Ecologist*, *2*(1), 1–43. https://theecologist.org/article/blueprint-survival

Hawken, P. (1993). *The ecology of commerce: A declaration of sustainability*. Harper Business. https://p2infohouse.org/ref/31/30233.pdf

Hicks, J. R. (1939). *Value and capital: An inquiry into some fundamental principles of economic theory*. Clarendon Press. http://digamo.free.fr/hicks39.pdf

Kyoto Protocol. (1997). *United Nations Framework Convention on Climate Change*. https://unfccc.int/kyoto_protocol

Lovins, A. B., Lovins, L. H., & Hawken, P. (1999). *Natural capitalism: Creating the next industrial revolution*. Little, Brown and Company. https://www.environmentandsociety.org/mml/natural-capitalism-creating-next-industrial-revolution

Meadows, D. H., Meadows, D. L., Randers, J., & Behrens, W. W. (1972). *The limits to growth: A report for the Club of Rome's project on the predicament of mankind*. Universe Books.

Raworth, K. (2018). *Doughnut economics: Seven ways to think like a 21st century economist*. Chelsea Green Publishing.

Rockström, J., Steffen, W., Noone, et all. (2009). Planetary boundaries: Exploring the safe operating space for humanity. *Ecology and Society*, 14(2), 32. https://www.ecologyandsociety.org/vol14/iss2/art32/

Sachs, J. (2015). *The age of sustainable development*. Columbia University Press. https://www.researchgate.net/publication/321491959_The_Age_of_Sustainable_Developm

ent

Sen, A. (1999). *Development as freedom*. Oxford University Press. http://www.c3l.uni-oldenburg.de/cde/OMDE625/Sen/Sen-intro.pdf

United Nations Conference on the Human Environment. (1972). *The Stockholm Declaration*. https://www.un.org/en/conferences/environment/stockholm1972

United Nations Framework Convention on Climate Change. (2015). *Paris Agreement*. https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

United Nations. (1992). *Agenda 21*. United Nations Conference on Environment and Development. https://sustainabledevelopment.un.org/outcomedocuments/agenda21

United Nations. (2015). *Sustainable development goals (SDGs) – 2030 Agenda*. https://sdgs.un.org/goals

Walras, L. (1874). *Éléments d'économie politique pure (Elements of pure economics)*. F. Rouge. http://digamo.free.fr/walras96.pdf

Ward, B., & Dubos, R. (1972). *Only one Earth: The care and maintenance of a small planet*. W.W. Norton & Company. https://unesdoc.unesco.org/ark:/48223/pf0000088941

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THE TRANSITION TO GREEN ENERGY AS A STRATEGY FOR STRENGTHENING THE ECONOMIC SECURITY OF THE REPUBLIC OF MOLDOVA

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Abstract: *The research aims to evaluate the impact of the transition to green energy on the economic security of the Republic of Moldova by analyzing the benefits of diversifying energy sources and reducing dependency on imports, thus enhancing national energy autonomy. The research methodology employs a mixed approach, combining quantitative analysis of statistical data on energy consumption, production, and dependence, with qualitative analysis of relevant international policies, ensuring rigorous substantiation of the conclusions. The importance of the research arises from the necessity to strengthen the economic security of the Republic of Moldova through the transition to green energy as a sustainable solution to mitigate vulnerabilities arising from external energy dependence and fluctuations in the international energy market. The development and integration of renewable energy sources contribute to economic stability, attract investments, facilitate alignment with European standards on environmental protection and energy efficiency, thereby promoting energy independence, sustainable economic growth, and environmental sustainability.*

Keywords: *green energy, economic security, renewable sources, energy diversification, energy efficiency, economic sustainability, energy dependence.*

Classification JEL: *Q43, O13, Q01, F52.*

UDC*: [620.9:504.06]:338.24(478)*

Introduction

In light of the rapid global transformations and due to certain national and international factors, for the Republic of Moldova, the transition to green energy is not an option, but a necessity, as the country remains largely dependent on imported energy resources. The Republic of Moldova is not among the states endowed with abundant conventional energy sources and cannot afford the luxury of a slower transition to green energy, as this shift has a direct impact on ensuring energy supply. This, in turn, directly affects the development of the economy and business environment, contributing to the well-being of the population and the economic security of the state.

The aim of this study is to assess the impact of the green energy transition on the economic security of the Republic of Moldova by analyzing the advantages of diversifying energy sources and reducing dependency on imports, with the goal of strengthening national energy autonomy. At the same time, the study explores European practices and policies that could influence national governmental strategies, encouraging a faster shift to renewable sources to ensure a more complex form of energy autonomy and reduce import reliance. This would lay a solid foundation for decreasing energy consumption, increasing the competitiveness of enterprises, and attracting

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foreign investors to projects with mutual benefits that would foster economic growth and ensure a stable economic security for the Republic of Moldova.

To achieve the proposed aim, this study adopts a mixed-method approach, combining quantitative analysis of statistical data related to energy consumption, production, and dependency with qualitative analysis of relevant international policies to ensure a rigorous foundation for the conclusions. The detailed analysis highlights the key challenges that hinder a rapid transition to green energy, underscoring the need for this transition to be adopted as a core strategy aimed at strengthening the country's economic security.

Results and Discussion

A thorough analysis of the topic addressed cannot be effectively conducted without clearly defining the key elements that will be studied in this article. The definition of each main component will help us better understand their significance within the context of the addressed issue.

The current geopolitical context requires that a state's national security encompasses all the constitutive elements of a security system, as these elements are interdependent and interconnected. It is essential that they be managed in a coordinated manner to ensure the protection and stability of the state (Figure 1).

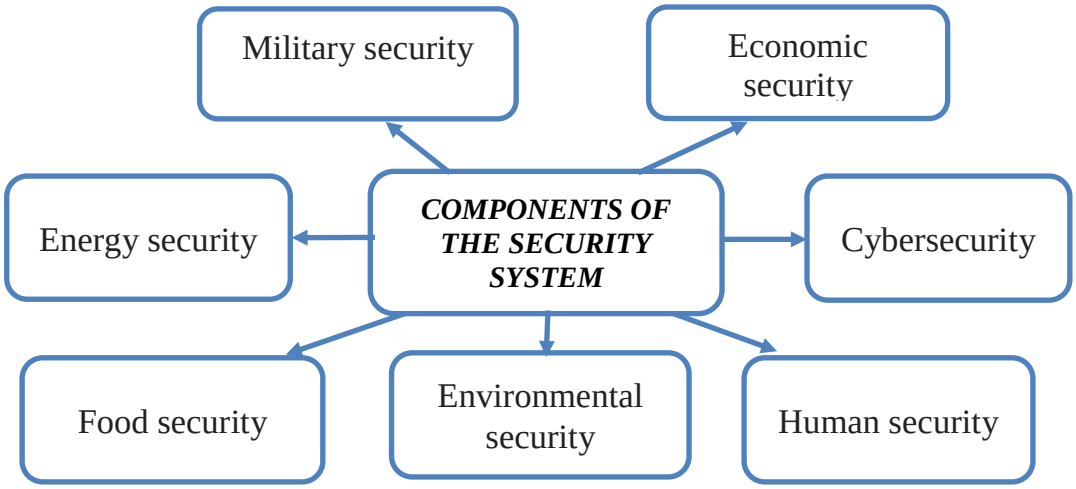

Figure 1. Components of the Security System

Source: adapted by the author based on Cutcovschi, V., 2024

Even though one element may seem independent, the others maintain their existence, underscoring their connection. Even though these elements of a security system are all intricately linked, economic considerations appear to take precedence over the others. Because having access to owning, and controlling finances, markets, and resources are fundamental needs for free and thriving development, which ensures a state's stability and security, economic strengthis more and morebecoming thecoreofany security system (Saţuța, 2007).

The economy is the bedrock of a state's survival because it enables other key aspects necessary for its functioning. The economy is the foundation of military strength and a key factor in determining a nation's power, encompassing both its social and political spheres. G. Belostecinic defines economic security as "a state of economic relations among economic actors, individuals, and state institutions, both domestically and in the realm of international economic activity" (Belostecinic & Sakovici & Moiseenko, 2011).

Acknowledging the need to define a key term within this study, we observe that a single, universally agreed-upon definition of "green energy" doesn't exist. Different organizations, institutions, and publications offer various interpretations. Generally, it's understood as energy generated from renewable resources, minimizing environmental impact, and thus contributing to a more sustainable energy system.

For instance, the International Renewable Energy Agency (IRENA), in its publications and materials, defines renewable energy (a term often used interchangeably with green energy) as "energy derived from natural sources that are replenished at a rate faster than they are consumed." Similarly, the United States Environmental Protection Agency (EPA) states that "green energy comes from renewable sources and often includes solar, wind, geothermal, biomass, and low-impact hydroelectric energy."

An additional definition is offered by the organization Green Start-up, which notes: "Green energy is a type of energy that comes from natural sources, whether it is sunlight, water currents, wind, or even waves, which generate tidal energy" (Ioniță, 2025).

Unlike the previous definitions, the National Grid company argues that although the terms green energy, renewable energy, and clean energy are often used interchangeably, there are certain distinctions among them. Green energy is described as "energy that can be produced using a method and from a source that does not harm the natural environment." The essential difference between green and renewable energy, in their view, lies in the fact that while most sources of green energy are also renewable, not all renewable energy sources are entirely green.

What green, clean, and renewable energy have in common is their growing use in generating electricity, aiming to gradually phase out the use of fossil fuels such as coal and natural gas – key contributors to climate change (National Grid, 2025).

Based on the above, we can conclude that: *green energy is energy derived from natural sources that regenerate naturally and have a lower environmental impact compared to conventional energy sources.*

Conventional energy sources, mainly fossil fuels, are associated with significant environmental issues, such as air pollution and climate change (Yan & Haroon, 2023). Transitioning to renewable energy sources, including wind, solar, and hydroelectric power, is essential for mitigating these adverse effects. The transformation is capital-intensive and requires systemic changes in energy infrastructure, which many countries are currently in the process of creating. Green finance, characterized by the allocation of financial resources to environmentally sustainable initiatives, has arisen as a mechanism to address this

disparity, fostering investments in renewable energy and other sustainable practices (Wen & He & Jing & Haroon, 2025).

The necessity of transitioning to green energy in the Republic of Moldova holds paramount importance from multiple perspectives: economic, political, and environmental. All these aspects, which are part of the broader security system previously mentioned, can be analyzed individually; however, given their interdependence and the fact that their effects ultimately impact the same entity-the state-we will examine them in an integrated manner.

The transition to green energy refers to the process of shifting from conventional energy sources, based on fossil fuels, to renewable and sustainable sources such as solar, wind, hydro, and bioenergy. Geothermal energy can also be included in this list; however, given its limited potential in the Republic of Moldova, we will focus primarily on the energy sources available in greater volume. In other words, the energy transition involves shifting energy production from sources that emit greenhouse gases-such as fossil fuels-to those that release little or no greenhouse gases. This change aims not only to reduce the negative environmental impact but also to increase energy efficiency and strengthen the state's economic security.

Table 1. Objectives of the green energy transition strategy

Objectives	Benefits
Reducing dependence on energy imports	Decreases vulnerability to external shocks and the energy policies of other states, particularly within the current geopolitical context.
Diversifying the energy mix	Increases the share of renewable sources in electricity and heat production, ensuring greater stability and resilience of the national energy system.
Stabilizing and reducing long-term energy costs	Although it requires initial investment, energy from renewable sources has low operating costs and eliminates the volatility associated with fossil fuel prices.
Stimulating sustainable economic development	Generates new employment opportunities in the production, installation, and maintenance of green technologies, as well as in related sectors.
Improving economic competitiveness	Access to clean and stable-priced energy can attract foreign investment and enhance the competitiveness of Moldovan enterprises.
Contributing to climate change mitigation	Contributes to the reduction of greenhouse gas emissions in accordance with the Republic of Moldova's international obligations.
Enhancing well-being and community health.	Reduces air contamination linked to burning fossil fuels.

Source: elaborated by the author

Any developed strategy is characterized by the establishment of specific goals that are intended to be achieved to ensure its success. The following table outlines the main objectives the Republic of Moldova aims to achieve through the implementation of its green energy transition strategy. These objectives are largely designed to enhance and develop the energy and economic sectors, as they form the foundation for ensuring long-term

economic security and improving the quality of life for the population. Alongside setting these objectives, we also identify the expected outcomes-or more precisely, the benefits-that are anticipated as a result of achieving the proposed goals. In our case, Table 1 presents the benefits expected to materialize.

Although plainly required and obviously advantageous, the Republic of Moldova faces certain obstacles in its move to renewable energy:

- Reliance on existing energy infrastructure – The current energy system is largely outdated and designed mainly for fossil fuels. Modernization and incorporating renewable energy sources will demand considerable investments. To effectively handle large amounts of fluctuating renewable energy, the system could necessitate substantial improvements. These upgrades could involve strengthening transmission lines, updating substations, and implementing smart grid technologies. The present grid might be unable to cope with the instability of solar and wind power, making grid enhancements unavoidable. Connection capacity with Romania needs upgrading to enable energy trading and balance the grid. Enhancing cross-border lines is key for both importing and potentially exporting green energy. Increased interconnection capacity enables the Republic of Moldova to access the EU energy market and provides a safeguard against internal supply variations (Governmental Investment Service, 2025).
- Limited energy storage capacity – Solar and wind power are intermittent powers, which pose severe challenges to grid stability and could have to be dealt with using energy storage, demand management, and flexible generation sources. Energy storage solutions – for instance, accumulators or batteries – have to be invested in to ensure a stable supply of electricity. Energy storage enables the storage of excess renewable energy when available and released when needed, ensuring a more stable and uniform energy supply.
- High Initial Costs – The upfront money invested in the technology of renewable energy sources such as solar panels, wind turbines, grid modernization, and storage systems can be extremely high and will demand serious money as well as new funding modalities. Government funding, international funding, and private sector investments will be most critical in overcoming this barrier. Renewable energy projects usually need high initial capital investment that has to come from a combination of public and private funding sources.
- Limited Technical and Human Capacities – The establishment of a workforce capable of installing, maintaining, and operating renewable energy systems, as well as the operation of an advanced grid with integrated renewable sources, will require long-term investments in education, training, and technology transfer (Ministry of Energy of the Republic of Moldova, 2025). The acquisition of local expertise is essential to the long-term sustainability of the green energy transition. There must be a skilled workforce to facilitate the effective installation and performance of renewable energy technologies.
- Insufficient or Unclear Regulatory Framework and Policies – Although the Republic of Moldova has advanced its energy law to EU levels, further efforts are needed to streamline permitting procedures, define in clear terms and with guidelines the development of renewable energy, and open access to the grid for renewable energy

producers. A predictable and stable regulatory environment is necessary to encourage investment and stimulate the development of the renewable energy industry. Clear and enabling regulations reduce risks for investors and facilitate the process of implementing renewable energy projects. Elimination of administrative bottlenecks and facilitation of right coordination among concerned stakeholders are also crucial (IRENA, 2019). Bureaucracy and lack of coordination hinder the progress of renewable energy projects. Efficient administrative procedures and better inter-institutional coordination can accelerate the process of green energy projects.

- Limited Public Awareness and Acceptance – Lack of knowledge or inadequate awareness of the benefits of green energy can create resistance to change. Public education and targeted awareness campaigns are essential to build confidence, facilitate behavior change, and secure public support for renewable energy projects.
- Limited Access to Financing and Investment – Attracting private investment and securing international funding continue to pose difficulties. Bolstering financial tools, creating a more favorable investment environment, and easing the path to green finance are essential to fully unlock the renewable energy sector's potential.

Moldova's energy system heavily depends on outside sources, with 82.78% of its total energy needs in 2022 met by imports. In 2022, electricity demand was 4.4 TWh. Of that, 10.72% came from Ukraine/Cuciurgani Moldavskaya GRES (MGRES), a gas-fired plant (61.19%) in Transnistria, or 10.86% from Romania. This strong dependence on external energy puts the country's economy at risk from supply interruptions or price volatility. It presents a danger to Moldova's economic, social, and energy security and a considerable challenge to the nation's sustainable economic advancement.

Lately, Moldova has been trying to boost energy efficiency and develop a renewable energy sector, while also drawing in foreign investment in the energy field. Using renewable energy resources can greatly lessen reliance on imported energy.

The shift towards renewable energy sources has accelerated, starting around 2018, and this momentum grows each year. The data in Figure 2 shows the yearly growth of installed renewable energy capacities. The figures show the advancement of each type of renewable energy source present on the local energy market. The most dramatic growth, in installed capacity, has been felt by photovoltaic systems (2018 – 4.020 MW; 2025 – 433.37 MW), followed by wind power systems. Biogas systems have made extremely timid progress, and hydro systems have changed little.

Photovoltaic systems, with a total installed capacity of 433.37 MW, represent the most widespread technology, accounting for 67% of the total installed renewable energy capacity. These are followed by wind power installations, with a total capacity of 188.98 MW, representing 29% of the total. Hydropower and biogas installations account for 16.75 MW (3%) and 7.01 MW (1%) respectively (National Energy Service, 2025).

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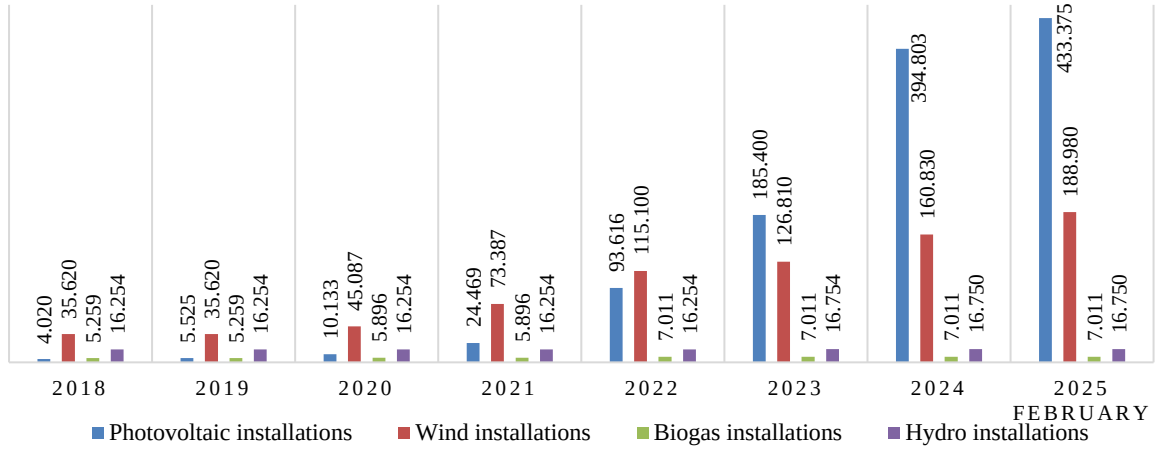

Figure 2. Evolution of installed E-RES capacities in the period 2018 – Feb. 2025, MW

Source: elaborated by the author based on data from the National Energy Service. (n.d.), 2025

The evolution of electricity production capacities from renewable sources reflects the Republic of Moldova's commitment to the green energy transition and the integration of alternative electricity generation sources into the national energy mix. The increasing share of renewable energy confirms the country's progress toward achieving the target of at least 27% in gross final energy consumption by 2030. This objective is aligned with both European Union policies and international agreements aimed at reducing greenhouse gas emissions and promoting energy sustainability.

Conclusions

In conclusion, the transition to green energy represents an essential and multifaceted strategy for strengthening the economic security of the Republic of Moldova. The country's current dependence on fossil fuel and electricity imports exposes it to significant vulnerabilities, further exacerbated by regional geopolitical instability. The adoption of green energy offers a promising pathway to reduce this dependency, stabilize energy prices, create new economic opportunities, attract investments, and ensure energy security.

The analyzed findings indicate significant potential for the development of renewable energy in the Republic of Moldova, particularly in the fields of solar and wind energy. The data analyzed in this, such as: national energy statistics, data on the installed capacity of renewable energy sources, data on energy resource imports, cover the analysis period between 2018-2025, being taken from the official websites of the relevant institutions. The limitations of the methodological analysis were caused by incomplete data for some sectors of renewable energy sources, dependence on national estimates, statistical data that were not analyzed and published by the National Bureau of Statistics.

Achieving the targets set in the National Integrated Energy and Climate Plan (NECP) by 2030 would lead to a substantial reduction in import dependency and a considerable increase

in the share of renewable energy within the national energy mix. Its economic advantages will be the provision of employment, capital investment attraction, and energy price stabilization, which will make the Moldovan economy more competitive and the quality of life higher. Though it would mean increased costs now, the economy will undoubtedly benefit in the mid and far future. If all countries in the area progress similarly, Moldova's failure to make tangible improvements could lead to economic decline and chronic reliance on imports.

Despite the shift to green energy, several obstacles remain. The existing energy infrastructure requires improvements, despite the potential for absorbing large investments. It's also essential to develop technological skills and capacities and to constantly improve the laws and regulations. The intermittent nature of renewable sources like solar and wind means that efficient storage and grid management strategies are needed. Energy storage plays a vital role in supporting widespread renewable energy use, as it mitigates generation variations and ensures a more consistent power supply.

Moldova's focus on renewable energy, along with its work to foster a favorable investment climate, should draw in renewable energy investments - from within the country and from abroad - which would boost economic growth and spur technological advancements. Recently, international investment firms and banks have shown an interest in investing in this sector. A transparent regulatory system, inviting policies, and the opportunity to align Moldova's market with the European Union offer an attractive outlook for investments in green energy. Institutional funding from the EBRD and USAID is already flowing into the construction of energy interconnections and the expansion of renewable energy capacity. This external support is crucial for financing the initial stages of the transition, providing not only financial resources but also technical expertise and best practices for the development of the green energy sector.

References

Belostecinic, G., Sakovici, V., & Moiseenko, E. (2011). *Securitatea economică a statului: teorie, metodologie, practică*. Chișinău: ASEM. ISBN 978-9975-75-574-0.

Corețchi, B. (2023). Securitatea economică durabilă prin inovații: un model integrat pentru Republica Moldova. In *Materialele conferinței științifico-internaționale "Economic Security in the Context of Systemic Transformations"* (pp. 41–46). ASEM. https://doi.org/10.53486/escst2023

Cutcovschi, V. (2024). Impactul factorilor economici asupra securității economice a Republicii Moldova. In *Statul de drept și reziliența economică în contextul aderării Republicii Moldova la Uniunea Europeană* (p. 370). USM.

Ioniță, M. (2022) Energia verde. Energia regenerabilă. Ce este, cum funcționează și câte tipuri există. *Energy&Mobility*, 18 mai. https://green.start-up.ro/ro/energia-verde-energia-regenerabila-ce-este-cum-functioneaza-si-cate-tipuri-exista/

IRENA. (2019). *Evaluarea gradului de pregătire privind valorificarea energiei regenerabile: Republica Moldova*. Abu Dhabi. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Feb/IRENA_RRA_Moldova_2019_RO.pdf

Ministerul Energiei al Republicii Moldova. (n.d.). *Starea actuală a domeniului energiei*

regenerabile în Republica Moldova: Potențial, provocări și perspective. https://energie.gov.md/en/content/starea-actuala-domeniului-energiei-regenerabile-republica-moldova-potential-provocari-si

National Grid. (n.d.). *What is green energy?* https://www.nationalgrid.com/stories/energy-explained/what-is-green-energy

Sațuta, A. (2007). Национальная безопасность как социальное явление: современная парадигма. *Вестник Военного университета*, *3*(11), 36.

Serviciul guvernamental pentru investiții. (n.d.). *Obiectivele ambițioase ale Moldovei în domeniul energiei verzi*. https://invest.gov.md/obiectivele-ambitioase-ale-moldovei-in-domeniul-energiei-verzi/

Serviciul Național pentru Energie. (n.d.). *Capacități instalate*. https://cned.gov.md/ro/content/capacitati-instalate

Wen, B., He, Y., Jing, X., & Haroon, M. (2025). Advancing renewable energy and green finance for economic growth and ecological resilience. *Energy Strategy Reviews, 59*, 101747. https://doi.org/10.1016/j.esr.2025.101747

Yan, J., & Haroon, M. (2023). Financing efficiency in natural resource markets mobilizing private and public capital for a green recovery. *Resources Policy*, *85*, Part B, 103841. https://doi.org/10.1016/j.resourpol.2023.103841

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MODERNIZATION OF THE STARTUP ECOSYSTEM OF BELARUS AT THE PRESENT STAGE AS AN ELEMENT OF ECONOMIC SECURITY

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Abstract: *The article is devoted to the modernization of the Startup Ecosystem in Belarus at the present stage. The article considers the evolution of the development of the Startup Ecosystem of the Republic of Belarus. The article provides a literary review of the definition of "Startup Ecosystem" and determines the relationship with economic security. The evolution of the development of elements of the Startup Ecosystem in Belarus is analyzed, various legislative acts of the Government of the Republic of Belarus and the President of the Republic of Belarus in this area are considered. The presented study of the Republic of Belarus is based on its own long-term analysis of the Startup Ecosystem in the country, as well as the experience of assessing the effectiveness of its individual organizations. It is noted that the development of the Startup Ecosystem at the current stage of development has a state focus and is carried out mainly by state organizations.*

Keywords: *economic security of the state, Startup Ecosystem, small and medium entrepreneurship, High-Tech Park.*

JEL Code: *030, P40, R10.*

UDC*: 338.24:334.72(476)*

Introduction

The concept of national security of Belarus includes economic security as one of the main elements. The national interests of Belarus are recognized, in particular, as sustainable socio-economic development and high competitiveness of the Belarusian economy; improvement of scientific, technological and educational potential. In the economic sphere, the main national interests are, in particular, economic growth and increased competitiveness of the Belarusian economy based on its structural restructuring, improvement of the management system, sustainable innovative development, active investment in human capital and high technologies, cost reduction and development of high-tech, export-oriented and import-substituting industries.

The main threats to national security in terms of economic security are, in particular: insufficient volumes and low quality of investments; lagging behind other countries in the pace of economic transition to advanced technological structures due to its high-cost structure and low technological level of development; reduction of scientific, technological and educational potential to a level that is incapable of ensuring scientific, technological and innovative development; destruction (termination) of scientific ties of the Republic of Belarus, primarily with countries with high scientific and technological potential; slowdown in the development of information and communication technologies; violation of the cyber

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stability of the national segment of the Internet, critically important information technology facilities and state information systems.

Startup Ecosystem play an important role in ensuring economic security. The National Statistical Committee of the Republic of Belarus does not maintain statistics on the Startup Ecosystem. In the Startup Ecosystem Development Index "StartupBlink" 2024, Belarus ranks 82nd (2023 - 80) in the Global Ranking, 21st in the Eastern Europe Ranking, and also has one city - Minsk, which ranks 319th in the top 1000 cities. All this testifies to the great potential of the Startup Ecosystem in the interests of the economic security of Belarus. The Startup Ecosystem itself requires modernization at the current stage of economic security development.

In the economic sphere, the internal sources of threats to national security are: outdated technologies and fixed assets, prevalence of material- and energy-intensive industries, low quality of manufactured products and their slow renewal; presence of unreasonable administrative barriers to business development and entrepreneurial activity; imbalance in economic development; unfavorable conditions for attracting investments and loans; discrepancy between the level of personnel training and the structure of the economy's needs for specialists and workers, shortage of qualified specialists for modern industries and organization of business processes.

In the scientific and technological sphere, the internal sources of threats to national security are, in particular: insufficient efficiency of the national innovation system, including mechanisms for technology transfer from science to production, equipment of the material and technical base of scientific institutions, financing system, industry science; decrease in the level of training and provision of scientific personnel, including highly qualified ones, increase in the average age of scientific workers.

The need for the state to take active measures to stimulate business activity among young people is urgent. Self-realization through the implementation of a startup idea benefits not only young people, but also the state as a whole. This applies to both individual startups and intra-company entrepreneurship. It is the new ideas of the younger generation that should play one of the significant roles in the innovative development of the Republic of Belarus. All this requires the development of a set of measures to activate the startup movement in the Republic of Belarus based on the development of competencies and financing, as well as mechanisms for the implementation of various innovative ideas.

The relevance of the study lies in the need to activate the startup ecosystem in order to ensure the economic security of any country in the world. The example of Belarus shows the active development of the startup ecosystem in a post-Soviet country.

In this regard, the need for research and deeper study of new approaches to modernization of the Startup Ecosystem at the macro level in the context of economic security of Belarus, based on the national interests and priorities of Belarus, becomes most urgent. The practical significance lies in the formation of an effective and efficient Startup Ecosystem, the modernization of which is impossible without understanding the evolution of its development.

The scientific significance of the article lies in the attempt to systematically consider the stages of development of the Startup Ecosystem of Belarus with the peculiarities of each stage.

The aim of the work is to reveal the evolutionary processes of the startup ecosystem in Belarus as an element of the economic security of the state. The author's hypothesis is that the startup ecosystem is an important part of ensuring the economic security of the country. The objectives of the study included identifying the stages of development of the startup ecosystem of Belarus, determining the characteristic features of each stage in historical retrospect.

The structure of the article is as follows: first, an introduction to the topic under discussion with an overview of the relevance of the study. The second part provides links to modern literature on the development of Startup Ecosystem and economic security. The third part analyzes the development of the Startup Ecosystem in historical retrospect in Belarus. In conclusion, conclusions are made and new research directions for the development of the SE are proposed.

The study of Startup Ecosystem is one of the mainstreams of the analysis of entrepreneurship development in the world. Undoubtedly, the origin of this concept is taken from various concepts of "ecosystem", "business ecosystem" and is closely related to the entrepreneurial ecosystem. The analysis did not reveal a general characteristic of Startup Ecosystem. Therefore, it can be considered fair to define a Startup Ecosystem as an interconnected set of organizations and events that form the conditions for the creation and development of startups, as well as the startups themselves, distinguished by territorial characteristics (Marakhina, 2020, p. 49). Some scientists believe that "the startup ecosystem is made up of various resources, tools and stakeholders (entrepreneurs, government organizations, educational institutions and other stakeholders)" (Sogacheva & Devyatilova, 2023, p. 74). StartupBlink understands this concept as "the result of the environment in which startups and other supporting players operate" (StartupBlink, 2023).

In our opinion, the most detailed and correct definition of the Startup Ecosystem can be considered the opinion of Abuselidze et al. Abuselidze et al. (2024) represent the Startup Ecosystem as an institutional mechanism open to the expansion of inter-industry networks and changes in the competitive market environment in favor of the architecture of a sustainable innovative economy.

In our opinion, the most extensive and correct definition of a Startup Ecosystem can be considered as "an institutional mechanism open to the expansion of inter-industry networks and changing the competitive market environment in favor of the architecture of a sustainable innovative economy" (Abuselidze et al., 2024).

In the Netherlands, economic security is defined as "the smooth functioning of the Kingdom of the Netherlands as an efficient and effective economy" (The Security Strategy for the Kingdom of the Netherlands, 2023, p. 12). Bakalskaya E. et al. argue that "the category of economic security at the national level is associated with the efficiency of functioning and competitiveness of the country's economy, which, in turn, is determined by the state and level of socio-economic development of its constituent regions" (Bakalskaya, E. et al., 2020, p. 62).

Based on the most general definition of Dutch economic security, its connection with the development of start-ups is obvious. Madi & Madi (2024) note the potential of start-ups to revolutionize sectors such as digital technologies and sustainable energy, and to stimulate job creation and GDP growth in Germany; Adwani (2025) argues that start-ups are the most important drivers of innovation, job creation and economic growth. Looking at the development of start-ups in India, Leelavathi (2023) notes that an economy is better when there are more people in work. Sopjani (2019) constitutes the role of start-ups in the economy by creating models designed to improve the well-being and productivity of a country, while relying on these aspects as the most important determinants for driving change.

Data and Methodology

This study uses qualitative research methods to improve readers' understanding of the issues related to the development of the Startup Ecosystem in Belarus in a historical perspective. In particular, legislative acts in the field of the Startup Ecosystem are analyzed, and the study is based on personal experience in assessing the development of these organizations. Qualitative analysis is used to identify the stages of development of the Startup Ecosystem in Belarus. Accordingly, this is the theoretical basis on which further research is built. The analysis of the development of the Startup Ecosystem in Belarus is based on data from Belagroprombank OJSC, Alfa Bank, the National Legal Internet Portal of the Republic of Belarus, the State Institution "Secretariat of the Supervisory Board of the High-Tech Park" and other Internet sources.

Results

The Startup Ecosystem of Belarus currently has several stages of development.

The first stage (2005 - 2008) is characterized by the adoption of the Directive of the President of the Republic of Belarus of June 14, 2007 No. 3 "On priority areas for strengthening the economic security of the state" (National Legal Internet Portal of the Republic of Belarus, 2025). The Directive notes the need to create a multi-level system for the popularization of intellectual creativity and innovative entrepreneurship as a state-significant and socially prestigious area of activity; development and state support for the startup movement, including the provision of information and financial support to organizations that prepare and conduct events to involve young people in innovative and entrepreneurial activities, and establish professional and business ties between inventors and entrepreneurs offering innovative products and technologies with potential investors and business partners. A characteristic element is the creation of the High-Tech Park, which was created in accordance with the Decree of the President of the Republic of Belarus dated September 22, 2005 No. 12 "On the High-Tech Park" for the development in Belarus of software, information and communication, and

other new and high technologies aimed at increasing the competitiveness of the national economy (National Legal Internet Portal of the Republic of Belarus, 2025).

The second stage (2009 – 2015) is characterized by the emergence of the main elements of the Startup Ecosystem. During this period, LLC "Startup Technologies" was created, which was engaged in holding various events in the area under consideration. The first Minsk Startup Weekend took place in 2009. Regional InvestWeekends were considered preparatory and qualifying, Minsk InvestWeekends were the final ones. Invest Weekend (InvestWeekend) was a Republican competition of business ideas and projects aimed at increasing the number of innovative business projects, implementing breakthrough business ideas and introducing technologies, supporting innovators, inventors and aspiring entrepreneurs, attracting investments in business projects and companies at early stages of development.

The following year (2010), the Public Association "Community of Business Angels and Venture Investors "BAVIN" was created. The main objective of the organization was to attract and select innovative projects on an ongoing basis, refine them and present them to investors, as well as hold various events. A distinctive feature of the organization in question was business angels - 20 successful entrepreneurs from the real sector of the economy (IT, insurance, construction, mass media, logistics, energy, retail, production). The community was also created in a social network in 2011. The creation of the Public Association "Community of Business Angels and Venture Investors "BAVIN" allowed Belarus to be represented in various international organizations on the topic under consideration. Thus, in 2011, the Public Association "Community of Business Angels and Venture Investors "BAVIN" became a full member of the European Business Angel Network (EBAN). Along with this, partnerships were established with government agencies and other national associations of business angels.

Since 2013, the Social Projects Competition «Social Weekend» has been held and lasted until 2021. Today, the founders have left Belarus. At this stage, the popular competition "100 Ideas for Belarus" was launched, which is still held by the public association "Belarusian Republican Youth Union". The competition selects the best projects in various fields that could be useful for society. The goal of the competition is to activate the innovative thinking of young people, involve them in solving the problems of socio-economic development of the Republic of Belarus, stimulate civil initiatives for the implementation of innovative projects and scientific and technical developments. The competition is held in the following main nominations: energy, including nuclear energy, and energy efficiency; agro-industrial technologies and production; industrial and construction technologies and production; medicine, pharmacy, medical equipment; chemical technologies, petrochemistry; bio - and nanoindustry; information and communication and aerospace technologies; rational use of natural resources and deep processing of natural resources; national security and defense, protection from emergency situations; society, economy and social sphere.

Limited Liability Company "Minsk City Technopark" was established on November 4, 2011, as part of the implementation of the State Program for Innovative Development of the Republic of Belarus. Today, it occupies one of the main places in the Startup Ecosystem of Belarus.

The third stage (2016-2019) is characterized by the formation of the Angels Band business angel network, which united about 100 investors. In addition, the Russian-Belarusian venture company RBF VENTURES was created at the third stage (2016). Foreign technical assistance played an active role in studying Belarusian startups. For the first time, such a study was conducted in 2018 as part of the venture environment development program in the Republic of Belarus - AID-Venture, which was implemented by a consortium of partners consisting of the Bel.biz group of companies, the 500 Startups venture fund (USA) and the international educational program for venture investors Angel Labs. The AID-Venture program was designed for 5 years (since 2016) and provided, in particular, for the implementation of the best foreign practices of venture financing in the national legislation of the Republic of Belarus.

For the first time in the history of small and medium entrepreneurship in Belarus, on October 17, 2018, the Strategy for the Development of Small and Medium Entrepreneurship "The Republic of Belarus – a Country of Successful Entrepreneurship" for the period up to 2030 was approved, which noted, in particular, the need to introduce venture investment and financing instruments through the formation and development of guarantee, collateral and venture organizations.

In addition, at the third stage, IGROW Attraction Centers (coworkings) of OJSC "Belagroprombank" were created (2019). The first center opened in the city of Drogichin, Brest region, on November 27, 2019, and on December 4, 2019, the center in Minsk received its first visitors in the format of a startup hub. Today, the bank's coworking spaces are represented in such cities as Vileyka, Baranovichi, Borisov, Slutsk, Soligorsk, Bereza, Glubokoye, Polotsk, Gomel, Braslav, Nesvizh, Kalinkovichi and many other settlements of the republic. Igrow Attraction Centers are the largest network infrastructure for supporting entrepreneurship, consisting of 46 coworking spaces throughout Belarus. The activities of the centers are aimed at: providing support to representatives of small and medium businesses, private clients in various fields; creation and development of the business community, support of local initiatives; generating innovative business in areas that are not new and fast-growing in Belarus. On the basis of coworkings, OJSC "Belagroprombank" began to conduct and continues to conduct to this day the annual Republican competition program of OJSC "Belagroprombank" "Startup Marathon".

The fourth stage (2020 - 2021) is characterized by a slowdown in the development of the Startup Ecosystem of Belarus due to the relocation of members of the business angel network "Angels Band", as well as individual events in the regions, which is associated with the COVID-19 pandemic.

The fifth stage (2022 - present) is characterized by the revival and increase in activity of the existing landscape. In 2022, the Limited Liability Company "Sibs Invest" (LLC "Sibs Invest") was established. Under the name of the operator of the online borrowing service "Malimon", the organization holds various hackathons. In 2024, the hackathon "SOCIAL IMPACT" was held, the purpose of which was to revive the startup culture in Belarus and

provide support to aspiring specialists who need knowledge and experience to implement social projects. This organization also has its own startup school and Pre-Accelerator, holds the National MALIMON Invest Day.

The country has a "Spark venture studio", which includes an innovation incubator, a community of mentors and investors. The project is carried out with the support of Alfa-Bank, MTBank, etc. The small business incubator of the municipal unitary enterprise "Youth Social Service" regularly holds Startup seminars "How to become an entrepreneur as a student".

Let us especially dwell on the Republican youth project "100 ideas for Belarus", which is carried out by the Public Association "Belarusian Republican Youth Union", the Ministry of Education of the Republic of Belarus, the State Committee on Science and Technology of the Republic of Belarus, the National Academy of Sciences of Belarus. The main objectives of the Project: motivation and development of youth inventiveness, rationalization; identification and implementation in the real sector of the economy of innovative projects and scientific and technical developments of practical interest for the socio-economic development of the country; assistance in promoting innovative projects and scientific and technical developments.

Young people (a team of up to 3 authors) aged 14 to 31 years and young scientists 2 (institutions of higher education, organizations subordinate to the NAS of Belarus, engaged in scientific research) are allowed to participate in the Project until they reach the following age: Doctor of Sciences - up to 40 years old, Candidate of Sciences, an employee without a degree who has received higher education, a postgraduate student, a master's student - up to 35 years old, who have submitted their applications (projects, business ideas) for consideration. Three groups of participants have been defined: Group 1 - students of general secondary, vocational and secondary specialized education institutions; Group 2 - students, cadets; Group 3 - working youth, young scientists, representatives of institutions and organizations subordinate to the National Academy of Sciences of Belarus. Three winning projects are defined in each nomination of the Project (one from each group of participants). Table 1 presents individual projects of the winners of the competition in question in 2023.

The Ministry of Education of the Republic of Belarus holds competitive selections among students and cadets of higher education institutions, with the organization of an exhibition of youth projects and scientific and technical developments. Territorial committees of the Public Association "Belarusian Republican Youth Union" hold competitive selections among students of general secondary, vocational and secondary specialized education institutions, working youth with the organization of an exhibition of youth projects and scientific and technical developments. The National Academy of Sciences of Belarus holds a competitive selection among young scientists of institutions and organizations subordinate to the National Academy of Sciences of Belarus with the organization of an exhibition of youth projects and scientific and technical developments. Project evaluation criteria: relevance of the stated topic and practical significance of the project; novelty of the idea; feasibility of the project; modernity, innovativeness of approaches to solving the stated problem; clarity and logical justification in setting goals, objectives of the innovative project and clarity of ways to

achieve them; compliance with the requests for innovative developments of ministries, departments, organizations and enterprises for their further implementation in the real sector of the economy of the Republic of Belarus.

Table 1. Individual projects of the winners of the Republican youth project "100 ideas for Belarus" in 2023

Nomination	Project name
Agro-industrial technologies and farming	Polysaccharide jam
	New aspects in processing non-traditional meat raw materials
	Lactose-free cheese - a unique dairy product
Energy, including nuclear energy, and energy efficiency	Self-charging electric vehicle
	Hydrogen engine
Industrial and construction technologies	Robotic mobile manipulation platform "Leviathan"
	FilamentProfiPrint
	Creation of high-tech composite materials based on polymer waste and tire recycling products for the manufacture of construction products
Healthcare (medical technologies, pharmaceuticals, bio and nanoindustry)	Trichrome "Cornflowers"
	Biocompatible antibacterial coating for synthetic vascular prostheses
	Touch glasses for visually impaired people
	Interactive 3D brain model with educational functions
Ecology (rational use of natural resources and deep processing of natural resources)	The design of Palivoda horned hives and their impact on the honey productivity of bee colonies
Chemical technologies, petrochemistry	Natural antioxidants as a means of extending the shelf life of linseed oil
	Fluorescent methanol express sensor
	Glass ceramics for white light-emitting devices based on laser diodes
National Security and Protection from Emergencies	Automated Control Complex for Chemical and Radiation Situations
	Creation of a device for colorimetric analysis of surface waters for the presence of nitrate ion using the rivanol reaction method
	Fire Aspiration Hand Nozzle - PARS
Information and Communication Technologies	Application for generating potential drugs
	Service Station
	Smart Speaker with Voice Assistant Based on "Raspberry Pi 3B"

Source: 100 ideas https://100ideas.by

The High-Tech Park has begun active work on developing the Startup Ecosystem of Belarus. Taking into account the experience of the BSU Startup Center Department of the International Marketing Center, the Startup Center of the State Institution Secretariat of the Supervisory Board of the High-Tech Park was created in 2024. Business incubator functions: free space to work on a startup project in a coworking space, where you can turn your own ideas into real project; practical support for startup projects that are developing their own products; development of a special innovative IT environment; ehematic events where the best specialists in their field speak; speakers cover various topics in the IT sphere, based on their extensive experience.

The High-Tech Park is a rapid growth in the creation of new companies. In 2020-2021, 417 companies joined the Park, in 2022-2024 - plus 221 new companies. Today, the High-Tech Park has more than 1,000 residents and about 60 thousand employees. The Park is home to about 100 development centers of foreign corporations. More than 35% of the Park residents

are companies with foreign capital. Since 2017, the Park has attracted a total of more than $ 2.3 billion in foreign investment. In 2024, the Park's exports amounted to $ 1.8 billion. The positive foreign trade balance of the High-Tech Park in 2024 is $ 1.6 billion. The High-Tech Park today is 2% of our country's GDP. The volume of production of residents in 2024 amounted to 7 billion 887 million rubles. The High-Tech Park is a major taxpayer. According to the Ministry of Taxes and Duties of Belarus, in 2023, residents of the High-Tech Park paid 667.6 million rubles to the budget. In 2024, residents of the High-Tech Park created almost 7 thousand new jobs. In general, it should be noted that quite a lot of startup project competitions are held in Belarus (See table 2).

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Under the auspices of the High-Tech Park, a concept for the development of startup activities and an ecosystem for preparing new young companies with high-tech products and the potential for successful expansion in the markets of the Republic of Belarus and friendly countries is being developed. One of the elements of the concept's implementation is to increase the involvement of young people in innovative entrepreneurship and the effectiveness of project commercialization by developing the infrastructure of innovative entrepreneurship together with higher education institutions.

Table 2. Nominations of individual business idea and youth project competitions in the Republic of Belarus

Name of the competition (project)	Organizers	Nominations
Innovative Projects Competition	State Committee on Science and Technology of the Republic of Belarus	Best Innovative Project Best Youth Innovative Project Additional nominations approved by various enterprises and organizations
Greatstartup	State Institution "Administration of the China-Belarus Industrial Park "Great Stone" LLC "Minsk City Technopark" State Institution "Secretariat of the Supervisory Board of the High-Tech Park" Chinese-Belarusian CJSC "Industrial Park Development Company"	Smart project Hardware project
ENCOBI	LLC "InKata" Mogilev Regional Executive Committee Bobruisk City Executive Committee JSC "Mogilev Agency for Regional Development"	Best Business Idea Best Youth Business Idea
Minsk Change	Minsk City Executive Committee Academy of Public Administration under the President of the Republic of Belarus	Participants receive creative assignments to develop innovative projects in the main areas of city life, taking into account the goals and objectives of the socio-economic development of the Republic of Belarus and the city of Minsk for 2021–2025, as well as youth initiatives: • Ideological and information work • Youth policy • Urban development and architecture • Ecology and improvement • Housing and communal services • Transport provision • Education • Health care • Social protection • Culture and art • Sports and tourism • Industry • Small business development, economics, etc/
105 Ideas for Industry Development	Ministry of Labor and Social Protection of the Republic of Belarus	- Investing in youth is investing in the future; - Inclusive employment - Because family matters - Fatherhood is your main project - Through funding today to a decent tomorrow - Youth social leader - Together we are strong - Showing care is expressing gratitude; - A decent life is our concern; - Work is beautiful - if it is safe; - Burning hearts; - Numbers have a face
MedicalStartup	Republican Youth Council under the Ministry of Health of Belarus	- Clinical medicine - Fundamental medicine - Pharmaceutical sciences

Source: author's own development

Another important player in the Startup Ecosystem of Belarus at the present stage is LLC "Minsk City Technopark". The Scientific and Technological Park of BNTU "Polytechnic" also actively works with startups. It is engaged in various types of activities, the key ones being the development and production of medical devices for traumatology, orthopedics, cardiology, cardiovascular and maxillofacial surgery. The knee joint endoprosthesis developed and manufactured by Polytechnic for several years is well known not only in Belarus but also beyond its borders.

The activity of OJSC "Belagroprombank" is also quite noticeable. "Startup Marathon" is the development and support of the startup movement and small innovative entrepreneurship. What do the participants of the Startup Marathon Competition Program of OJSC "Belagroprombank" receive? Owners of a startup idea (Pre-Seed stage) will learn how to launch a startup correctly. Developers of innovative technologies (Seed stage) will learn how to build a business model and calculate the economic efficiency of their product. Current startup projects (Alpha stage) will be able to present their projects to investors and receive additional investments. Nominations of the Startup Marathon Competition Program: 1) Successful Start - nomination for Pre-Seed and Seed stage startups; 2) Effective Business Startup - nomination for Alpha stage startups. Special nominations of the Startup Marathon competition program: 1) Best female startup idea - nomination for Pre-Seed and Seed stage startups managed by a woman; 2) Best female business - nomination for Alpha stage startups managed by a woman.

An active private player in the Startup Ecosystem at the present stage is "Zborka Labs", along with Malimon and "Spark venture studio". To date, more than 100 founders and more than 400 team members have been trained. Separate projects of the organization: Oxygen Technologies (AI service that identifies diseases in 1 second from an X-ray image based on 1.5 million images), Online platform for charitable organizations; Utlik - a system designed to create and train cyber-employees based on artificial intelligence; Agrotech startup - a robotic system for applying plant protection products using drones. The project is a FaaS (Farming-as-a-Service) tool consisting of 2 parts: Hardware (IoT solution) and Software (software that collects data to determine field boundaries and conduct subsequent analysis); Dog&Care is an application that uses AI technologies to offer dog owners recommendations on pet care. It allows you to keep records and get reminders for all your dog care needs. A very interesting project is "Subaba" - it is a global search platform that will provide you with an easy way to search for cars around the world. It allows you to search for a car on several sites such as Craigslist, Facebook Marketplace, CarGurus, eBay - all in one place.

Conclusions

The analysis revealed that the most active organizations in the Startup Ecosystem landscape today are the State Institution "Secretariat of the Supervisory Board of the High-Tech Park", OJSC "Belagroprombank", the public association "Belarusian Republican Youth

Union", the Republican Innovative Unitary Enterprise "Scientific and Technological Park of the Belarusian National Technical University "Polytechnic", LLC "Minsk City Technopark". These organizations are state-owned. The activities of the High-Tech Park demonstrate the relationship of its residents with the Startup Ecosystem in terms of university startup schools, which are gradually uniting under the roof of the High-Tech Park. Companies - residents of the High-Tech Park actively participate in mentoring sessions and hackathons for representatives of startup schools of regional universities of Belarus. Thus, the state now plays a significant role in the development of the Startup Ecosystem, which is recognized as one of the foundations of the country's economic security. From our point of view, it is also advisable to use the potential of the private sector and various banks to activate the formation of the Startup Ecosystem of Belarus.

References

Marakhina, I. (2020). Investment infrastructure of the Belarusian startup ecosystem: entities, problems and development directions. *Banking Bulletin*, *7*, 49–58.

Sogacheva, O., & Devyatilova, A. (2023) Development of a regional startup ecosystem in a modern business environment. *Region: systems, economics, management*, *4*(63), 72–77. https://doi.org/10.22394/1997-4469-2023-63-4-72-77

StartupBlink. (2023). *Discover the Winners of the Innovation Economy.* https://www.startupblink.com/

Abuselidze, G., Tsiklashvili, N., Verulidze, V., Glonti, V., & Gechbaia, B. (2024). Challenges and Perspectives of the startup ecosystem for the Development of Innovative Economy in Georgia. *European Journal of Sustainable Development*, *13* (3), 70-70. https://doi.org/10.14207/ejsd.2024.v13n3p70

The Security Strategy for the Kingdom of the Netherlands. (2023). https://www.government.nl/topics/security-strategy-for-the-kingdom-of-the-netherlands/documents/publications/2023/04/03/security-strategy-for-the-kingdom-of-the-netherlands

Bakalskaya, E. (2020). Economic Security. *Information and education: the boundaries of communications INFO*, *12* (20), 61-63.

Madi, Z. e., Madi, S. (2024). The Role of Startups in Driving Economic Growth in Germany: Opportunities and Challenges in 2025. *International journal of economic performance*, *7*(02), 1-17. https://www.ijep.dz/index.php/IJEP/article/view/321/301

Adwani, R. (2025). Innovative Financing Models for Startups. *Challenges and Opportunities in a Globalized Economy*, *1*(32), 417-429. http://doi.org/10.2139/ssrn.5162026

Leelavathi, C. (2023) Opportunities & Challenges Of Startups In India. *Worldwide International Inter Disciplinary Research*, *142.* https://www.wiidrj.com/_files/ugd/622008_f06f92422770415fb060fe93a61fb3e0.pdf#page=153

Sopjani, X. (2019). Challenges and opportunities for startup innovation and entrepreneurship as tools towards a knowledge-based economy: The case of Kosovo. https://repository.rit.edu/cgi/viewcontent.cgi?article=11380&context=theses

National Legal Internet Portal of the Republic of Belarus (2025). https://pravo.by/

100 ideas for Belarus (2025). https://100ideas.by

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THE RESILIENCE OF THE BANKING SYSTEM OF THE REPUBLIC OF MOLDOVA DURING CRISIS PERIODS: EVIDENCE FROM THE LAST 10 YEARS

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Ion PÂRȚACHI*[2]

Abstract: *As a developing country with an open economy, the Republic of Moldova is highly dependent on the import of energy resources and sensitive to the exchange rates fluctuations, the resilience of the banking system is a crucial for maintaining and development of the financial intermediation (deposits taking and loans providing). This is because reliable and stable intermediation services are provided for clients from one side and help to implement the investment programs that are supported by international financial organizations and the local government from the other side. As a robust economy requires a comprehensive and coherent legal environment, authorities implemented regulatory frameworks that build more stability and predictability and diminish the potential negative impact of crises that can affect the financial system and as a result to client trust in the robustness of banks. Quantitative analysis performed on freely available data sources stated the resultative effect on shocks impact, but do not take into consideration the corrective impact of the actions that the government activate during the extreme economic condition environment. Although the direct limitation of the profit distribution from the supervisory authority is not appreciated by the market players and their shareholders, there are reasons that preserve resilience at a controlled and sustainable level, the attractivity of the banking sector for investors on increasing/maintaining the investments or entering the market remained valid. As a next step, development of a high-frequency early warning indicator enhances the ability to detect operational disturbances within the banking system.*

Keywords: *banking crises, net interest income, banking profit, digitalization.*

JEL Code: *G14, G21, G28*

UDC: *[005.336:336.71(478)]:338.124.4*

Introduction

The context of the current article is focused on the evolution of the banking sector of the Republic of Moldova resilience, during the crisis period. For the purposes of the research - the timeline of the past ten years is used, as this time horizon covers mainly three crises that were identified by time passing, as follows:

- Internally generated Banking Crisis (2014-2015);
- External generated Crisis related to the War in Ukraine (2022-2023).

As COVID-19 Crisis in particular case of the banking system has a limited neutral effect (as for the purposes of the current research the shock of pandemic emergency accelerates the digital evolution of the banking system operational environment). That is why the COVID-19 impact was not included in the perimeter of the study.

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Table 1. The Summary of criteria for the Crises in the last 10 years

Criteria	*Banking Crisis (2014-2015)*	*War in Ukraine (2022-2023)*
Origin	Internal	External
Reason	Bad managment	Armed Agression
Impact on banking system	Lost of the trust	Increased the risk of uncertainty, deposits run, volatile and high interest rates, liquidity shortage
Mitigation actions (short term)	Direct intervention (3 banks went on liquidation procedure)	Indirect (focus on the operative evolution of banking system)
Mitigation actions (short term)	BASEL III framework implementation, big focus on the governance	Business continuity scenarios tested, calibration/recalibration of stress tests scenarios

Source: Prepared by authors

The following research will be focused on some generic areas/results that characterize the banking system's resilience, especially during the two listed crises. The speedy development of banking services in a developing country because of the implementation of digital services as a need demanded by clients, can lead to an increase of uncertainty for the time frame when a major shock can heat the economy. Potential risks mitigation is partially covered by the regulatory framework, that in a post-Soviet country as Moldova is in the process of converge to the best practices and to EU-level framework now.

Literature review

The maturity of the banking system of the Republic of Moldova counts 35th year of market free operational environment. In addition, the data sets that can be used for empirical analysis allow the researchers to complete the optimal data starting from earlies 2000`s. Another challenge is the diverse methodologies of data compilation for data sets public available. Here can be listed as an example balances sheet data that till 2010 were available based on local accounting standards, but since 2011 are available in the IFRS format. The same is about the evolution of the supervisory framework by accelerating evolution from the BASEL I framework to BASEL III (the prompt implementation decision was made immediately after the banking crisis started).

As some research tried to identify a composite indicator (Ruza et al., 2019), by identifying the relation that can describe appropriate and robust stability and resilience of a banking system, the focus was based on advanced economies. Another vision on measuring systemic banking resilience was based on the application of reverse stress testing (Feyen, E., & Mare, D. S., 2021). At the same time, for the literature that were published before the financial crisis from early 2000s, I can mention the loss in foreign exchange reserves, high real

interest rates, low output grow as factors that best signalize the inception of a banking crisis (Demirguc-Kunt A., & Detragiache E., 1998).

It can be the case that the crisis that generates the increase of the interest rates influences the loans provided to individuals versus loas provided to corporates. As mentioned by the supervisor of banks (National Bank of Moldova, 2024), the 2023 was characterized by increase of loans production to individuals (consumer loans +12%, mortgages +8%) and by reduction of loans provided to corporates (food industry -6%, constructions -16%, energy industry -19%). On the financing part, 2023 resulted in deposits balances increase by 20% (y-o-y).

Data and Methodology

The descriptive analysis of the evolution of selected indicators in the figures presented below underlines the distribution across the specified timeline in accordance with the crises mentioned and shows the effect indicators at the level of banking system.

It is worth saying that the effect of non-regulatory actions was not counted for the current research (as governmental support to clients of banks during the crises, moratoria that was applied by banks as the supporting measure for debtors, others).

The comparative analysis as a compartmental action/reaction related to the crises periods was summarized and a graphical interpretation included in the current research.

As the reporting framework that prescribes the reports compilation to the supervisor is defined in the *Instruction on compilation and submission of reports by banks for prudential purpose*[1], it is necessary to mention that the supervisor can modify the normative rules of compilation and in some cases, in order to adjust to the economic environment, can impose special rules for a limited period of time, in following areas:

- increase of the reporting deadlines, by shortening of the frequency of regulatory reports;
- waivers granted for some regulatory indicators that can reduce the risk exposure of banks during the crisis.

The development of the reporting framework in the last ten years can be characterized by the continuous development of the number of reports that became mandatory for banks. Part of new requirements were introduced as the result of lessons learned from the crisis time, as a metrics that can prevent or predict the distress in some operational areas.

The Model and Findings

The current research analyzes empirical data that describes the main influencing position on bank`s profitability and were identified as main drivers in the basic profit and loss statements. For compatibility purposes, the quarterly data used refers to the following data:

1 *Instruction on compilation and submission of reports by banks for prudential purposes, approved by the Decision of the Council of Administration of the National Bank of Moldova no.279 of 01 December 2011*

- Size dimensions (number of branches and active staff);
- Profit and total equity evolution;
- Required reserves and cost of remuneration on it;
- Net interest income evolution (interest income and interest expenses);
- Foreign investments share in total equity of banking system.

In the current research, the effect of the government support/decisions were not quantified, as the granularity and coverage should be counted and systematized. In this regard, the support mentioned above represents the limitation that was ignored in the current work.

The impact of the dynamic development of the reporting framework can be observed in Figure1. Especially there are two focus areas that reveal the effect of essential regulatory framework revision.

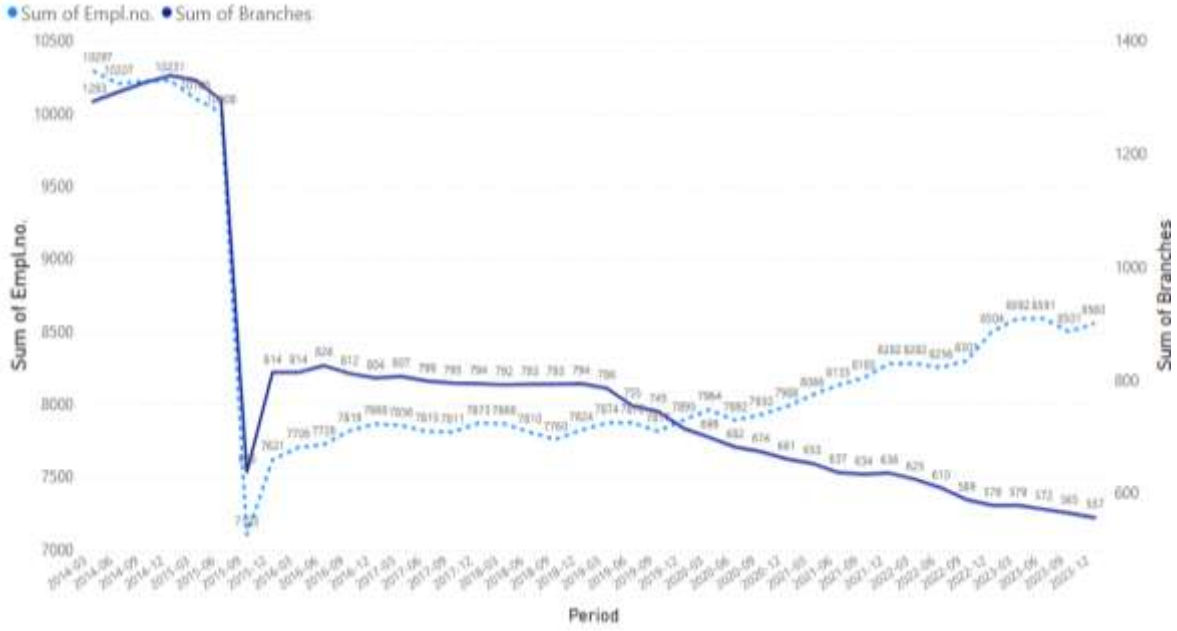

Figure 1. Evolution of the staff and branches number of the banking system

Source: https://www.bnm.md/bdi/pages/reports/drsb/DRSB1.xhtml?id=0&lang=ro

The first area is visible at the end of 2015, when the regulator withdraws banking licenses from banks that were involved in the banking crisis. As result the number of branches and active employees decreased sharply. The second area represents following years, when it was a mix of factors that contributed to the opposite evolution of the number of branches and employees number. Here we can identify the contribution of digital development (as regard to the branch number reduction with 32%). Another effect that is observed is that despite the decrease in branch numbers, the total staff of the banking staff increased by 12%. The main effect that accelerated the employees' number in the last five years is driven by regulatory requirements that focus on the control functions of banks (as areas that can detect/prevent the risking areas that can have an impact on daily activity). It can be observed that as the war in

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Ukraine started and sanctions against Russia were imposed, the complexity of daily transactions influence the staff increase.

As the resilience in at the banking system level is crucial for the ensuring the robust and sustainable development of the financial sector and the economy of a country (Ruza et al., 2019), the prudent an equilibrated capitalization of banks contribute as building blocks to the strong and resilient development of the banking system of the Republic of Moldova.

We can observe in Figure 2 the strong pattern of capital accumulation in the banking system. It should be mentioned that the crises and all macroeconomic environment that is related to the crises time influence the profitability of banks in a positive way on short-term horizon (packs can be observed in Figure 2). Main driver for that increase is mostly generated by the very high reservation rate that is characteristic to the Republic of Moldova.

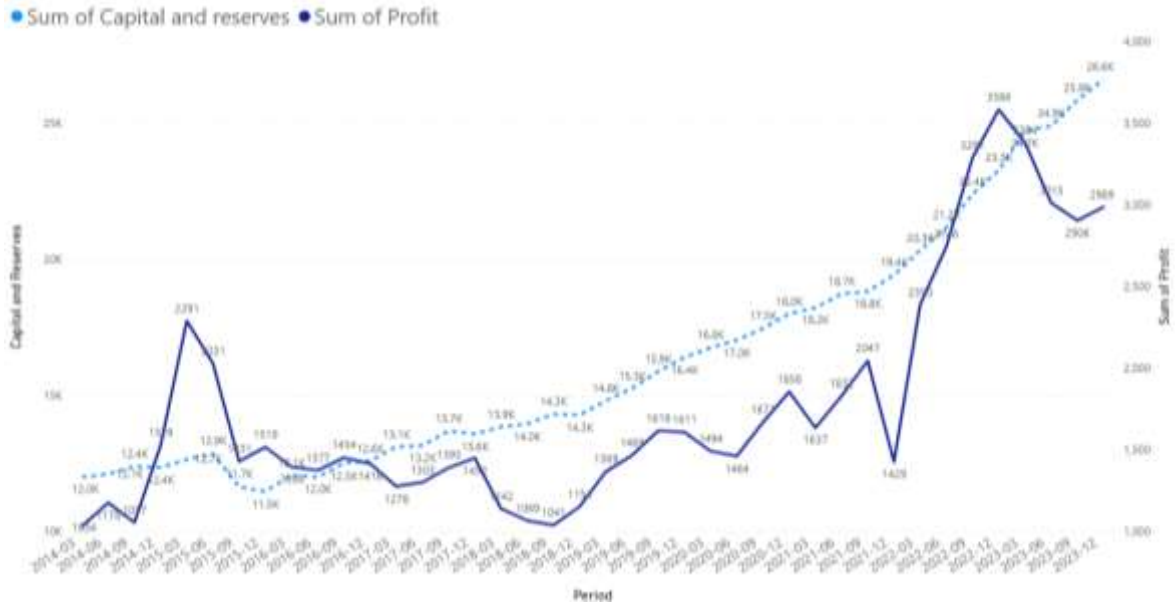

Figure 2. Profit and Total Equity evolution

Source: https://www.bnm.md/bdi

Requires reserves play a role as an instrument of the monetary policy transmission to the market. Thus, as the result of the government support of 13 bn MDL to cover the liquidity shortage of three banks that generated the banking crisis, required reserves in MDL increased to 35% (Figure 3). Impact on the banking system is sizable as the remuneration rate is the same as for the overnight deposits facilities at the NBM (base rate -2%). Another side of the high reservation rate level is the constraint for banks for lending resources. That arrive from the reduction of the potential available resources for the lending or investments, as 35% from the attracted deposits with the maturity less than 2 years should be allocated in the banks` accounts at the National Bank of Moldova.

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Figure 3. MDL Required Reserves evolution (volumes and remuneration rates)

Source: https://www.bnm.md/bdi/pages/reports/dop/DOP2.xhtml

The optimization of the liquidity allocation for investment/lending activity through allowing banks to hold T-bills as a portion of required reserves. Of course there should be a structured approach, that can be calibrated by time, and at the same time it can be dynamic as a dimension. The evolution of the interest income, interest expense and the net interest income is illustrated in Figure 4.

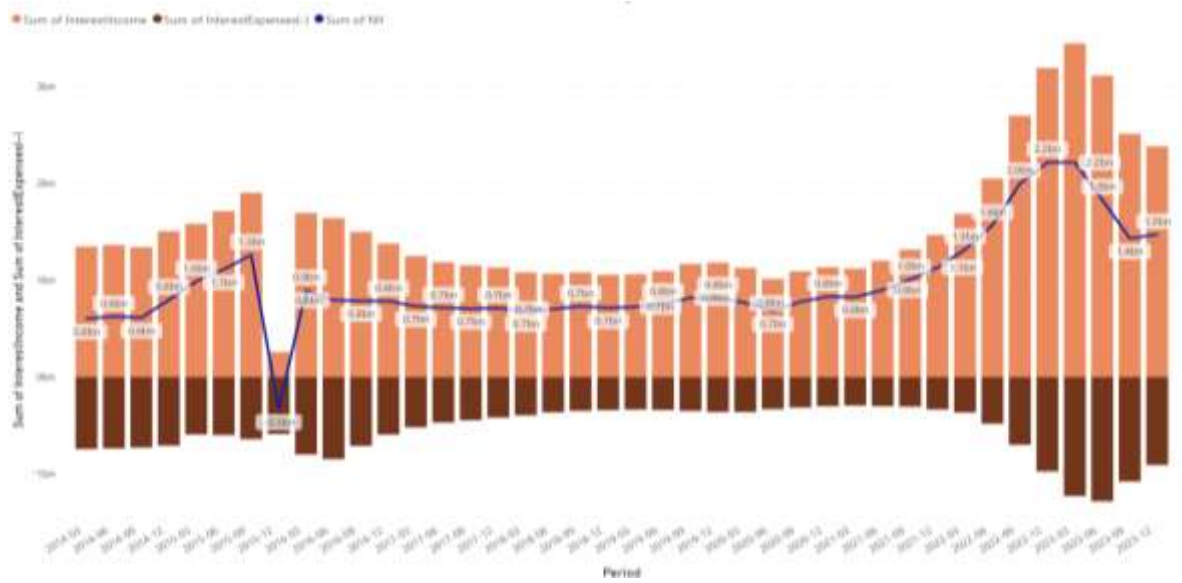

Figure 4. Interest Income and Expenses evolution

Source: https://www.bnm.md/bdi/pages/reports/drsb/DRSB6.xhtml

As was previously mentioned, the increase in interest income is mainly from the financial assets that are sensitive to the interest rate evolution (floating short-term T-bills, certificates of the National Bank of Moldova, required reserves placed at the National Bank of Moldova).

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Hopefully, accumulation of profit by banks is supportive to the increase the resilience of banking system and avoid shortages in the solvability and liquidity risks.

Being a country under developing, the Republic of Moldova is a BBB rated country as of Moody`s rating. In this context, the margins that are potentially to the Banking system attract foreign investors, and the proportion of share of foreign investments in the equity of banking system is very high (Figure 5). The visible decrease of the share of investment in the equity of the banking system was generated by the special procedure of "shareholders transparence" exercise that was applied for 2 big banks, and consist in the cancelling of shares that belongs to untransparent shareholders and the replace of such shares by newly issued, that according to the graph denote that the new shares were bought by non-resident investors.

It should be mentioned that the international expertise of international banking groups like OTP Bank, Intesa Sanpaolo, ProCredit Bank, and Banca Transilvania play a contributive role for the resilience of the entire banking system, as the expertise of European banks is already available inside mentioned groups and cand be applied for the purposes of the development of the reporting framework.

Figure 5. Evolution of Share of Foreign Investments in the Banking System

Source: https://legacydata.imf.org

Conclusions

It should be noted that each crisis described above was followed by a reactive measure that was calibrated to the impact of diminishing on the whole economy and as well on the banking system. That is why crisis originated from bad management, was followed by the improvement/development of a normative framework that strengthens the role of comprehensive governance processes, as a fundamental pillar in fair and responsible management of a financial institution.

For the case of external crisis, the development of an extended stress testing scenario was applied and the cross-border evolution of an economy in war was included as a variable that needs to be taken into consideration for the forward-looking assessment. Here the immediate effect of the liquidity shortage was included as a trigger factor.

At the same time, as financial intermediation as a service provided by banks became more digital (digitalization), cyber risk identification and mitigation should play an important role for both parties (clients and the bank).

The research on the identification of the potential effect of crises (internal/external) will be continued and the mitigators that were used by authorities (by government or supervisor) will be considered. In this regard, the use of a Z-score will be developed, especially for the relevant index calculation based on cluster analysis (systemically important banks vs others) and specific calibration analysis based on size and cost efficiency.

References

Demirguc-Kunt, A., & Detragiache, E. (1998). The determinants of banking crises in developing countries. *International Monetary Fund Staff Paper*, *45*(1), 81-109. https://www.imf.org/external/pubs/ft/staffp/1998/03-98/pdf/demirguc.pdf

Feyen, E. H. B., & Mare, D. S. (2021). *Measuring systemic banking resilience: A simple reverse stress testing approach* (Policy Research Working Paper No. 9864). World Bank. https://documents1.worldbank.org/curated/en/696701638211617923/pdf/Measuring-Systemic-Banking-Resilience-A-Simple-Reverse-Stress-Testing-Approach.pdf

International Monetary Fund. (2025). *International financial statistics*. IMF Data access to macroeconomic & financial data. https://legacydata.imf.org/?sk=4c514d48-b6ba-49ed-8ab9-52b0c1a0179b

International Monetary Fund. (2024). *Republic of Moldova: Sixth reviews under the Extended Credit Facility and Extended Fund Facility arrangements, request for modifications of performance criteria, and second review under the Resilience and Sustainability Facility Arrangement—Press release; Staff report; and Statement by the Alternative Executive Director for the Republic of Moldova* (IMF Country Report No. 2024/355). European Department. https://www.elibrary.imf.org/view/journals/002/2024/355/002.2024.issue-355-en.xml?cid=559769-com-dsp-crossref

National Bank of Moldova. (2025). *Report: Information on financial and economic activities of banks*. NBM Interactive Database. https://www.bnm.md/bdi/pages/reports/drsb/DRSB1.xhtml

National Bank of Moldova. (2011). Instruction on compilation and submission of reports by banks for prudential purposes. *Official Monitor of the Republic of Moldova*, *216-221*, art. 2008. https://www.bnm.md/en/content/instruction-procedure-preparing-and-submission-banks-reports-prudential-purposes-approved

National Bank of Moldova. (2024). *Financial situation of the banking sector for 2023*. https://www.bnm.md/en/content/financial-situation-banking-sector-2023

Ruza, C., de la Cuesta, M., & Paredes-Gazquez, J. (2019). Banking system resilience: An empirical appraisal. *Journal of Economic Studies*, *46*(6), 1241–1257. https://doi.org/10.1108/JES-06-2018-0199

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FINANCIAL REPORTING: ANALYSIS OF THE REGULATORY FRAMEWORK OF THE REPUBLIC OF MOLDOVA

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Abstract: *This research analyses the regulatory framework for financial reporting for entities in the Republic of Moldova, which depends on the way accounting is organized: based on national accounting standards or international accounting standards, as well as the category of the entity, which is distinct for accounting purposes versus the national legislative framework that defines the classification of small and medium-sized entities. The study uses scientific research methods such as the analysis of the regulatory framework governing the study, the synthesis of information regarding various provisions, and comparison to identify the distinctive features related to financial reporting. The study reveals that for entities organizing their accounting according to national accounting standards, three sets of financial reporting are foreseen depending on the category of the entity, the content of which is established by the National Accounting Standard (NAS) "Presentation of Financial Statements," while for entities organizing their accounting according to International Financial Reporting Standards (IFRS), IAS 1 "Presentation of Financial Statements" contains minimum presentation requirements for information to adapt to each type of entity. Regarding the identification of the category of entities, the research examines the indicators presented by the accounting regulatory framework, versus the categories of entities defined by the Law on Small and Medium Entities.*

Keywords: *Accounting, financial statements, regulatory framework, national accounting regulations.*

JEL Code: *M41*

UDC: 657.37(478)

Introduction

Financial reporting is an extremely important topic in the economic field, which is why the specialized literature is rich in this regard, with numerous studies examining this subject of great interest to all stakeholders. Over time, various concepts, procedures, and increasingly complex standards have been developed to guide the business world, leading to more complex financial statements that entities are required to prepare, for better transparency and comparability of the entity's data. What is certain is that the main source of information for users, to base their economic and financial decisions, is the entity's financial statements. Moreover, obtaining an accurate image of the financial position and financial performance represents the fundamental objective of accounting, achieved through the perspective of financial statements.

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Although financial statements may seem similar from one country to another, there are differences that have likely been caused by a variety of social, economic, and legal factors, as well as the fact that different countries, when establishing national provisions, have considered the needs of different users of financial statements (Lazari & Cucoș, 2017, p. 32). Meeting the main economic conditions for joining the European Union requires the development of an efficient accounting and financial reporting system in the Republic of Moldova, which fully meets the needs of the contemporary market economy (Grabarovschi et al., 2023, p. 99).

Financial reporting by entities has attracted increasing interest since the initial implementation of national accounting standards in the Republic of Moldova. The methods of financial reporting, the sets of financial statements, and their content have evolved over time, remaining a subject of continuous research and frequently discussed in domestic publications. A fundamental theoretical and practical approach to financial reporting is presented in the works of professors Nederița (Nederița, 2021) and Țurcanu (Țurcanu & Golocialova, 2015).

Financial accounting information is made public through the system of financial statements, the regulation of which in the Republic of Moldova and globally is strict, considering the impact on the decisions that users will make based on these statements. This research will focus on studying the financial reporting conducted by entities in the Republic of Moldova.

Data and Methodology

The research is based on a thorough documentation of the regulatory framework for financial reporting in the Republic of Moldova, with a presentation of the types of reports depending on the way accounting is organized and the category of entities. The study employs scientific research methods such as the analysis of the regulatory framework governing the research, the synthesis of information regarding various provisions, and comparison to identify the distinctive features related to financial reporting. The aim of this research is to highlight the types of financial statements prepared by entities in the Republic of Moldova.

The scientific novelty of the research lies in the presentation and analysis of the financial reporting methods used by entities in the Republic of Moldova, in accordance with the applicable accounting regulatory framework - either national (National Accounting Standards) or international (International Financial Reporting Standards) - and depending on the category of the entity. This study provides a better understanding of the factors that influence entities' financial reporting decisions.

The Model and Findings

In addition to the classification of entities according to accounting regulations, accounting principles, qualitative characteristics of financial information, recognition and

measurement rules, rules for the operation of accounting accounts, and the recording of economic transactions, the accounting regulations in the Republic of Moldova also provide a regulatory framework for the preparation and presentation of various components of individual and consolidated financial statements.

The concept of financial reporting is commonly used in American accounting literature, encompassing financial statements and other relevant information about the economic and financial activity of the entity. Another definition found in American specialized literature is that financial reporting is the process of producing statements that describe the financial position of an entity (Lazari & Cucoș, 2017, p. 32).

In the Republic of Moldova, the regulatory framework for financial reporting is based on the Accounting and Financial Reporting Law, according to which financial statements represent a set of reports that characterize the financial position, financial performance, and other information related to the entity's activities for a specific reporting period (Accounting and Financial Reporting Law No 287, 2017). According to the International Financial Reporting Conceptual Framework, the objective of financial statements is to provide financial information about the reporting entity that is useful to existing and potential investors, lenders, and other creditors in the decisions they make regarding the provision of resources to the entity (Conceptual Framework for Financial Reporting). These decisions involve the acquisition, sale, or holding of equity and debt instruments, and the granting or settlement of loans and other forms of credit.

The European Directive 2013/34, in turn, establishes that annual financial statements pursue different objectives, not only providing information to investors on capital markets but also presenting past transactions and improving corporate governance (Directive 2013/34/EU of the European Parliament and the Council of June 26, 2013, on Annual Financial Statements, Consolidated Financial Statements, and Related Reports of Certain Types of Undertakings). For this purpose, the European Union legislation in the field of accounting establishes a proper balance between the interests of the recipients of financial statements and the interest of businesses to avoid being excessively burdened with reporting requirements.

The method of accounting, the application of accounting standards - whether national or international - and the preparation of financial statements are outlined in Article 5 of the Accounting and Financial Reporting Law (Accounting and Financial Reporting Law No 287, 2017). The first step in the accounting regulation process begins with the classification of entity categories. It is important to mention that the classification of entities for the purposes of accounting and financial reporting is based on different sets of indicators than those used for the classification of entities at the national level, as established by the Law on Small and Medium Entities. Table 1 presents the indicator sizes used to determine the entity category according to the two legislative acts: the Law on Small and Medium Entities (Law on Small and Medium Enterprises, No. 179, 2016) and the Accounting and Financial Reporting Law (Accounting and Financial Reporting Law No 287, 2017).

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Table 1. Entity Categories Based on Established Indicators

The Law on Small and Medium Entities		The Accounting and Financial Reporting Law	
Entity Category	**Indicator**	**Entity Category**	**Indicator**
Micro Entities	Entities with no more than 9 employees, an annual turnover of up to 18 million lei, or total assets of up to 18 million lei	**Micro Entities**	Entities that, as of the reporting date, do not exceed the limits of two of the following criteria: a) Total assets – 5,600,000 lei; b) Sales revenue – 11,200,000 lei; c) Average number of employees during the reporting period – 10.
Small Entities	Entities with no more than 49 employees, an annual turnover of up to 50 million lei, or total assets of up to 50 million lei	**Small Entities**	Entities that, as of the reporting date, do not exceed the limits of two of the following criteria: a) Total assets – 63,600,000 lei; b) Sales revenue – 127,200,000 lei; c) Average number of employees during the reporting period – 50.
Medium Entities	Entities with no more than 249 employees, Entities with an annual turnover of up to 100 million lei or total assets of up to 100 million lei	**Medium Entities**	Entities that, as of the reporting date, do not exceed the limits of two of the following criteria: a) Total assets – 318,000,000 lei; b) Sales revenue – 636,000,000 lei; c) Average number of employees during the reporting period – 250.
Large Entities	Entities that exceed the following cumulative conditions: a) Have an average annual number of employees (the average number of employees during the financial period) of over 250; b) Have an annual turnover (revenue from sales) of more than 100 million lei or own total assets (both fixed and current assets) exceeding 100 million lei, according to the latest approved financial statement.	**Large Entities**	Entities that, as of the reporting date, exceed the limits of two of the following criteria: a) Total assets – 318,000,000 lei; b) Sales revenue – 636,000,000 lei; c) Average number of employees during the reporting period – 250.
		Public Interest Entity	An entity whose securities are admitted to trading on a regulated market; a bank; an insurer (reinsurer)/insurance company; a collective investment scheme in securities with legal personality; a large entity that is a state-owned enterprise or a joint-stock company in which the state's share exceeds 50% of the share capital.

Source: Elaborated by the authors based on the Law on Small and Medium Entities, Article 5 (Law on Small and Medium Enterprises, No. 179, 2016), and the Law on Accounting and Financial Reporting of the Republic of Moldova, Article 4 (Accounting and Financial Reporting Law No 287, 2017)

Based on the examination of both the Law on Small and Medium Entities (Law on Small and Medium Enterprises, No. 179, 2016) and the Law on Accounting and Financial Reporting

(Accounting and Financial Reporting Law No 287, 2017), the assignment and classification of entities are determined by the indicators presented in the entity's financial statements for the last reporting period. The Law on Small and Medium Entities defines the size of the indicators only to classify entities as micro, small, and medium, and only by interpreting the provisions of Article 4 can it be determined which entities belong to the category of large Entities.

If the provisions of the Law on Accounting and Financial Reporting are examined, the indicators for identifying all categories of entities are included. As a result of examining the indicators that form the basis for classifying entities, the following conclusions can be drawn: the indicators are the same, with the following differences: the Law on Small and Medium Entities presents the indicator for the number of employees, while the Law on Accounting and Financial Reporting refers to the average number of employees. Additionally, the provisions of Article 22, letter j establish that the explanatory note to the financial statements must present the average number of employees during the reporting period, therefore, both the Law on Small and Medium Entities and the Law on Accounting and Financial Reporting will use this indicator, and it is necessary to appropriately formulate the information presented in the financial statements. Regarding this indicator, the Law on Small and Medium Entities specifies that micro-entities have up to 9 employees, while the regulatory framework establishes an average number of 10 employees. For small entities, the law indicates 49 employees, and the regulatory framework establishes 50 employees; for medium-sized entities, the law specifies 249 employees, while the regulatory framework uses 250 employees. Clearly, both regulatory frameworks could be unified with the same number to avoid discrepancies that could create confusion in the interpretation of this indicator when assigning an entity to the correct category.

Regarding the turnover indicator presented by the Law on Small and Medium Entities (Law on Small and Medium Enterprises, No. 179, 2016) and the sales revenue established by the Law on Accounting and Financial Reporting (Accounting and Financial Reporting Law No 287, 2017), it can be noted that the "turnover" indicator is not present in the financial statements (according to the national accounting standards - NAS), which means it requires further determination, and this concept will be examined. Some economic sources (WikipediA) define turnover as "the total sales made (invoiced) during a fiscal year." However, this could be confused with referring only to sales revenue or all revenues from operational activities, and often the term sales revenue presented in the financial statements is used instead.

Additionally, regarding this indicator, it is important to mention that there are different values in both regulatory acts for the same category of entity. This difference could lead to inconsistencies or confusion in interpreting the turnover indicator, particularly in the classification and reporting of entities in accordance with the respective laws.

Regarding the following indicator, total assets, it has the same formulation, and the divergence is determined only by the values indicated in the two legislative frameworks, and there is a significant difference between these values.

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In the context of the above examination and presentation, we propose formulating the indicators from the Law on Small and Medium Entities (Law on Small and Medium Enterprises, No. 179, 2016) based on the indicators present in the financial statements, or aligning the formulation of the indicators according to the Law on Accounting and Financial Reporting (Accounting and Financial Reporting Law No 287, 2017), along with the need for a national approach regarding the indicators that establish the entity category, to avoid generating different dilemmas, interpretations, and misclassification across different regulatory frameworks.

It is important to mention that the Law on Accounting and Financial Reporting (Accounting and Financial Reporting Law No 287, 2017), in addition to the entity categories, also presents the categories for groups of entities and the classification indicators for small, medium, and large groups, which influence consolidated financial reporting.

The structure and content of the financial statements differ depending on the category of the entity and, at times, the field of activity. In the continuation of the research, the regulatory framework for financial reporting and the methodology of financial reporting for entities in the Republic of Moldova will be examined and presented, as shown in Table 2.

Table 2. Regulatory Framework and Financial Reporting Methodology in the Republic of Moldova

<table>
<tr><th colspan="7">Depending on the method of accounting and the application of accounting standards</th></tr>
<tr><td colspan="4">Financial statements according to National Accounting Standards (NAS)</td><td colspan="3">Financial statements according to IFRS (International Financial Reporting Standards)</td></tr>
<tr><td colspan="7">Regulatory framework:</td></tr>
<tr><td colspan="7">The Law on Accounting and Financial Reporting</td></tr>
<tr><td>NAS Presentation of Financial Statements</td><td>NAS Presentation of Consolidated Financial Statements</td><td>Methodological Guide for Preparing Financial Statements</td><td>Methodological Guide for Preparing Consolidated Financial Statements</td><td>The Conceptual Framework for Financial Reporting</td><td>IAS 1 Presentation of Financial Statements
IAS 7 Statement of Cash Flows</td><td>IFRS 10 Consolidated Financial Statements</td></tr>
<tr><td colspan="7">Depending on whether it is an individual entity or a group of entities</td></tr>
<tr><td colspan="2">Individual financial statements – are prepared for each individual entity</td><td colspan="2">Consolidated financial statements – are prepared by the parent entity (at the group level).</td><td colspan="2">Individual financial statements</td><td>Consolidated financial statements</td></tr>
</table>

Source: Prepared by the authors based on the national and international accounting regulatory framework.

If for entities that organize their accounting according to national accounting standards, different sets of financial statements are stipulated by the NAS "Presentation of Financial Statements," then according to the international accounting standard that regulates where the information appears in the financial statements, IAS 1 "Presentation of Financial Statements" applies to all entities applying IFRS. In the continuation of the research, the accounting

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regulatory framework in the Republic of Moldova was examined, and both the types of financial reporting established as mandatory for each category of entity and the forms included were identified and presented, being systematized in Table 3.

Thus, based on the information presented in Table 3, it can be observed that for each category of entity, the required set of financial reporting is described, as well as the option to choose an alternative set of financial reporting later. The set of financial statements selected and applied by each entity is specified in its Accounting Policies. Additionally, we would like to emphasize that in order to meet the qualitative requirement of enhancing financial information, namely comparability, which implies that financial statements should contain comparative information, it is necessary to apply the same sets of reports from one period to another, rather than applying a different set when the entity transitions to another category based on the recorded indicators.

Table 3. The regulatory framework of financial reporting in Republic of Moldova

Entity category (art. 4 and 2)	The method of accounting and the application of standards	The set of financial statements	The forms of each set of financial statements
Micro entity	✓ Keep double-entry bookkeeping and prepare abbreviated financial statements according to SNC ✓ May prepare simplified or full financial statements ✓ May keep accounting and prepare financial statements based on IFRS	**Abbreviated financial statements according to NAS (National Accounting Standards)**	a) The abbreviated balance sheet; b) The abbreviated profit and loss statement; c) The explanatory note.
Small entity	✓ Keep double-entry bookkeeping and prepare simplified financial statements according to SNC ✓ May prepare full financial statements ✓ May keep accounting and prepare financial statements based on IFRS	**Simplified financial statements according to NAS (National Accounting Standards)**	a) The balance sheet; b) The profit and loss statement; c) The explanatory note.
Medium entity **Large entity**	✓ Keep double-entry bookkeeping and prepare full financial statements according to SNC. ✓ May keep accounting and prepare financial statements based on IFRS.	**Complete financial statements according to NAS**	a) The balance sheet; b) The profit and loss statement; c) The statement of changes in equity; d) The cash flow statement; e) The explanatory note.
Public interest entity	Keep double-entry bookkeeping and prepare financial statements according to IFRS	**Financial statements according to IFRS**	a) Statement of financial position at the end of the period; b) Statement of profit or loss and other comprehensive income for the period; c) Statement of changes in equity for the period; d) Statement of cash flows

			for the period; e) Notes including significant accounting policies and other explanatory information.
Non-commercial organizations and branches of non-resident entities	Keep double-entry bookkeeping and prepare financial statements according to the methodological guidelines approved by the Ministry of Finance	**Financial statements according to the methodological guidelines**	a) The balance sheet; b) The statement of income and expenses; c) The statement of changes in funding sources; d) Explanatory notes to the financial statements
Savings and loan associations	They keep double-entry bookkeeping and prepare financial statements according to the methodological guidelines approved by the Ministry of Finance	**Financial statements according to methodological guidelines**	a) Balance sheet; b) Profit and loss statement; c) Statement of changes in equity; d) Cash flow statement; e) Notes to the financial statements
Individuals carrying out entrepreneurial activity	✓ Until they are registered as VAT payers, they maintain accounting in single-entry based on cash accounting, without preparing financial statements, according to the methodological guidelines approved by the Ministry of Finance. ✓ After being registered as VAT payers, they maintain accounting in double-entry and prepare abbreviated financial statements according to SNC.	**Without financial statements** **Abbreviated financial statements**	a) Abbreviated balance sheet; b) Abbreviated profit and loss statement. c) Explanatory note
Individuals who carry out professional activities in the justice sector and the offices they establish, as well as individual practices of family doctors	They keep accounting in a single-entry system based on cash accounting, without preparing financial statements, according to the methodological guidelines approved by the Ministry of Finance	**Without financial statements**	-

Source: Elaborated by the authors based on the Law on Accounting and Financial Reporting (Accounting and Financial Reporting Law No 287, 2017) and the accounting regulatory framework

Currently, the Public Depository of Financial Statements has been established in the Republic of Moldova. It automatically provides data related to the financial statements submitted by legal entities in the country and ensures public access to these financial statements. According to aggregated data from the Public Depository, there are 93,828

entities, including 85,441 commercial entities. A total of 413,146 financial statements are stored in the system, of which 230,346 pertain to the period 2022–2024 (Public Depository of Financial Statements).

A new challenge in the financial reporting landscape for entities in the Republic of Moldova is ESG reporting. ESG reporting is beginning to gain momentum, influenced by European regulations and global sustainability trends. These developments enable the Moldovan business environment to strengthen its competitiveness in European markets and contribute significantly to the transition toward a sustainable and circular economy (Bahnaru, 2024, pp. 82–83).

Conclusions

This research focuses on examining the financial reporting carried out by entities in the Republic of Moldova, understanding the specifics and characteristics of the financial statements presented by entities, as they provide the financial position, financial performance, and other relevant information related to the entity's activities over a reporting period. According to the Accounting and Financial Reporting Law of the Republic of Moldova (Accounting and Financial Reporting Law No 287, 2017), financial reporting is conducted based on the applicable accounting regulatory framework: national (National Accounting Standards - NAS) or international (International Financial Reporting Standards - IFRS). For entities that organize their accounting in accordance with NAS, three sets of financial reporting are provided, depending on the entity's category, with their content established by NAS "Presentation of Financial Statements". For entities that organize their accounting in accordance with IFRS, IAS 1 "Presentation of Financial Statements" contains minimum presentation requirements for information that cater to each type of entity. Additionally, the study identified a discrepancy between the accounting regulatory framework and the Law on Small and Medium-Sized Enterprises regarding the determination and identification of the entity's category, both for the established indicators and the sizes presented for each indicator. This discrepancy may lead to divergences and the use of different categories for the same entity, depending on the applicable regulatory framework, potentially causing confusion.

References

Legea contabilității și raportării financiare Nr. 287 din 15-12-2017 [Accounting and Financial Reporting Law]. (2018). *Monitorul Oficial al Republicii Moldova*, *1-6*, art. 22. https://www.legis.md/cautare/getResults?doc_id=125231&lang=ro#

Bahnaru, R. (2024). ESG reporting in the Republic of Moldova: challenges and opportunities in aligning with European and International standards. *Eastern European Journal of Regional Studies*, *10*(2), 74–84.

International Accounting Standards Board. (2018). *Conceptual Framework for Financial Reporting*. https://www.ifrs.org/content/dam/ifrs/publications/pdf-

standards/english/2021/issued/part-a/conceptual-framework-for-financial-reporting.pdf

Directive 2013/34/EU of the European Parliament and the Council of June 26, 2013, on Annual Financial Statements, Consolidated Financial Statements, and Related Reports of Certain Types of Undertakings. (2013, June 29). *Official Journal of the European Union, L. 182/19* https://eur-lex.europa.eu/legal-content/RO/TXT/PDF/?uri=CELEX:32013L0034&from=PL

Biroul Național de Statistică al Republicii Moldova. (2025). *Depozitarul public al situațiilor financiare*. https://depozitar.statistica.md/

Grabarovschi, L., Lazari, L., & Lewandowska, H. (2023). Particularitățile aplicării IFRS în sistemul național de contabilitate și raportare. In *International Scientific Conference on Accounting – ISCA* (pp. 99-109). ASEM. https://doi.org/10.5281/zenodo.8227307 https://caae.ase.md/files/conferinte/isca/Culegere_ISCA_2023.pdf

Horomnea, Emil. (2010). *Fundamentele științifice ale contabilității. Doctrină. Concepte. Lexicon.* [Fundamentals of Accounting Science. Doctrine. Concepts. Lexicon]. Tipo Moldova Publishing House.

International Accounting Standard 1: Presentation of Financial Statements. (2018). https://mf.gov.md/ro/content/standardele-interna%C8%9Bionale-de-raportare-financiar%C4%83-2017-red-book

Istrate, Costel. *Contabilitate și raportări financiare individuale și consolidate*. Polirom.

Lazari, L., & Cucoș, N. (2017, March 17). Raportarea financiară: realitatea Republicii Moldova și perspective ale integrării în spațiul european. In *Challenges of Accounting from the Perspective of Young Researchers*. International Scientific Conference. ASEM. https://caae.ase.md/files/caae/conf/Conf_video_2017.pdf

Lege cu privire la întreprinderile mici şi mijlocii Nr. 17 din 21-07-2016 [Law on Small and Medium Enterprises]. (2018). *Monitorul* Oficial *al Republicii Moldova , 1-6,* art. 651. https://www.legis.md/cautare/getResults?doc_id=137022&lang=ro#

Ministerul Finanțelor. (2020). Cu privire la aprobarea Ghidului metodologic de întocmire a situațiilor financiare: Ordin Nr. 154 din 09-12-2020 [Methodological Guide for Preparing Financial Statements]. *Monitorul Oficial al Republicii Moldova, 360-371,* art. 1389. https://www.legis.md/cautare/getResults?doc_id=124687&lang=ro

Ministerul Finanțelor. (2020). Cu privire la aprobarea Ghidului metodologic de întocmire a situațiilor financiare consolidate și de modificare a Standardului Național de Contabilitate „Prezentarea situațiilor financiare consolidate": Ordin Nr. 155 din 09-12-2020 [Methodological Guide for Preparing Consolidated Financial Statements]. *Monitorul Oficial al Republicii Moldova, 360-371* art. 1390. https://www.legis.md/cautare/getResults?doc_id=124688&lang=ro

Ministerul Finanțelor. (2015). Cu privire la aprobarea Indicaţiilor metodice privind particularităţile contabilităţii în organizaţiile necomerciale şi completarea Planului general de conturi contabile, aprobat prin Ordinul ministrului finanţelor nr. 119 din 06.08.2013: Ordin Nr. 188 din 30-12-2014 [Methodological Instructions Regarding the Particularities of Accounting in Non-Profit Organizations and the Completion of the General Chart of Accounts]. *Monitorul Oficial al Republicii Moldova, 11-2,* art. 55. https://www.legis.md/cautare/getResults?doc_id=118579&lang=ro

Ministerul Finanțelor. (2020). Cu privire la aprobarea Indicaţiilor metodice privind contabilitatea în cabinetele individuale ale medicilor de familie: Ordin Nr. 181 din 31-12-2019

[Methodological Instructions Regarding Accounting in Individual Medical Practices of Family Doctors]. *Monitorul Oficial al Republicii Moldova, 7-13* art. 20 https://www.legis.md/cautare/getResults?doc_id=143757&lang=ro#

Ministerul Finanțelor. (2019). Cu privire la aprobarea Indicaţiilor metodice privind contabilitatea pentru persoanele fizice care desfășoară activitate profesională în sectorul justiției: Ordin Nr. 216 din 28-12-2018 [Methodological Instructions Regarding Accounting for Individuals Engaged in Professional Activities in the Justice Sector]. *Monitorul Oficial al Republicii Moldova, 6-12* art. 60. https://www.legis.md/cautare/getResults?doc_id=143755&lang=ro#

Ministerul Finanțelor. (2017). Cu privire la aprobarea Indicațiilor metodice privind particularitățile contabilității și prezentării informațiilor în situațiile financiare ale asociațiilor de economii și împrumut: Ordin Nr. 166 din 30-12-2016 [Methodological Instructions Regarding the Specifics of Accounting and Presentation of Information in the Financial Statements of Savings and Loan Associations]. *Monitorul Oficial al Republicii Moldova, 19-23*, art. 62. https://www.legis.md/cautare/getResults?doc_id=97314&lang=ro

Ministerul Finanțelor. (2013). Privind aprobarea Standardelor Naţionalede Contabilitate: Ordin Nr. 118 din 06-08-2013 [Methodological Instructions Regarding Accounting for Individuals Engaged in Entrepreneurial Activities]. *Monitorul Oficial al Republicii Moldova, 177-181*, art. 1224. https://www.legis.md/cautare/getResults?doc_id=131868&lang=ro#

National Accounting Standard "Presentation of Financial Statements". (2013). *Monitorul Oficial al Republicii Moldova, 177-181*, art. 1224. https://www.legis.md/cautare/getResults?doc_id=131868&lang=ro#

Nederiţa, A. (2021). Noile formate de situaţii financiare: conţinutul de bază şi interconexiunea cu conturile contabile [The new formats of financial statements: basic content and interconnection with accounting accounts*]*. *Contabilitate şi audit*, *2*, 5-14.

Cifră de afaceri. (2024). In *Wikipedia*. https://ro.wikipedia.org/wiki/Cifr%C4%83_de_afaceri

Ţurcanu, V., & Golocialova, I. (2015). *Raportarea financiară conform standardelor internaţionale* [Financial reporting according to international standards]. Chişinău, 2015.

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THEORETICAL APPROACHES TO URBAN RESILIENCE

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Abstract: *This paper investigates the concept of resilience through its social, ecological, economic, and institutional dimensions. It explores key factors such as social cohesion, social capital, and community infrastructure in enhancing social resilience. The analysis extends to ecological resilience, focusing on biodiversity, habitat complexity, and the functional roles ecosystems play in responding to disturbances. Economic resilience is discussed in terms of the capacity of regional economies to recover and maintain stability in the face of external shocks, while institutional resilience examines how governance structures adapt and implement effective responses to ongoing challenges. The paper further evaluates methods for assessing resilience, including the Social Vulnerability Index (SoVI) and its application in identifying vulnerable populations and areas. In doing so, it highlights strategies for strengthening resilience across these dimensions, such as fostering robust social networks, improving infrastructure, ensuring responsive governance, and promoting ecological conservation. The findings underline the importance of an integrated, multi-dimensional approach to resilience in both human and ecological systems.*

Keywords: *ecological resilience, social resilience, economic resilience, institutuional resilience, SOVI index.*

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Introduction

Resilience is a concept widely employed across various disciplines, encompassing ecological sciences, social sciences, and development studies. Broadly defined, resilience refers to a system's ability to absorb disturbances while maintaining its core functions and structures (Walker et al., 2006). Initially rooted in ecological studies (Holling, 1973), the concept has been progressively integrated into fields such as resource management, engineering, urban planning, and disaster studies, contributing to a growing body of theoretical and empirical research.

In contemporary discourse, resilience has become a fundamental notion in development policies and strategic frameworks. Institutions like the World Bank have integrated resilience into urban and institutional governance, emphasizing its role in mitigating risks associated with climate change, economic shocks, and social instability. Despite its widespread use, the concept remains subject to multiple interpretations, often lacking a precise operational

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definition (Cornwall, 2007). This theoretical ambiguity underscores the necessity of a comprehensive exploration of resilience as a theoretical construct, assessing its evolution, conceptual frameworks, and implications for contemporary development strategies.

The purpose of this article is to provide a critical review of resilience as a theoretical paradigm, analyzing its conceptual foundations, interdisciplinary applications, and methodological considerations. The study aims to clarify key dimensions of resilience by synthesizing existing literature, evaluating theoretical models, and discussing implications for policy and practice. Unlike empirical studies focusing on specific regions or case studies, this article adopts a theoretical perspective, emphasizing the intellectual trajectory of resilience research.

Following this introduction, the first section synthesizes key findings from the scientific literature, examining theoretical advancements and their implications for resilience-oriented strategies, the second section presents a critical review of qualitative studies addressing the four types that the territorial resilience covers. The third section explores methodological approaches used to assess resilience. Finally, the conclusion summarizes the main insights and suggests potential directions for future research in resilience theory.

By providing a structured examination of resilience as a theoretical construct, this article seeks to contribute to the ongoing academic discourse, offering a nuanced understanding of its significance and potential applications in various fields of study.

Literature Review

In line with the multidimensional nature of territorial resilience, the following section explores the four key domains most frequently discussed in the literature: ecological, institutional, social, and economic resilience. These dimensions represent interrelated yet distinct theoretical perspectives through which resilience has been conceptualized and applied across disciplines. The analysis presented here is based solely on theoretical contributions and qualitative academic literature, without the inclusion of empirical case studies or indicator-based assessments. This approach aims to provide a comprehensive synthesis of how resilience is conceptually structured, highlighting the main thematic directions, overlaps and critical perspectives that underpin current academic discourse and policy debates.

The concept of territorial resilience implies a multidimensional approach, encompassing ecological, social, economic, and institutional aspects, which is why it is necessary to present these aspects.

Ecological resilience is often defined as the capacity of an ecosystem to absorb disturbances and still maintain its fundamental structure and functions (Folke et al., 2004). In urban contexts, ecological resilience focuses on enhancing the city's ability to withstand environmental shocks, such as floods or heatwaves, through green infrastructure and sustainable urban planning (Beilin & Wilkinson, 2015). The adoption of green spaces, permeable pavements,

and water retention systems has been central to many cities' strategies for ecological resilience (Revi et al., 2014). Several cities, including Rotterdam, Copenhagen, and Vienna, have been pioneers in implementing such measures as part of their climate adaptation strategies. Nevertheless, recent critiques argue that such approaches often remain technocratic and fail to consider questions of equity and environmental justice, particularly regarding access to ecological benefits across socio-economic groups (Anguelovski et al., 2016).

Institutional resilience refers to the ability of institutions, particularly government structures, to function effectively during crises and to recover quickly (Krlev, 2023). Research has shown that the adaptability of institutions plays a crucial role in how communities withstand and recover from both natural and economic disasters (Holling, 1973). Strong governance, the ability to implement policies effectively, and public trust are key factors in fostering institutional resilience. Examples of successful institutional resilience include the rapid responses of Scandinavian countries to natural disasters and economic recessions (Giacometti et al., 2018). However, such models may not be easily replicable in other contexts, as they are deeply rooted in political culture, civic engagement, and stable institutional environments. Moreover, excessive emphasis on formal efficiency can obscure the roles of informal institutions and local networks that often mediate resilience on the ground (Meerow et al., 2016).

Social resilience involves the capacity of communities to cope with adversity, including social and economic challenges. It emphasizes the role of social networks, community cohesion, and the equitable distribution of resources in responding to crises (Adger, 2000). Research by Rydin et al. (2012) and Cohen et al. (2017) highlights how fostering community engagement, ensuring access to essential services, and reducing social inequalities are vital strategies for enhancing social resilience. Successful examples include the integration of social welfare programs and community-based disaster response systems. However, critiques from critical geography and urban studies (MacKinnon & Derickson, 2013) highlight that resilience, if uncritically adopted, can reinforce existing inequalities by placing responsibility for adaptation on vulnerable populations rather than addressing structural causes of vulnerability.

Economic resilience is defined as the ability of an economy to recover from external shocks, such as financial crises or global disruptions. A resilient economy is one that can adapt to changing conditions, maintain sustainable growth, and reduce vulnerability (Martin et al., 2016). The diversification of industries, the flexibility of labor markets, and the support of SMEs have been identified as key factors in achieving economic resilience (Hussen saad et al., 2021). Cities like Lisbon and Barcelona have been successful in their economic recovery strategies, which include fostering entrepreneurship and innovation to diversify their economic base (Gómez-Baggethun & Barton, 2013). Nonetheless, scholars argue that market-based approaches to resilience may overlook marginalized economic actors and prioritize recovery over transformation, potentially exacerbating inequality (Bristow & Healy, 2014).

Theoretical contributions by Adger (2000) and Folke et al. (2004) emphasize the adaptive capacity of systems and highlight the need to consider feedback mechanisms and multi-scalar

interactions. Nonetheless, the integration of these domains remains a theoretical ambition rather than a consistent practice in urban planning or governance (Meerow et al., 2016). As such, the literature reveals a gap between theoretical aspirations and practical implementation, underscoring the necessity for frameworks that bridge the conceptual richness of resilience with tools applicable to specific urban and territorial contexts.

Data and Methodology

This article adopts a theoretical and conceptual methodology, grounded in an extensive review of the scientific literature. No statistical or empirical data analysis has been employed. Instead, the research follows a qualitative and interpretative approach, aiming to synthesize, compare, and critically examine key contributions on territorial resilience, as articulated in ecological, institutional, social, and economic domains.

The rationale for selecting these four dimensions derives from their consistent presence across interdisciplinary studies of resilience, and from their relevance in shaping how territories respond to complex and overlapping crises. The methodology does not rely on a codified protocol for systematic review, as the focus is not on quantifying evidence but on constructing a robust conceptual framework that can inform further theoretical development.

The review process involved three analytical stages. First, key theoretical frameworks were identified and examined, focusing on how resilience is defined and operationalized in each of the four domains. Second, the literature was analyzed for its treatment of integrative approaches - exploring whether and how the four dimensions interact or are addressed collectively. Third, the limitations and critiques of current resilience frameworks were examined, particularly with regard to their normative assumptions and their applicability in urban or regional governance contexts.

This approach is grounded exclusively in secondary sources - peer-reviewed articles, theoretical essays, and academic reports - and does not attempt to extract policy recommendations from empirical data. Instead, it offers a structured, multidimensional conceptualization of territorial resilience that may serve as a foundation for future empirical or comparative studies.

The methods of quantifying the resilience factors

Given the theoretical nature of this study, the following section elaborates on the key indicators and methodologies used to assess the four types of territorial resilience - ecological, institutional, social, and economic - as well as the Scale of Vulnerability and Resilience Index (SOVI). These theoretical tools are explored in order to understand their role in evaluating territorial resilience across different regions like in the European Union and Romania.

1. Ecological resilience: theoretical perspectives, indicators, and assessment approaches

In the broader landscape of territorial resilience, ecological resilience is defined as the capacity of ecosystems to absorb disturbances and reorganize while maintaining essential

structures, functions, and feedback mechanisms (Folke et al., 2004). It has become increasingly relevant in the context of global environmental crises, urbanization, and unsustainable resource exploitation. The purpose of this section is to present the main theoretical contributions to the study of ecological resilience, to identify the core factors emphasized in academic discourse, and to review the conceptual methodologies and indicators proposed for its assessment. Through this analytical overview, the aim is to clarify both the scientific relevance and the methodological limits of this resilience dimension within territorial systems.

Firstly, biological diversity plays a crucial role in ecological resilience, as it has been demonstrated that ecosystems with higher biodiversity are more capable of withstanding disturbances and recovering quickly. Studies such as those conducted by Folke et al. (2004) have shown that increased species diversity helps maintain ecosystem stability and attenuate the impact of disturbances, a viewpoint supported by other researchers (Hooper et al., 2005; Fischer et al., 2006). For instance, coral reefs and tropical forests are ecosystems with high biodiversity, which allows them to recover rapidly after external disturbances.

Another critical factor is the trophic structure, which profoundly influences the stability and recovery of ecosystems. This refers to the relationships between species within food chains and their complexity. O'Leary et al. (2017) highlight those systems with more trophic levels, such as marine ecosystems, are more resilient to disturbances like overfishing due to their complex trophic networks and interspecific relationships. Therefore, a marine ecosystem with a diversified trophic structure will have a greater capacity to resist and recover after a disturbance.

Habitat complexity also plays a pivotal role in ecological resilience by providing refuges and alternative resources for species affected by disturbances. Brookes et al. (2005) emphasize that larger habitat dimensions allow organisms to coexist on a broader scale, leading to increased resource usage pathways (St. Pierre & Kovalenko, 2014). At the scale of a patch, habitat complexity can increase species diversity beyond the effects of size, underscoring the physical habitat's importance in a variety of systems and its independent effects on surface area, habitat, or zone (Kovalenko et al., 2012; Matias et al., 2010). For example, complex wetlands such as mangroves and coral reefs provide a diversified habitat that supports a wide variety of species.

Ecological functions, such as nutrient cycling, pollination, and organic matter decomposition, are essential for maintaining resilience. Disturbances that affect these functions can significantly impact an ecosystem's ability to recover. Areas with high habitat complexity can play a crucial role in nutrient processing due to turbulence resizing (Commito & Rusignuolo, 2000; Madsen et al., 2001), reduced flow rates (Atilla et al., 2005), and/or extended reactive surface areas, leading to increased microorganism numbers and, over time, higher rates of sedimentation and nutrient retention.

The evaluation of ecological resilience involves measuring and monitoring various components of an ecosystem to determine its capacity to withstand and recover from disturbances. This can be done using specific ecological resilience indicators, such as metrics

of species diversity, habitat health, ecological functions, and structural stability (Dakos & Kéfi, 2022). For example, indicators such as species richness, abundance of key species, and recovery rates after disturbances are used to assess ecosystem resilience. Additionally, certain methods are used for this assessment, such as:

- Temporal analysis: long-term monitoring of ecosystems to observe changes in diversity and functioning over time (Fath et al., 2003; Mayer et al., 2006; Kéfi et al., 2014; Sundstrom et al., 2016).
- Ecological modeling: the use of mathematical and computational models to simulate ecosystem responses to disturbances and assess their resilience (Dakos & Kéfi, 2022).
- Controlled disturbance experiments: conducting controlled experiments to observe ecosystem responses to different types of disturbances (Boettiger et al., 2013; Kéfi et al., 2014).

Ecological resilience literature also explores strategies to enhance resilience, particularly through nature-based solutions, sustainable resource management, and habitat conservation. For instance, reforestation and coral reef restoration are repeatedly mentioned as effective approaches to reinforce ecological feedback loops (Hughes et al., 2003). Furthermore, efforts to reduce greenhouse gas emissions (IPCC, 2023), mitigate land degradation, and integrate organic land-use practices are seen as foundational for maintaining ecosystem balance.

However, as noted by Dias (2023), biodiversity loss continues to accelerate due to intensive agriculture, overexploitation, and pollution - creating a widening gap between theoretical models and practical implementation. While ecological resilience is often framed as a desirable goal in policy discourse, scholars such as Vale (2014) and Cretney (2014) have raised critical questions about its normative implications: resilience for whom, to what, and at what cost?

Sustainable management of natural resources involves practical use of resources in a way that does not compromise ecosystems' capacity to recover and adapt to changes. For instance, sustainable fishing and responsible forest management help maintain ecological functions and protect biodiversity. Implementing sustainable land management practices, such as agroforestry, reforestation, and conservation agriculture, can reduce carbon levels and mitigate emissions generated by land-use changes (Smith et al., 2019).

Reducing the impact of human activities is critical for ecological resilience. The primary driver of human-induced climate change is the emission of greenhouse gases (GHGs), particularly carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). These gases trap heat in Earth's atmosphere, leading to global warming and climate change (IPCC, 2023). Reducing the impact of human activities on the environment includes lowering greenhouse gas emissions, waste management, pollution prevention, and protecting critical habitats.

Nature-based solutions, such as green infrastructure, ecological restoration, and organic farming, can significantly contribute to ecological resilience (Smith et al., 2019). These solutions harness natural processes to address environmental issues and improve ecosystems' capacity to adapt to changes.

Ecological indicators include biodiversity, which measures species diversity and ecosystem health (Folke et al., 2004), environmental quality, including air, water, and soil quality indicators (Folke et al., 2004), and natural resources, which measure the availability and management of resources like water, forests, and agricultural land (Adger, 2000). Examples include agriculture, forestry, and fishing as a percentage of GDP.

Despite its conceptual maturity, the ecological resilience remains challenging to operationalize, especially in urban contexts. Urban ecosystems are characterized by fragmented green areas, high anthropogenic pressure, and uneven institutional capacities to implement ecological strategies. In many Eastern European cities, for example, resilience strategies are still constrained by weak intersectoral coordination and limited ecological data (Toto et al., 2023, Bănică et al., 2020).

Moreover, the integration of ecological indicators into urban planning processes is inconsistent, with local governments often lacking the tools to measure resilience beyond environmental compliance. Thus, Sandu, Bănică & Muntele (2021) and Sandu (2021) reveal a persistent gap between theoretical ambitions and practical implementation, especially in socio-institutionally diverse regions like Central and Eastern Europe.

2. Social Resilience: theoretical perspectives, evaluation methods and strategic approaches

Building on the theoretical foundations outlined in the literature review, this section explores how social resilience is conceptualized and operationalized in territorial and urban contexts. The focus shifts from definitional aspects to a critical analysis of the mechanisms through which communities build adaptive capacity in response to disruptions.

Social resilience is not a fixed attribute but a dynamic, evolving process embedded in the structures, relationships, and institutions of a society. It is strongly influenced by social cohesion, which refers to the degree of trust, solidarity, and civic engagement within a community.

Studies have shown that social trust and civic participation are essential for social resilience (Putnam, 2000). Therefore, the socio-cultural norms underlying community support and cohesion can foster resilience over time, both by encouraging the development of social capital and acting as a buffer against potential losses generated by conflicts, as communities go through periods of deficit (Carmen et al., 2022).

Social capital, which includes networks, norms, and values that facilitate collective action and cooperation within a community, has been widely used to understand interventions aimed at enhancing adaptation capacities and resilience. These include those directly related to climate change and community-level concerns, such as natural hazards (Babcicky & Seebauer, 2016) and, more generally, supporting health outcomes (Cattell, 2001), strengthening economic development (Flora et al., 1997), and increasing participation in collective decision-making (Cleaver, 2005). Social capital has also often been viewed as a core concept for community resilience (Adger, 2000; Berkes & Ross, 2012). A strong social capital can contribute to social resilience by mobilizing resources and support during crises (Coleman, 1988).

Community infrastructure, such as health centers, schools, and volunteer organizations, plays a crucial role in social resilience. These institutions provide the necessary support and resources to cope with disruptions and facilitate recovery. For example, improving community resilience requires approaches that go well beyond technical or infrastructural interventions to consider various social and psychological factors. In emergency management, quality infrastructure (e.g., roads and housing) is important for access to vital services (e.g., food and healthcare) (Javadpoor et al., 2021). In other fields, such as rural development and urban studies, income levels and diverse institutions that mediate interests and access to resources and opportunities are important in shaping coping abilities and adapting to long-term constraints (Tajuddin & Browski, 2021; Pandey et al., 2021). For example, social support networks and community centers are essential during crises (Aldrich & Meyer, 2015).

Social policies and government programs that support education, health, employment, and social protection contribute significantly to social resilience. For example, social insurance systems and support programs for low incomes can help buffer the impact of economic crises (Moser, 1998). It has been found that decisions made at higher levels of government influence local decisions and practices that reduce social capital and resilience (Luthe & Wyss, 2015). This loss of community resilience has occurred through ideological shifts in national political processes, for instance, through market-based approaches that increase competition among local producers (favoring individualism over cooperation) or through technical solutions rather than holistic ones (Sinclair et al., 2014; Guillotreau et al., 2017). For community resilience, the role of social capital can be inadvertently eroded through government-driven change programs.

The assessment of social resilience involves measuring and analyzing the capacity of communities to resist and recover from disruptions. Methods used in the assessment include resilience social indicators and surveys, case studies, etc. Key indicators include social cohesion levels, measured through social trust, civic participation, and community solidarity (Slavova & Simpson, 2023), social capital, evaluated through network density, norms of reciprocity, and involvement in community organizations (Aldrich & Meyer, 2015), access to social services, measured by the availability and accessibility of healthcare, education, and social assistance services (UN Habitat, 2020), and social support policies, evaluated by the existence and effectiveness of government social protection programs (Velasco & Domínguez, 2022).

Social surveys collect data to measure social trust, cohesion, and social capital, while social network analysis studies the structure and density of social networks to understand connections and mutual support in the community. Case studies analyze community responses to specific disruptions to identify success factors and lessons learned. The assessment of social resilience in cities affected by natural disasters, such as New Orleans after Hurricane Katrina, highlighted the importance of social cohesion and social capital in community recovery (Rodriguez, Quarantelli & Dynes, 2007).

To enhance social resilience, certain strategies can be applied to strengthen social cohesion, develop social capital, improve community infrastructure, and implement

appropriate social policies. Strengthening social cohesion can be achieved by promoting trust and solidarity within the community. Volunteering activities, community events, and civic engagement initiatives can help build social relationships. For example, community development programs and intercultural dialogue initiatives can strengthen social cohesion (Kawachi & Berkman, 2000). A higher level of social resilience leads to more heterogeneous societies (Marshall & Smaigl, 2013). Conversely, a deterioration in this element anticipates a reduction in social resilience (Markolf et al., 2018). Policies that contribute to the development of a large middle class and the reduction of social inequalities enhance social resilience. As mentioned, anything that helps build social cohesion has the potential to improve a community's resilience (Bunch et al., 2011). Based on this relationship, promoting social cohesion is a key element for social resilience (Patel & Gleason, 2018).

Developing social capital involves supporting social networks and community organizations. Creating spaces and opportunities for social interaction and cooperation can contribute to the growth of social capital. Pfefferbaum et al. (2017), Karunarathne & Lee (2019), Rustinsyah et al. (2021) have also confirmed the positive relationship between social capital and community resilience through both theoretical and empirical research. For example, mentorship programs and public-private partnerships can help build social capital (Putnam, 2000).

Improving community infrastructure, such as health centers, schools, and public spaces, is essential for social resilience. Investments in community infrastructure can facilitate access to services and create support points during crises. For instance, developing multifunctional community centers can provide support in various areas, from health to education (Aldrich & Meyer, 2015). It would be how a community or society responds, as a whole, to the difficulties, disturbances, and tensions it faces, but as a group (Bolzan & Gale, 2018; Moberg & Galaz, 2005; Carpenter & Brock, 2008). Through the development of this infrastructure, communities, societies, and not just individuals, would be the ones to provide responses to shocks. Thus, in addition to facing these disturbances, societies could transform the processes of change imposed by difficulties into opportunities while maintaining their original essence (Adger, 2000).

Implementing appropriate social policies includes programs for social protection, assistance for low incomes, and support for employment. Policies that support equity and social inclusion can contribute to the resilience of vulnerable communities. Family support within the members of a society, which specifically fosters social and community inclusion, is one of the most important drivers of social resilience (Liebenberg & Moore, 2018). Various studies have highlighted the value of social support, and above all, family support for overcoming general tension situations (Onyedibe et al., 2018), especially in medical emergencies (Kong et al., 2018). The importance of this factor is emphasized both for youth (Omar, 2011; Van der Wal & George, 2018) and the elderly (Chang & Yarnal, 2018). This family support leads to improved social resilience by generating what are called "personal support networks" in society (Oh & Jun, 2018; Distelberg & Taylor, 2015). Policies supporting low-income families and professional training programs can help reduce social vulnerability (Moser, 1998).

Vulnerability analysis is essential for understanding risks and managing them in various contexts. One of the recognized methods for measuring social vulnerability is the Social Vulnerability Index (SoVI). This index provides a quantifiable approach to assess the susceptibility of communities to various hazards, thus helping to implement risk reduction measures and enhance resilience.

Vulnerability, in the context of risk analysis, refers to the degree to which a system, community, or region is predisposed and incapable of coping with the negative effects of a hazard. It is influenced by three main factors:

- Exposure: The degree to which a system is exposed to hazards;
- Sensitivity: The degree to which a system is affected by exposure to hazards;
- Adaptive Capacity: The ability to adapt and recover from negative impacts.

For example, a community located in an active seismic zone has high vulnerability to earthquakes, especially if its infrastructure is not designed to withstand such events. Similarly, an agricultural community in a drought-prone region is vulnerable due to dependence on rainfall and limited irrigation capacity (Turner et al., 2003).

The assessment of social resilience involves a range of tools and indicators designed to measure how communities resist and recover from disruptions. These include sociological surveys, case studies, and social network analysis. Indicators commonly examined include levels of civic participation, trust in local authorities, density of social ties, access to basic services, and the presence of effective social policies. The Social Vulnerability Index (SoVI), developed by Cutter et al. (2003), remains a widely used tool in this field. It aggregates socio-demographic variables - such as income, education, age, and health status - into a composite index that reveals patterns of vulnerability and adaptive capacity across territorial units.

While analytical tools offer structured ways to quantify resilience, the scientific literature also points to persistent challenges. One critical debate concerns the tension between top-down policy approaches and community-led responses. Although state-level programs provide systemic protection, they may undermine local cohesion and erode social capital when imposed without participatory frameworks. A study by Almazán-Casali et al. (2021) illustrate how technocratic or market-driven reforms have sometimes displaced informal support systems and generated fragmentation in local governance.

This issue is particularly salient in Central and Eastern Europe, where cities continue to face difficulties in consolidating social resilience. Factors such as emigration (Muntele & Horea-Șerban, 2021), demographic aging, fragmented service provision, and institutional distrust limit the potential for sustained recovery and adaptation (Bănică et al., 2020). Another danger that leads to socio-economic gaps is the cultural lag (Șerbu, 2016). All of these situations underscore the need for context-sensitive resilience strategies that reflect regional socio-political and economic particularities.

Strengthening social resilience requires coordinated efforts across community, institutional, and policy levels. Investments in community infrastructure must be

complemented by policies that foster social inclusion, encourage civic engagement, and support the development of resilient social networks. Ultimately, a resilient society is not only one that withstands shocks but also one that adapts, transforms, and thrives without losing its core values and cohesion.

3. Institutional resilience: dimensions, indicators, and assessment methods

Institutional resilience plays a decisive role in supporting the capacity of urban and territorial systems to withstand and recover from disruptions. In contemporary governance, challenges such as overlapping crises, fragmented administrative structures, and reduced civic trust test the responsiveness and adaptability of institutions beyond their formal mandates.

Effective leadership is crucial for institutional resilience. Leaders and organizations often face challenges and crises that test the strength and flexibility of their systems and resources. Successfully leading an organization has always been more difficult during periods of rapid change, but the unique stress factors that organizations worldwide face today have sparked renewed interest in studying personal and organizational behaviors, with a focus on what constitutes effective and adaptable leadership. Interestingly, some leaders and organizations not only survive but also thrive in these situations, while others wobble or collapse under the stress of change. Boin and Hart (2003) analyzed the factors underlying these differences. Transformational business models have recently focused on the importance of resilience in both leadership and organizational success. Leaders who can make swift and well-informed decisions in crisis situations help maintain institutional stability. Studies have shown that leaders who foster a culture of preparedness and adaptability contribute significantly to organizational resilience (Boin & Hart, 2003).

A solid organizational infrastructure, which includes well-defined processes, adequate resources, and advanced technology, contributes to an institution's ability to handle crises. Institutions with robust infrastructure can react more efficiently to disruptions and can resume normal activities more quickly (McEntire, 2011). Planning capacity is also key. Preemptive planning and emergency preparedness are essential for institutional resilience. Institutions with continuity plans and crisis response procedures can better manage disruptions. For instance, financial institutions that have crisis management plans are more resilient in the face of economic shocks (Özkan, 2011). Inter-institutional collaboration plays a significant role. Effective collaboration between different institutions and organizations can strengthen institutional resilience. Partnerships and support networks allow for better coordination of resources and crisis responses. For example, collaboration between government agencies and non-governmental organizations during natural disasters can enhance the efficiency of the response (Kapucu, 2006).

In Central and Eastern Europe, efforts to consolidate institutional resilience encounter specific barriers. These include the persistence of administrative inertia, inconsistent policy implementation, and a legacy of hierarchical governance that hampers horizontal cooperation. Even where strategic frameworks exist, limited civic participation and low

inter-agency interoperability often reduce their practical impact (Poljak Istenič & Kozina, 2019; Sandu et al., 2021).

Assessing institutional resilience involves measuring and analyzing the capacity of institutions to withstand and recover from disruptions. This is evaluated both through indicators that show the level of institutional resilience and through specific assessment methods. Key indicators include crisis response capacity, measured by response time and effectiveness in managing crises; operational stability, assessed by the continuity of essential activities during disruptions; adaptability, measured by the ability to implement changes and adapt to new conditions; and inter-institutional collaboration, evaluated by the level of cooperation and coordination with other institutions.

Despite increasing attention to institutional resilience, its assessment remains largely conceptual, with limited operational tools tailored to urban or territorial contexts. Methods for assessing resilience include institutional audits, which evaluate processes and crisis response capacity through internal and external audits; crisis simulation exercises, which test response capacity and coordination between institutions; and analysis of past crisis performance, studying institutional performance during previous crises to identify strengths and areas for improvement. The assessment of institutional resilience during the COVID-19 pandemic highlighted the importance of preemptive planning and adaptability. Institutions that had continuity plans and could quickly adapt their processes managed the crisis more effectively (Moșteanu, 2024).

To enhance institutional resilience, strategies must improve leadership, strengthen organizational infrastructure, develop planning capacity, and promote inter-institutional collaboration. Improving leadership can be achieved through ongoing training and the development of crisis management skills. Leaders need to be able to make rapid, informed decisions and communicate effectively with employees and the public. Leadership development programs and crisis simulations can help improve leadership skills (Boin & Hart, 2003). Strengthening organizational infrastructure involves investments in technology, efficient processes, and adequate resources. Institutions need robust information management systems and well-defined procedures to handle crises. For instance, developing early warning systems and internal communication platforms can improve response capacity (McEntire, 2011).

Developing planning capacity includes creating and regularly updating continuity plans and crisis response procedures. Institutions should conduct crisis simulation exercises and periodically assess the effectiveness of their plans. For example, central banks and financial institutions that perform regular stress tests are better prepared for financial crises (Özkan, 2011). Promoting inter-institutional collaboration can be achieved by creating partnerships and support networks. Institutions must collaborate with other organizations, including governments, non-governmental agencies, and the private sector, to coordinate resources and crisis responses. For instance, public-private partnerships for disaster management can enhance response efficiency (Kapucu, 2006).

Governance capacity measures the efficiency and transparency of government institutions, public participation in decision-making, and the enforcement of laws and regulations (Brooks et al., 2005). Examples include the Government Effectiveness Index (ranging from -2.5 (weak) to 2.5 (strong)) and Regulatory Quality (ranging from -2.5 (weak) to 2.5 (strong)). Planning and policies include indicators related to the existence and implementation of adaptation and risk reduction policies (Brooks et al., 2005), such as the Corruption Index (ranging from -2.5 (weak) to 2.5 (strong)). Inter-institutional collaboration measures the level of cooperation and coordination between different agencies and organizations involved in risk management and adaptation to climate change (Adger et al., 2005). Even though these methods of assessment do exist they provide only a general framework for assessing governance capacity, yet may fail to capture informal institutional dynamics or subnational variation, especially in post-socialist urban systems. A promising direction would include the use of qualitative institutional audits, combined with scenario-based stress tests and retrospective evaluations of past crisis responses. These can help map institutional resilience not only through static indicators but also by understanding how institutions adapt over time. A more grounded assessment of institutional resilience involves identifying measurable indicators that can be contextualized within urban governance. For instance, in Warsaw (Poland), the Municipal Crisis Management Plan includes specific benchmarks for response times, redundancy of critical infrastructure, and public communication systems tested biannually through simulation exercises. This allows for monitoring operational continuity and adaptability based on performance during drills and public feedback collection.

Similarly, in Cluj-Napoca (Romania), resilience indicators have been indirectly integrated into digital governance platforms. The city's participatory budgeting process and the establishment of an inter-agency urban development council have improved both civic engagement and inter-institutional coordination. Metrics such as the frequency of stakeholder consultations, the proportion of budget allocated to risk management, or the responsiveness of the e-governance portal can serve as proxies for institutional adaptability and openness.

In Budapest (Hungary), post-pandemic institutional evaluations involved structured interviews across departments and the review of public health contingency protocols. This qualitative assessment was linked to adjustments in administrative workflows and decision-making hierarchies, thus reinforcing institutional learning mechanisms - a key feature of long-term resilience.

These examples highlight that while universal metrics like the World Bank's Government Effectiveness Index or Corruption Control Index offer macro-level snapshots, local-level tools - such as emergency audit logs, simulation scores, and co-governance indicators - are better suited for capturing institutional resilience in urban contexts. Developing such hybrid evaluation frameworks, tailored to local governance realities, represents a promising direction for both academic research and public policy design.

4. Economic resilience factors, methods for quantifying and indicators

Economic resilience is influenced by various factors, particularly in the context of global events such as the 2008 financial crisis, increased economic uncertainty, climate change, the COVID-19 pandemic, and the economic consequences of the 2022 military conflict. These factors have significantly increased interest in analyzing economic resilience in the discourse surrounding economics and sustainable development. According to research and analyses in the literature, several key elements contribute to the economic resilience of a country or region.

Sectoral diversity helps to spread risks and minimize the impact of a shock in a specific sector. Economies with a broad industrial base are less vulnerable to disruptions. This plays a vital role in ensuring economic resilience as it reduces the likelihood of a recession in a sector that has a significant impact on the overall economy. Diversification can involve expanding and developing sectors such as agriculture, industry, services, technology, tourism, and others, in line with the country's or region's resources and comparative advantages. A report by the World Bank in 2019 highlighted the essential role of economic diversification in promoting economic resilience. According to Sekar et al. (2019), sectoral diversity can reduce the risk of exposure to fluctuations in a single sector and can enhance economic resilience by creating opportunities across multiple fields, thereby compensating for potential declines in other sectors. Furthermore, studies by Martin (2012) and Lange et al. (2019) showed that regions with diversified economies are more capable of withstanding economic shocks and recovering more quickly.

Financial infrastructure, represented by a robust and well-regulated financial system, is essential for economic resilience. Access to finance, liquidity, and the ability to manage financial risks contribute to economic stability. Claessens et al. (2018) argue that a solid and well-regulated financial system can contribute to economic resilience by stabilizing the economy during times of crisis. Claessens & Kose (2017) contend that financial institutions need to be well supervised and adhere to strict rules and regulations to avoid financial crises that can have negative effects on the economy. A report published by the European Central Bank (ECB) in 2016 emphasized that ensuring the stability of the financial system is crucial for strengthening economic resilience in the Eurozone, and that implementing appropriate policies and measures is necessary to prevent financial crises. Moreover, the 2008 financial crisis demonstrated the importance of financial infrastructure in maintaining economic resilience (Reinhart & Rogoff, 2009).

Government policies play a crucial role in promoting economic resilience. These include macroeconomic stabilization measures, fiscal and monetary policies, and social assistance programs that can cushion the impact of economic shocks on the population. According to a study by the World Bank (2020), strong governance and institutions can play a key role in strengthening economic resilience by promoting sound fiscal management, effective regulation, and fair competition in the private sector. Moreover, appropriate government policies and efficient regulation can support long-term economic development, contributing to the creation of a favorable environment for businesses and investments (Hallegatte et al., 2018).

For instance, Iceland's rapid response policy to the banking crisis in 2008 helped the country recover quickly (Jonung et. al. 2009).

Human capital, particularly education and workforce skills, significantly contributes to economic resilience. A well-educated and adaptable workforce can foster innovation and respond more effectively to economic changes. Investments in education and vocational training are essential for building resilient human capital (Hanushek & Woessmann, 2010). Furthermore, the health of the population plays a crucial role in economic resilience, as a healthy population is more capable of engaging in economic activities and coping with crises (World Bank, 2020).

Evaluating economic resilience involves measuring and analyzing the capacity of an economy to withstand and recover from disruptions. Similar to other forms of resilience, it is assessed using key indicators and specific evaluation methods. Key indicators include GDP growth rate, which measures overall economic performance and recovery capacity after shocks (Hallegatte, 2014), unemployment rate, which indicates labor market stability and the ability to maintain employment in the face of disruptions (Hallegatte, 2014), economic diversity, assessed through sectoral diversification indices (Hallegatte, 2014), and the health of the financial system, measured through banking stability, liquidity, and risk management capacity (Hallegatte, 2014). However, traditional indicators - such as GDP or unemployment - often fail to reflect subnational disparities or the capacity for long-term structural transformation. For example, if we take into consideration only the GDP of the Member States as indicator of territorial development we would see that this actually shows the increase in regional disparities as also shown by Aursulesei et al. (2020). In urban contexts, more granular indicators are increasingly used, such as SME survival rates, municipal fiscal buffers, or investment flows in innovation and green sectors. For instance, during the COVID-19 pandemic, cities like Tallinn (Estonia) and Cluj-Napoca (Romania) tracked real-time employment shifts and adjusted local economic strategies based on dynamic labor market data. Similarly, the Herfindahl-Hirschman Index (HHI) is employed in order to assess the sectoral concentration in city economies, allowing urban administrations to target diversification efforts more precisely.

The most used method of evaluating the economic resilience include time series analysis, which involves long-term monitoring of economic indicators to identify trends and fluctuations in the context of shocks; econometric models, which use statistical models to analyze relationships between economic variables and simulate the impact of disruptions; and comparative case studies, which compare the responses of different economies to similar disruptions to identify success factors and lessons learned. The evaluation of the economic resilience of European Union member states during the global financial crisis revealed significant differences in recovery capacity, highlighting the importance of fiscal policies and economic diversity (Alessi et al., 2020).

Strategies to enhance economic resilience require initiatives that diversify the economy, improve financial infrastructure, develop effective government policies, and invest in human

capital. Economic diversification reduces dependence on a single sector and distributes risks, promoting stability and recovery capacity. Diversification initiatives include the development of new industries and the promotion of innovation and entrepreneurship. For example, Dubai diversified its economy by developing the tourism and financial services sectors, reducing its dependence on oil (Mishrif & Kapetanovic, 2018).

Improving financial infrastructure involves developing a robust, regulated, and accessible banking system capable of providing financing and liquidity during crises. Measures such as strict regulations, banking supervision, and deposit insurance programs contribute to financial stability (Chronopoulos et al., 2023). Effective government policies include fiscal and monetary incentives, support programs for businesses, and social assistance for the population. For instance, the economic stimulus package adopted by the United States during the COVID-19 crisis included measures to support businesses and the population, helping stabilize the economy (CBO, 2020).

Investments in education and vocational training are essential for developing an adaptable and innovative workforce. Continuous training and retraining programs help the workforce respond more effectively to economic and technological changes (OECD, 2012).

In conclusion, the factors influencing economic resilience include sectoral diversity, financial infrastructure, government policies, and human capital. Evaluating economic resilience involves assessing key indicators and employing methods such as time series analysis, econometric models, and case studies. To enhance resilience, strategies should focus on economic diversification, strengthening financial infrastructure, implementing effective government policies, and investing in human capital.

Conclusions

The analysis of the various factors that contribute to economic resilience underscores the complex interplay between sectoral diversity, financial stability, government policies, and human capital in shaping the capacity of economies to withstand and recover from crises. One of the most critical findings from this research is the significant role that **sectoral diversification** plays in enhancing resilience. Economies that rely on a wide range of industries and sectors are generally better equipped to absorb the impact of economic disruptions. When one sector experiences a downturn, others may continue to perform well, thereby cushioning the overall economy from the full force of the shock. This diversification acts as a safeguard, ensuring that the economy can maintain its structural integrity even when specific industries face challenges. The importance of sectoral diversity cannot be overstated, as it provides the foundation for sustainable growth and stability in the face of economic volatility.

Equally crucial is the presence of a **robust financial infrastructure**. A strong, well-regulated financial system forms the backbone of any resilient economy. It is the key mechanism through which economies can access capital, manage liquidity, and ensure the

smooth functioning of financial markets during times of crisis. The capacity of financial institutions to withstand shocks, combined with effective regulatory oversight, is essential for mitigating systemic risks. In periods of economic distress, the ability to maintain the flow of credit and investments allows businesses to survive and recover, while also enabling governments to implement stimulus measures. The financial sector, therefore, plays an indispensable role in sustaining economic resilience, particularly during times of financial or economic shocks.

Government policies are another cornerstone of resilience. The capacity of governments to enact **effective fiscal and monetary policies** during crises determines how quickly and efficiently economies can recover. However, the mere existence of policy frameworks is insufficient unless supported by institutional agility and effective coordination mechanisms. A resilient economy depends not only on state intervention but also on the ability to involve regional and local actors in decision-making, especially in complex urban environments where vulnerabilities are unevenly distributed. In some contexts, mismatches between central policy design and local implementation have revealed the need for a more bottom-up, participatory approach in building resilience. Well-designed policies, such as fiscal stimulus packages, social safety nets, and targeted support for industries in distress, can provide much-needed relief during difficult times. Additionally, governments that have well-established crisis management frameworks and institutions are better positioned to address the challenges posed by crises. Good governance, coupled with sound economic policies, fosters an environment where the economy can quickly adapt to disruptions, thereby accelerating recovery. It is the agility of policy responses that often makes the difference between a prolonged economic downturn and a rapid recovery.

Moreover, the significance of **human capital** in building resilience cannot be overlooked. A workforce that is well-educated, skilled, and adaptable is a fundamental asset in navigating through economic disruptions. Education and training equip individuals with the necessary tools to innovate, adapt to new technologies, and pivot in response to changing economic conditions. Human capital investments help to foster a culture of resilience, as a well-prepared and skilled workforce is more likely to find solutions to emerging problems, driving recovery in the process. A healthy population is equally important, as public health plays a key role in maintaining productivity and stability during times of crisis. Therefore, investments in education, healthcare, and workforce development are integral to strengthening the resilience of any economy.

The evaluation of **economic resilience** is also vital for understanding how effectively economies cope with and recover from crises. The use of indicators such as GDP growth rates, unemployment levels, and sectoral performance can provide valuable insights into the health and resilience of an economy. But these traditional indicators must be interpreted alongside more dynamic metrics reflecting structural transformation, policy responsiveness, and institutional depth. While assessment tools provide valuable guidance, they must also be

sensitive to territorial disparities and sectoral vulnerabilities that shape resilience trajectories differently across regions. Advanced evaluation techniques, such as time series analysis and econometric modeling, offer a comprehensive way to assess the impact of various shocks and identify areas where resilience needs to be strengthened. By employing these evaluation methods, policymakers and economists can better understand the dynamics of economic recovery and tailor their strategies accordingly.

Finally, **strategies for enhancing resilience** must be multifaceted and adaptable to changing circumstances. Economies can improve their resilience by focusing on long-term investments in diversification, financial stability, governance, and human capital. The process of building resilience requires a proactive approach, where the potential risks are anticipated and mitigated before they manifest. Diversification of sectors, for instance, can buffer economies from sector-specific risks, while a strong financial infrastructure ensures that the economy can withstand financial shocks. Furthermore, robust governance frameworks and effective public policies enable a timely and coordinated response to crises, while investments in human capital ensure that the workforce is adaptable and ready to face new challenges.

In conclusion, economic resilience is not the result of any single factor but rather the outcome of a series of interconnected elements. A holistic approach that combines diversification, financial strength, government intervention, and human capital development is essential for ensuring long-term stability and recovery. By fostering a diversified economy, strengthening financial systems, enacting responsive government policies, and investing in education and workforce development, economies can better withstand shocks and recover more swiftly. Through continuous evaluation and adaptation of resilience strategies, economies can not only respond effectively to future crises but also emerge stronger and more stable in the long run.

This article has highlighted the need for a more integrated and context-aware perspective, especially relevant for regions with fragile institutional legacies and high exposure to external shocks. Only through such an approach can resilience become more than a theoretical ambition and evolve into a practical tool for sustainable territorial development.

References

Adger, W. N. (2000). Social and ecological resilience: are they related?. *Progress in human geography*, *24*(3), 347-364. https://doi.org/10.1191/030913200701540465

Aldrich, D. P., & Meyer, M. A. (2015). Social Capital and Community Resilience. *American Behavioral Scientist*, *59*(2), 254-269. https://doi.org/10.1177/0002764214550299

Alessi, L., Benczur, P., Campolongo, F., Cariboni, J., Manca, A. R., Menyhert, B., & Pagano, A. (2020). The Resilience of EU Member States to the Financial and Economic Crisis. *Social Indicators Research*, *148*, 569-598. https://doi.org/10.1007/s11205-019-02200-1

Almazán-Casali, S., Puga, B. P., & Lemos, M. C. (2021). Who Governs at What Price? Technocratic Dominance, Ways of Knowing, and Long-Term Resilience of Brazil's Water System. *Front. Water*, *3*, 735018. https://doi.org/10.3389/frwa.2021.735018

Anguelovski, I., Shi, L., Chu, E., Gallagher, D., Goh, K., Lamb, Z., Reeve, K., & Teicher, H. (2016). Equity Impacts of Urban Land Use Planning for Climate Adaptation: Critical Perspectives from the Global North and South. *Journal of Planning Education and Research, 36*(3), 333–348. https://doi.org/10.1177/0739456X16645166

Atilla, N., Fleeger, J. W., & Finelli, C. M. (2005). Effects of habitat complexity and hydrodynamics on the abundance and diversity of small invertebrates colonizing artificial substrates. *Journal of Marine Research, 63* (6), 1151–1172. https://elischolar.library.yale.edu/journal_of_marine_research/117

Aursulesei, T. M., Topliceanu, Ș. C., & Maha, L.-G. (2020). The relationship between the European Union's economic power status and the economic convergence of the Member States. *Eastern European Journal of Regional Studies*. *6*(1), 24-43. https://csei.ase.md/journal/files/issue_61/EEJRS_61_24-43_AUR.pdf

Babcicky, P., & Seebauer., S. (2016). The two faces of social capital in private flood mitigation: Opposing effects on risk perception, self-efficacy and coping capacity. *Journal of Risk Research, 20*, 1017–1037. https://doi.org/10.1080/13669877.2016.1147489

Bănică, A., Muntele, I., & Popescu, C. (2020). Towards green resilient cities in eastern European Union countries. *Sustainable Cities and Society, 52*, 101840. https://doi.org/10.37043/JURA.2020.12.1.4

Beilin, R., & Wilkinson, C. (2015). Introduction: Governing for urban resilience. *Urban Studies*. *52*(7), 1205-1217. https://doi.org/10.1177/0042098015574955

Berkes, F., & Ross, H. (2012). Community resilience: Toward an integrated approach. *Society & Natural Resources, 26*(1), 5–20, https://doi.org/10.1080/08941920.2012.736605

Boettiger, C., Ross, N., & Hastings, A. (2013). Early warning signals: the charted and uncharted territories. *Theoretical Ecology*, *6*, 255-264. https://doi.org/10.1007/s12080-013-0192-6

Boin, A., & Hart, P. (2003). Public Leadership in Times of Crisis: Mission Impossible?. *Public Administration Review*, *63*(5), 544-553. https://www.jstor.org/stable/3110097

Bolzan, N., & Gale, F. (2018). Social resilience: Transformation in two Australian communities facing chronic adversity. *International Social Work, 61*(6), 843-856. https://doi.org/10.1177/0020872816673888

Bristow, G., & Healy, A. (2014). Regional resilience: An agency perspective. *Regional Studies, 48*(5), 923–935. https://doi.org/10.1080/00343404.2013.854879

Brooks, N., Adger, W. N., & Kelly, P. M. (2005). The determinants of vulnerabilirt and adaptive capacity at the national level and the implications for adaptation. *Global Environmental Change*, *15*(2), 151-163. https://doi.org/10.1016/j.gloenvcha.2004.12.006

Brookes, J. D., Aldridge, K., Wallace, T., Linden, L., & Ganf, G. G. (2005). Multiple interception pathways for resource utilisation and increased ecosystem resilience. *Hydrobiologia*, *552*, 135–146. https://doi.org/10.1007/s10750-005-1511-8

Bunch, M. J., Morrison, K. E., Parkes, M. W., & Venema, H. D. (2011). Promoting Health and Well-Being by Managing for Social-Ecological Resilience: the Potential of Integrating Ecohealth and Water Resources Management Approaches. *Ecological and Society*, *16*(1), 6. https://doi.org/10.5751/ES-03803-160106

Carmen, E., Fazey, I., Ross, H., Bedinger, M., Smith, F. M., Prager, K., McClymont, K., & Morrison, D. (2022). Building community resilience in a context of climate change: The role of social capital. *Ambio, 51*, 1371–1387. (2022). https://doi.org/10.1007/s13280-021-01678-9

Carpenter, S., & Brock, W. (2008). Adaptive capacity and traps. *Ecology and Society*. *13*(2), 40-56. https://www.jstor.org/stable/26267995

Cattell, V. (2001). Poor people, poor places, and poor health: the mediating role of social networks and social capital. *Social Science & Medicine*, *52*(10), 1501-1516. https://doi.org/10.1016/S0277-9536(00)00259-8

CBO. (2020). *Key Methods That CBO Used to Estimate the Effects of Pandemic-Related Legislation on Output*. Congressional Budget Office. https://www.cbo.gov/system/files/2020-10/56612-Key-Methods.pdf

Chang, P.-J., & Yarnal, C. (2018). The effect of social support on resilience growth among women in the Red Hat Society. *Journal of Positive Psychology*, *13*(1), 92-99. https://doi.org/10.1080/17439760.2017.1374442

Chronopoulos, D. K., Wilson, J. O. S., & Yilmaz, M. (2023). Regulatory oversight and bank risk. *Journal of Financial Stability*, *64*, 101105, https://doi.org/10.1016/j.jfs.2023.101105

Claessens, S., & Kose, M. A. (2017). Macroeconomic implications of financial imperfections: A survey. *BIS Working Paper*, *677*, 1-124. https://papers.ssrn.com/sol3/Delivery.cfm/SSRN_ID3076410_code1109023.pdf?abstractid=3076410&mirid=1

Claessens, S., Coleman, N., & Donnelly, M. (2018). "Low-For-Long" interest rates and banks' interest margins and profitability: Cross-country evidence. J*ournal of Financial Intermediation*, *35*(A), 1-16. https://doi.org/10.1016/j.jfi.2017.05.004

Cleaver, F. (2005). The inequality of social capital and the reproduction of chronic poverty. *World Development*, *33*(6), 893-906. https://doi.org/10.1016/j.worlddev.2004.09.015

Cohen, O., Goldberg, A., Lahad, M., & Aharonson-Daniel, L. (2017). Building resilience: The relationship between information provided by municipal authorities during emergency situations and community resilience. *Technological Forecasting and Social Change*, *121*, 119-125. https://doi.org/10.1016/j.techfore.2016.11.008

Cornwall, A. (2007). Buzzwords and fuzzwords: deconstructing development discourse. *Development in Practice*, *17*(4-5), 471-484. https://oxfamilibrary.openrepository.com/bitstream/handle/10546/118173/bk-deconstructing-development-buzzwords-010910-en.pdf

Coleman, J. (1988). Social capital and the creation of human capital. *American Journal of Sociology*, *94*(1), 95–120. https://www.journals.uchicago.edu/doi/10.1086/228943

Commito, J. A., & Rusignuolo, B. R. (2000). Structural complexity in mussel beds: the fractal geometry of surface topography. *Journal of Experimental Marine Biology and Ecology*, *255*(2), 133-152. https://doi.org/10.1016/S0022-0981(00)00285-9

Cretney, R. (2014). Resilience for whom? Emerging critical geographies of socio-ecological resilience. *Progress in Human Geography*, *38*(5), 630–647. https://doi.org/10.1177/0309132513504325

Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003). Social vulnerability to environmental hazards. *Social Science Quarterly*, *84*(2), 242–261. https://doi.org/10.1111/1540-6237.8402002

Dakos, V., & Kéfi, S. (2022). Ecological resilience: what to measure and how. *Environmental Research Letters*, *17*(4), 1-22. https://iopscience.iop.org/article/10.1088/1748-9326/ac5767

Dias, R. (2023). *Ecological resilience in a changing world: Challenges and opportunities in*

biodiversity conservation in the face of climate change. Seven Editora Publishing House. https://doi.org/10.56238/alookdevelopv1-176

Distelberg, B., & Taylor, S. (2015). The roles of social support and family resilience in accesing healthcare and employment resources among families living in traditional public housing communities. *Child & Family Social Work*, *20*(4), 494-506. https://doi.org/10.1111/cfs.12098

ECB. (2016). *Financial Stability Review, Review of November 2016*. European Central Bank. https://www.ecb.europa.eu/pub/pdf/fsr/financialstabilityreview201611.en.pdf

Fath, B. D., Cabezas, H., & Pawlowski, C. W. (2003). Regime changes in ecological systems: an information theory approach. *Journal of Theoretical Biology*, *222*(4), 517–530. https://doi.org/10.1016/S0022- 5193(03)00067-5

Fischer, J., Lindenmayer, D. B., & Manning, A. D. (2006). Biodiversity, ecosystem function,and resilience: ten guiding principles for commodity production landscapes *Frontiers in Ecology and the Environment*, *4*(2), 80-86. https://doi.org/10.1890/1540-9295(2006)004[0080:BEFART]2.0.CO;2

Flora, J. L., Sharp, J., Flora, C., & Newlon, B. (2016). Entrepreneurial Social Infrastructure and Locally Initiated Economic Development in the Nonmetropolitan United States. *The Sociological Quaterly*, *38*(4), 623-645. https://doi.org/10.1111/j.1533-8525.1997.tb00757.x

Folke, C., Carpenter, S., Walker, B., Scheffer, M., Elmqvist, T., Gunderson, L., & Holling, C. S. (2004). Regime shifts, resilience and biodiversity in ecosystem management *Annual Review of Ecology, Evolution and Systems*, *35*, 557–81. https://doi.org/10.1146/annurev.ecolsys.35.021103.105711

Giacometti, A., Teräs, J., Perjo, L. Wøien, M., Sigurjonsdottir, H., & Rinne, T. (2018). *Regional Economic and Social Resilience: Conceptual Debate and Implications for Nordic Regions. Discussion paper prepared for Nordic thematic group for innovative and resilient regions*. Nordregio. https://www.nordregio.org/wp-content/uploads/2018/02/Regional-Economic-and-Social-Resilience-Conceptual-Debate-and-Implications-for-Nordic-Regions-1.pdf

Gómez-Baggethun, E., & Barton, D. N. (2013). Classifying and valuing ecosystem services for urban planning. *Ecological Economics*, *86*, 235-245. https://doi.org/10.1016/j.ecolecon.2012.08.019

Guillotreau, P., Allison, E. H., Bundy, A., Cooley, S. R., Defeo, O., Le Bihan, V., Pardo, S., Ian Perry, R., Santopietro, G., & Seki, T. (2017). A comparative appraisal of the resilience of marine social-ecological systems to mass mortalities of bivalves. *Ecology and Society*, *22*(1). https://doi.org/10.5751/ES-09084-220146

Hallegatte, S. (2014). Economic Resilience: Definition and Measurement. *Policy Research Working Paper*, *6852*, 1-44. https://documents1.worldbank.org/curated/en/350411468149663792/pdf/WPS6852.pdf

Hallegatte, S., Fay, M., & Barbier, E. (2018). Poverty and climate change: Introduction. *Environment and Development Economics*, *23*(3), 217-233. https://doi.org/10.1017/S1355770X18000141

Hanushek, E. A., & Woessmann, L. (2010). The Economics of International Differences in Educational Achievement. *Handbook of the Economics of Education, 3*, 89-200. https://doi.org/10.1016/B978-0-444-53429-3.00002-8

Holling, C. S. (1973). Resilience and Stability of Ecological Systems. *Annual Review of Ecology*

and Systematics, *4*, 1-23. www.jstor.org/stable/2096802

Hooper, D. U., Chapin III, F. S., Ewel, J. J., Hector, A., Inchausti, P., Lavorel, S., Lawton, J.H., Lodge, D. M., Loreau, M., Naeem, S., Schmid, B., Setälä, H., Symstad, A.J., Vandermeer,J., & Wardle, D. A. (2005). Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. *Ecological Monographs*, *75*(1), 3-35. https://doi.org/10.1890/04-0922

Hughes, T. P., Baird, A. H., Bellwood, D. R., Card, M., Connolly, S. R., Folke, C., & Roughgarden, J. (2003). Climate Change, Human Impacts, and the Resilience of Coral Reefs. *Science*, *301*(5635), 929-933. https://doi.org/10.1126/science.1085046

Hussen saad, M., Hagelaar, G., van der Velde, G., & Omta, S. W. F. (2021). Conceptualization of SMEs' business resilience: A systematic literature review. *Cogent Business & Management*, *8*(1). https://doi.org/10.1080/23311975.2021.1938347

IPCC (2023). Climate change 2021 – The Physical Science Basis. *Cambridge University Press*. https://doi.org/10.1017/9781009157896

Javadpoor, M., Sharifi, A., & Roosta., M. (2021). An adaptation of the Baseline Resilience Indicators for Communities (BRIC) for assessing resilience of Iranian provinces. *International Journal of Disaster Risk Reduction*, 66, 102609, https://doi.org/10.1016/j.ijdrr.2021.102609

Jonung, L., Jaakko, K., & Pentti, V. (2009). *The great financial crisis in Finland and Sweden The nordic experience of financial liberalization*. Edward Elgar Publishing. https://lup.lub.lu.se/search/files/69614742/JONUNG_EBOOK.pdf

Kapucu, N. (2006). Interagency Communication Networks during Emergencies: Boundary Spanners in Multiagency Coordination. *American Review of Public Administration*, *36*, 207-225. https://doi.org/10.1177/0275074005280605

Karunarathne, A. Y., & Lee, G. (2019). Traditional social capital and socioeconomic networks in response to flood disaster: A case study of rural areas in Sri Lanka. *International Journal of Disaster Risk Reduction*, *41*, https://doi.org/10.1016/j.ijdrr.2019.101279

Kawachi, I., & Berkman, L. F. (2000). Social Cohesion, Social Capital, and Health. *Social Epidemiology*. 174-190. https://faculty.washington.edu/matsueda/courses/590/Readings/Kawachi%20and%20Berkman.pdf

Kéfi, S., Guttal, V., Brock, W. A., Carpenter, S. R., Ellison, A. M., Livina, V. N., Seekell, D. A, Scheffer, M., van Nes, E. H., & Dakos. V. (2014). Early warning signals of ecological transitions: methods for spatial patterns, *PLoS One*, *9*(3), e92097, 1-13. https://doi.org/10.1371/journal.pone.0092097

Kong, L., Fang, M., Ma, T., Li, G., Yang, F., Meng, Q., Li, Y., & Li, P. (2018). Positive affect mediates the relationships between resilience, social support and posttraumatic growth of women with infertility. *Psychology Health & Medicine*, *23*(6), 707-716. https://doi.org/10.1080/13548506.2018.1447679

Kovalenko, K. E., Thomaz, S. M., & Warfe, D. M. (2012). Habitat complexity: approaches and future directions. *Hydrobiologia*, *685*, 1–17. https://doi.org/10.1007/s10750-011-0974-z

Krlev, G. (2023). Let's Join Forces: Institutional Resilience and Multistakeholder Partnerships in Crises. *Journal of Business Ethics*, *186*, 571-592. https://doi.org/10.1007/s10551-022-05231-w

Lange, S., Banning, M., Berner, A., Kern, F., Lutz, C., Peuckert, J., Santarius, T., & Silbersdorff, A. (2019). *Economy-Wide Rebound Effects: State of the art, a new taxonomy, policy and*

research gaps. Arbeitsbericht 1 des Forschungsprojekts ReCap. https://www.ioew.de/fileadmin/user_upload/BILDER_und_Downloaddateien/Publikationen/2019/ReCap_discussion_paper_1.pdf

Liebenberg, L., & Moore, J. (2018). A Social Ecological Measure of Resilience for Adults: The RRC-ARM. *Social Indicators Research*, *136*(1), 1-19. https://doi.org/10.1007/s11205-016-1523-y

Luthe, T., & Wyss., R. (2015). Introducing adaptive waves as a concept to inform mental models of resilience. *Sustainability Science*, *10*, 673–685. https://doi.org/10.1007/s11625-015-0316-6

Madsen, J. D., Chambers, P. A., James, W. F., Koch, E. W., & Westlake, D. F. (2001). The interaction between water movement, sediment dynamics and submersed macrophytes. *Hydrobiologia*, *444*, 71-84. https://doi.org/10.1023/A:1017520800568

Markolf, S. A., Chester, M. V., Eisenberg, D. A., Iwaniec, D. M., Davidson, C. I., Zimmerman, R., Miller, T. R., Ruddell, B. J., & Chang, H. (2018). Interdependent Infrastructure as Linked Social, Ecologican and Technological Systems (SETSs) to Address Lock-in and Enhance Resilience. *Earth's Future*, *6*(12), 1638-1659. https://doi.org/10.1029/2018EF000926

Marshall, N. A., & Smaigl, A. (2013). Understanding Variability in Adaptive Capacity on Rangelands. Rangeland. *Ecology & Management*, *66*(1), 88-94. https://doi.org/10.2111/REM-D-11-00176.1

Martin, R. (2012). Regional Economic Resilience, Hysteresis and Recessionary Shocks. *Journal of Economic Geography*, *12*(1), 1-32. https://doi.org/10.1093/jeg/lbr019

Martin, R., Sunley, P., Gardiner, B., & Tyler, P. (2016). How Regions React to Recessions: Resilience and the Role of Economic Structure. *Regional Studies*, *50*(4), 561–585. https://doi.org/10.1080/00343404.2015.1136410

Matias, M. G., Underwood, A. J., Hochuli, D. F., & Coleman, R. A. (2010). Independent effects of patch size and structural complexity on diversity of benthic macroinvertebrates. *Ecology*, *91*(7), 1908-1915. https://doi.org/10.1890/09-1083.1

Mayer, A., Pawlowski, C., & Cabezas, H. (2006). Fisher information and dynamic regime changes in ecological systems, *Ecological Modelling*, *195*(1-2), 72-82. https://doi.org/10.1016/j.ecolmodel.2005.11.011

McEntire, D. A. (2011). Designing Resilience: Preparing for Extreme Events. *International Journal of Disaster Resilience in the Built Environment*, 2(2), 178-180. https://doi.org/10.1108/ijdrbe.2011.2.2.178.1

MacKinnon, D., & Derickson, K. D. (2013). From resilience to resourcefulness: A critique of resilience policy and activism. *Progress in Human Geography*, *37*(2), 253–270. https://doi.org/10.1177/0309132512454775

Meerow, S., Newell, J. P., & Stults, M. (2016). Defining urban resilience: A review. *Landscape and Urban Planning*, *147*, 38–49. https://doi.org/10.1016/j.landurbplan.2015.11.011

Mishrif, A., & Kapetanovic, H. (2018). Dubai's Model of Economic Diversification. In A. Mishrif, & Y. Al Balushi (Eds), *Economic Diversification in the Gulf Region,* (Vol. 2, pp. 89-111). *The Political Economy of the Middle East*. Palgrave Macmillan. https://doi.org/10.1007/978-981-10-5786-1_5

Moberg, F., & Galaz, V. (2005). Resilience: going from conventional to adaptive freshwater management for human and ecosystem compatibility. *Swedish Water House Policy Brief, 3*(12). https://www.ircwash.org/sites/default/files/Moberg-2005-Resilience.pdf

Moser, C. O. N. (1998). The Asset Vulnerability Framework: Reassessing Urban Poverty Reduction

Strategies. *World Development*, *26*(1), 1-19. https://doi.org/10.1016/S0305-750X(97)10015-8

Moşteanu, N. R. (2024). Adapting to the Unpredictable: Building Resilience for Business Continuity in an Ever-Changing Landscape. *European Journal of Theoretical and Applied Sciences*, *2*(1), 444-457. https://doi.org/10.59324/ejtas.2024.2(1).37

Muntele, I., & Horea-Șerban, R. I. (2021). From Internal to International Migration in Romania – Continuity and Spatial Differntiation. *Eastern European Journal of Regional Studies*, *7*(1), 5-26. https://doi.org/10.53486/2537-6179.7-2.01

OECD. (2012). *Local Job Creation: How Employment and Training Agencies Can Help - The Labour Agency of the Autonomous Province of Trento, Italy*. Local Economic and Employment Development (LEED). https://www.oecd.org/content/dam/oecd/en/publications/reports/2012/10/local-job-creation-how-employment-and-training-agencies-can-help-the-labour-agency-of-the-autonomous-province-of-trento-italy_g17a21c1/5k919d0trlf6-en.pdf

Oh, S., & Jun, J. (2018). Structural relationships beween career barriers, social support levels, ego-resilience, job search efficacy, and career preparation behaviour of middle-aged unemployed me. *KEDI Journal of Educational Policy*, *15*(1), 21–42. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiIq-e_8caMAxVh-QIHHfVfK1IQFnoECBwQAQ&url=https%3A%2F%2Fwww.kedi.re.kr%2Feng%2Fkedi%2Fcmmn%2Ffile%2FfileDown.do%3FmenuNo%3D200067%26atchFileId%3DFILE_000000000003424%26fileSn%3D1%26bbsId%3D&usg=AOvVaw0YhCV2ijn9C8L5zjEoXevX&opi=89978449

O'Leary, J. L., Micheli, F., Airoldi, L., Boch, C., De Leo, G., Elahi, R., Ferretti, F., Graham, N. A. J., Litvin, S. Y., Low, N. H., Lummis, S., S., Nickols, K. J., & Wong, J. (2017). The Resilience of Marine Ecosystems to Climatic Disturbances. *BioScience*, *67*(3), 208-220. https://doi.org/10.1093/biosci/biw161

Omar, A. P. (2011). Un modelo explicativo de resiliencia en jóvenes y adolescentes. *Psicologia em Estudo*, *16*(2), 269-277. https://www.redalyc.org/articulo.oa?id=287122138010

Onyedibe, M. C., Ugwu, L. I., Philip, C. M., & Onuiri, C. (2018). Parents of children with Down Syndrome: Do resilience and social support matter to their experience of carer stress?. *Journal of Psychology in Africa*, *28*(2), 94-99. https://doi.org/10.1080/14330237.2018.1455308

Özkan, G. (2011). Impact of the global crisis on the governance structures of international financial institutions. *Emerging Markets Journal*, *1*, 1-12. https://doi.org/10.5195/emaj.2011.8

Pandey, A., Prakash, A., & Werners, S. E. (2021). Matches, mismatches and priorities of pathways from a climate-resilient development perspective in the mountains of Nepal. *Environmental Science & Policy*, *125*, 135-145. https://doi.org/10.1016/j.envsci.2021.08.013

Patel, R. B., & Gleason, K. M. (2018). The association between social cohesion and community resilience in two urban slums of Port au Prince, Haiti. *International Journal of Disaster Risk Reduction*, *27*, 161-167. https://doi.org/10.1016/j.ijdrr.2017.10.003

Poljak Istenič, S., & Kozina, J. (2019). Participatory planning in a post-socialist urban context: Experience from five cities in Central and Eastern Europe. In J. Nared & D. Bole (Eds.), *Participatory research and planning in practice* (pp. 31–50). Springer. https://doi.org/10.1007/978-3-030-28014-7_3

Pfefferbaum, B., Van Horn, R. L., & Pfefferbaum, R.L. (2017). A Conceptual Framework to Enhance Community Resilience Using Social Capital. *Clinical Social Work Journal*, *45*, 102-110, https://doi.org/10.1007/s10615-015-0556-z

Putnam, R. D. (2000). *Bowling Alone: The Collapse and Revival of American Community*. Simon

and Schuster Publishing House. https://doi.org/10.1145/358916.361990

Reinhart, C. M., & Rogoff, K. S. (2009). *This Time is Different: Eight Centuries of Financial Folly*. Princeton University Press. https://doi.org/10.2307/j.ctvcm4gqx

Revi, A., Satterthwaite, D., Aragón-Durand, F., Corfee-Morlot, J., Kiunsi, R. B. R., Pelling, M., Roberts, D. C., & Soleki, W. (2014). *Urban Areas in Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. https://www.researchgate.net/publication/275035197_Urban_Areas_in_Climate_Change_2014_Impacts_Adaptation_and_Vulnerability_Part_A_Global_and_Sectoral_Aspects_Contribution_of_Working_Group_II_to_the_Fifth_Assessment_Report_of_the_Intergovernmental_Pane

Rodriguez, H., Quarantelli, E. L., & Dynes, R. R. (2007). *Handbook of Disaster Research*. Springer Cham. https://doi.org/10.1007/978-3-319-63254-4

Rydin Y., Bleahu, A., Davies, M., Dávila, J. D., Friel, S., De Grandis, G., Groce, N., Hallal, P. C., Hamilton. I., Howden-Chapman. P., Lai. K. M., Lim, C. J., Martins, J., Osrin, D., Ridley, I., Scott, I., Taylor, M., Wilkinson, P., & Wilson, J. (2012). Shaping cities for health: complexity and the planning of urban environments in the 21st century. *Lancet*, *379*(9831), 2079-2108. https://doi.org/10.1016/S0140-6736(12)60435-8

Rustinsyah, R., Prasetyo R. A., & Adib, M. (2021). Social capital for flood disaster management: Case study of flooding in a village of Bengawan Solo Riverbank, Tuban, East Java Province, *International Journal of Disaster Risk Reduction*, *52*(1), 1-10. https://doi.org/10.1016/j.ijdrr.2020.101963

Sandu, A. (2024). The post-socialist cities from Central and Eastern Europe: Between spatial growth and demographic decline. *Urban Studies, 61*(5), 821–837. https://doi.org/10.1177/00420980231189261

Sandu, A., Bănică, A., & Muntele, I. (2021). Urban resilience: An instrument to decode the post-socialist socio-economic and spatial transformations of cities from Central and Eastern Europe. *Eastern Journal of European Studies, 12*(SI), 170–195. https://doi.org/10.47743/ejes-2021-SI08

Sekar, S., Lundin, K., Tucker, C., Figueiredo, J., Tordo, S., & Aguilaret, J. (2019). *Building resilience a green growth framework for mobilizing mining investment. Washington*. World Bank Publications. https://documents1.worldbank.org/curated/en/689241556650241927/pdf/Building-Resilience-A-Green-Growth-Framework-for-Mobilizing-Mining-Investment.pdf

Sinclair, K., Curtis, A., Mendham, E., & Mitchell, M. (2014). Can resilience thinking provide useful insights for those examining efforts to transform contemporary agriculture? *Agriculture and Human* Values, *31*, 371–384. https://doi.org/10.1007/s10460-014-9488-4

Slavova, I., & Simpson, R. (2023). *How to measure social cohesion*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH under the Qudra 2 – Resilience for refugees, IDPs, returnees and host communities in response to the protracted Syria and Iraq crises. https://www.international-alert.org/app/uploads/2023/11/ENG_Qudra2-Guidance-Note-5-Measuring-social-cohesion.pdf

Smith, P., Soussana, J.-F., Angers, D., Schipper, L., Chenu, C., Rasse, D. P., Batjes, N. H., van Egmond, F., McNeill, S., Kuhnert, M., Arias-Navarro, C., Olesen, J. E., Chirinda, N., Fornara, D., Wollenberg, E., Álvaro-Fuentes, J., Sanz-Cobena, A., & Klumpp, K. (2019). How to measure, report and verify soil carbon change to realize the potential for soil carbon sequestration for

atmospheric removal of greenhouse gases. *Global Change Biology, 26*(1), 219–241. https://doi.org/10.1111/gcb.14815

St. Pierre, J. I. & Kovalenko, K. E. (2014). Effect of habitat complexity attributes on species richness. *Ecosphere*, 5(2), 1-10. https://doi.org/10.1890/ES13-00323.1

Sundstrom, S., M., Eason, T., Nelson, R. J., Angeler, D., G., Barichievy, C., Garmestani, A. S., Graham, N. A. J., Granholm, D., Gunderson, L., Knutson, M., Nash, K. L., Spanbauer, T., Stow, C. A., & Allen, C.R. (2016). Detecting spatial regimes in ecosystems, *Ecology Letters, 20*(1), 19-32. https://doi.org/10.1111/ele.12709

Șerbu, R. (2016). Pear to Pear in Social Economy through Social Technologies, some Perspectives on this New Challenge in Eastern Europe. *Eastern European Journal of Regional Studies, 2*(2), 15-21. https://csei.ase.md/journal/files/issue_22/EEJRS_0202_SER.pdf

Tajuddin, N., & Dąbrowski, M. (2021). Enabling Socio-Ecological Resilience in the Global South: Insights from Chennai, India. *Sustainability*, *13*(19), 10522, 1-24. https://doi.org/10.3390/su131910522

Toto, R.., Grabkowska, M., Nientied, P., Smirnova, V., & Dragović, S. (2023). The Uncommonness of Urban Commons in Central and Eastern Europe. *International Journal of the Commons, 17*(1), 155–173. https://doi.org/10.5334/ijc.1189

Turner, B. L., II, Kasperson, R. E., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., Eckley, N., Kasperson, J. X., Luers, A., Martello, M. L., Polsky, C., Pulsipher, A., & Schiller, A. (2003) A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences*, *100* (14), 8074–8079. https://doi.org/10.1073/pnas.1231335100

UN Habitat (2020). *World Cities Report 2020 – The Value of Sustainable Urbanization*. https://unhabitat.org/sites/default/files/2020/10/wcr_2020_report.pdf

van der Wal, W., & George, A. A. (2018). Social support-oriented coping and resilience for self-harm protection among adolescents. *Journal of Psychology in Africa*, *28(*3), 237-241. https://doi.org/10.1080/14330237.2018.1475508

Vale, L. J. (2014). The politics of resilient cities: Whose resilience and whose city? *Building Research & Information, 42*(2), 191–201. https://doi.org/10.1080/09613218.2014.850602

Velasco, J. M., & Domínguez, M. G. (2022). Variables involved in the development of social resilience in sustainable economies. *Monograph: "New Communication Trends for the 21st Century", 12*(3). https://doi.org/10.37467/revvisual.v9.3791

Walker, B., Salt, D., & Reid, W. (2006). *Resilience Thinking: Sustaining Ecosystems and People in A Changing World.* Island Press. https://www.academia.edu/19455883/Resilience_thinking

World Bank. (2019). *Gulf Economic Update, December 2019: Economic Diversification for a Sustainable and Resilient GCC* (World Bank Publication No. 5). A World Bank Group Publication for the Gulf Cooperation Council Economies. https://documents.worldbank.org/curated/en/886531574883246643/pdf/Economic-Diversification-for-a-Sustainable-and-Resilient-GCC.pdf

World Bank (2020). *Human Capital Index 2020 Update: Human Capital in the Time of COVID-19.* World Bank. https://openknowledge.worldbank.org/bitstreams/8ca3928c-0e04-59bf-ba37-713442d6fab0/download

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STRENGTHENING RESILIENCE THROUGH ECONOMIC DIPLOMACY: NAVIGATING CHALLENGES IN THE ENERGY SECTOR

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Abstract: *One of the key means to foster resilience is by ensuring a secure energy sector. Shaped by the current geopolitical environment, the international energy system has been fronting significant multilayered challenges, that are exerting a growing influence on the energy security dynamics and economic stability. In this context, the energy transition that aims to build a more sustainable and cleaner future does not come without drawbacks, however it could also serve as a catalyst to strengthen the worldwide energy security and create new economic opportunities. In the last decades, governments have been focusing on economic diplomacy as a strategic instrument with an important role in fulfilling the national and international economic interests, strengthening at the same time resilience in the energy sector, enabling nations to navigate geopolitical uncertainties, to secure the energy supplies and to support sustainable energy transitions. Therefore, this paper aims to explore the means and the effects of economic diplomacy in enhancing energy security and sustainability, by focusing on the scientific literature and analysing the findings of the peer-reviewed articles on the matter. This study underscores that a proactive and dynamic approach in economic diplomacy is crucial for building resilient energy partnerships in this increasingly interconnected world.*

Keywords: *economic diplomacy, energy sector, resilience, energy security.*

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Introduction

Economic diplomacy covers a broader range of economic and commercial activities (Chatterjee, 2020) and in addition to the prominent activities concerning trade and investment activities, also plays an important role in fields such as finance, attracting technology and science or issues related to energy and global sustainability (Perez-Castejon, 2013). Bayne and Woolcock (2017) highlight that nowadays the activities have expanded and international trade relations also encompass intellectual property and investments, while the environmental policies interrelate with energy policy and economic management. Furthermore, lately, scientific studies that are focusing on the importance of energy interdependence in shaping the relationships between states have also begun to emerge (Gokce et al., 2024).

Governments have been focusing on economic diplomacy as a strategic instrument with an important role in fulfilling their national and international economic interests. A crucial component of economic diplomacy is energy diplomacy (Chaban & Knodt, 2015), a subset focused on strengthening resilience in the energy sector, enabling nations to navigate geopolitical uncertainties, securing energy supplies and promoting sustainable energy transitions, through international agreements and negotiations. Furthermore, the energy

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resources are appreciated as the main catalyst of the international economy and politics (Ozhurt Donduncu, 2024), global energy being considered one of the most important dimensions of the multilateral diplomacy (Griffiths, 2019). Energy diplomacy is primarily employed by both energy producing and energy consuming entities, that share a common goal of ensuring reliable access to supplies and resources, fostering cooperation between states and organizations operating in this sector (Ozhurt Donduncu, 2024), being at the same time a crucial factor in ensuring profitability in transnational energy agreements (Cardinale, 2019).

Based on the type of energy source involved, energy diplomacy can be categorized in the following key types, each with distinct geopolitical, economic and strategic implications and also their specific obstacles: coal diplomacy (Mar Rubio & Folchi, 2012), oil diplomacy (Boyuan et al., 2015, Liao, 2021), natural gas diplomacy (Prontera, 2017), nuclear energy diplomacy (Aalto et al., 2017), renewable energy diplomacy. Throughout history, distinct phases can be observed, where a particular energy source becomes dominant, driving the economic growth and influencing the industrial development, for example while the coal diplomacy has been historically important, it was followed by the oil diplomacy. Over time, the dominance of the existing energy carrier gradually declines, as a newer source proves to be more cost-effective, fulfilling the objectives concerning sustainability, leading in the end to the replacement of the older energy form.

Focusing on the transition from coal to oil, that dominated the 20th century, Mar Rubio and Folchi (2012) highlighted that the effectiveness of an energy system depends on a interplay of technical, economic, physical and also social factors, that include the energy density, conversion costs, transport, storage potential, financial risks, impact on health (Mar Rubio & Folchi, 2012). In his study on the Lausanne Conference, 1914-1928, rethinking the legacy of the 1923 Lausanne Treaty, Conlin (2024) is arguing that it overlooked the oil diplomacy and the author is highlighting the role of oil companies in influencing the events, suggesting the urge to appreciate these entities as active players, not just instruments of states.

Nowadays one of the biggest challenges that contemporary energy diplomacy is facing is represented by energy transition, that, according to Mar Rubio and Folchi (2012) can be defined as the step-by-step replacement of the energy sources or carrier, occurring when one energy source prevails, then gradually fades as a new one emerges and replaces it, process that can also be seen as a step toward modernization. The green economic diplomacy initiative, which emerged in the 1980s, is evolving and expanding, gaining prominence, while diplomatic efforts are aiming at promoting sustainable technologies in order to reduce the environmental impact. In some cases, such as Japan for example, governments historically have focused on protecting the environment, this being one of the key elements of the Japanese industrial policy (Okano-Heijmans, 2012). EU is also leveraging energy diplomacy as a key tool, that according to the European External Action Service is aiming at ensuring energy security (Ozhurt Donduncu, 2024).

As the energy demands of the emerging powers are constantly rising, the relationships between the primary energy consuming nations are a key concern for decision makers and also researchers (Chaban & Knodt, 2015). Furthermore, the relationship between producers and consumers is influenced by the current transition to a low carbon energy (Griffiths, 2019), the current century seeing a growing dominance of the cost-effective renewable technologies and a shift from carbon fuels, with the key uncertainty being the speed of this shift (Fattouh et al., 2018).

Nowadays, scholars concentrate on how governments use energy as an instrument in international affairs and economic development, or as a means to influence political decision, the connection between energy, security and foreign diplomacy being undeniable (Ozkurt Dorduncu, 2024).

Therefore, by focusing on the body of scientific literature on the subject of energy diplomacy, this paper aims to present the main challenges of the energy sector and explore the means of diplomacy in enhancing energy security and sustainability, underscoring that a proactive engagement is crucial for building resilient energy partnerships in this increasingly interconnected world.

Data and Methodology

The study is following a qualitative approach, namely a narrative literature review of the scientific papers. This research method has been chosen because literature reviews synthesize existing research, organizing and clarifying prior findings to establish a foundation for future scientific research (Massaro et al., 2016), enabling at the same time a comprehensive understanding of the current state of knowledge.

This paper is examining the findings of the peer-reviewed studies, from high quality journals, published in the 2015-2025 period. The 2014 situation in Ukraine disrupted a major gas supply route to the EU and undermined the EU's confidence in the Russian Federation as a reliable energy provider (Bocse, 2018) and then the situation has been amplified by the war between the Russian Federation and Ukraine, that started in 2022, war that has had a significant influence on the international energy sector. However, as the number of studies on the topic is limited, the analysed period has been extended until 2015, to cover a relevant number of scientific studies. Although the analysed period has been extended, it has been deliberately kept limited (to ten years), in order to maintain the rigor of the literature review methodology and at the same time a comprehensive and structured approach. The articles have been selected based on specific keywords such as energy, diplomacy, energy security, energy diplomacy etc. indexed by journal databases, namely Web of Science, Science Direct, Scopus, Springer Nature, Taylor and Francis published exclusively in peer-reviewed journals from different academic areas. The selection of the papers has been done considering the citation frequency, the prominence of the journal that published the article and the overall robustness of the research in the field. As it has been observed, most studies on the matter

follow a qualitative approach, while the number of studies that have employed quantitative studies remains limited (Li et al., 2025).

In this study I try to answer the following research question *"what is the role of diplomacy in addressing the current challenges of the energy sector?",* in an attempt to expose the foremost challenges of the energy sector and explore the means of diplomacy in enhancing energy security and sustainability.

Energy diplomacy has an interdisciplinary nature, as it combines elements of politics, economics, technology, environmental science and international relations to address global energy challenges. Therefore, studies on this topic have been published across various fields such as belonging to international relations, political science, environmental sciences, public administration, energy and fuels. The current paper has not been confined to a single field of study, encompassing studies from all fields that have addressed the topic of energy diplomacy.

Literature Review

According to Chatterjee (2020), a fundamental distinction between economic diplomacy and traditional diplomacy lies in their focus and objectives. While the traditional one mainly aims at fostering and sustaining relationships between states, economic diplomacy is more targeted and the agreements reached through economic diplomacy are expected to translate into concrete outcomes, such as industrial initiatives or other contributions to a nation's development, being deeply rooted in practical realities, shaped by a state's intellectual, industrial and scientific capabilities (Chatterjee, 2020). As a subset of economic diplomacy, there is not a universal definition of energy diplomacy, however scholars underline the connection between the national security and energy resources, demonstrating at the same time that cross-border energy infrastructure can play a role in reducing geopolitical tensions (Huda, 2024).

Nowadays, energy diplomacy has two distinct facets, whereas the traditional energy diplomacy focused on non-renewable resources, lacking alignment with the global efforts to accelerate the renewable energy deployment (Huda, 2024), which represents the modern dimension of energy diplomacy. Driven by the contemporary increasing environmental concerns, the international energy environment is facing a transition to a low carbon energy, from fossil fuels to renewable energy obtained from natural sources, evolution that is completely reshaping the geopolitical landscape and where the role of diplomacy in managing evolving energy relations is constantly growing (Griffiths, 2019).

Empirical studies focused on different regions or countries across the globe yield different findings, depending on the level of development, resources, actors involved etc. Chaban and Knodt (2015) address the topic of energy diplomacy in the context of the current landscape dominated by a constant competition between the power, resources of the prominent on the one hand and the emerging actors on the other hand. Furthermore, the uneven global distribution makes certain suppliers irreplaceable in the energy markets (Gokce et. al., 2024).

Analysing the dynamics of the European energy security policies, concerning natural gas and infrastructure, Prontera (2017) has identified a series of three state models likewise the *partner*, the *provider* and the *catalytic*, concluding that the last one is more appropriate in the current dynamics of energy politics, whereas the second one implies a state that is primarily an energy supplier. Historically, the European Union has depended on fossils, therefore has proactively sought to alternate energy sources in order to broaden its supply opportunities (Moghani & Maleki, 2024). Since the mid-2000s, the European Union's decision makers started applying instruments belonging to foreign policy in order to secure access to foreign energy supplies, actions that could be qualified as pertaining to energy diplomacy (Herranz-Surralles, 2015). In the more recent years, following the Russian invasion of the Ukrainian territory, the EU is actively updating its approach to external energy security, fast-tracking the initiatives concerning energy through energy diplomacy and also authors have noticed a reorientation towards key geopolitical areas, such as the eastern part of the Mediterranean Sea (Ozhurt Donduncu, 2024). Moghani and Maleki (2024) consider that the EU's susceptibility to disruptions in energy supply has heightened the importance of diversifying its energy sources. Moreover, in the case of the EU, many scholars highlight the importance of reaching a consensus among the EU member states (Chaban & Knodt, 2015; Dusciac & Robu, 2019; Ozhurt Donduncu, 2024) as a unified approach is crucial to ensuring the success of strategic objectives, that overall aim at enhancing energy security and strengthening the EU's geopolitical influence, as without coordinated participation these initiatives risk fragmentation and suboptimal functioning. A new approach to energy diplomacy would support the EU in advancing its goals, likewise enhancing market competition or safeguarding energy security (Cardinale, 2019).

Analysing the case of United Arab Emirates/UAE, an example of significant exporter of hydrocarbon with a well-defined strategy of using diplomacy as a key instrument, Griffiths (2019) emphasized that the bilateral energy diplomacy is crucial for securing energy supply, monetizing resources and promoting economic expansion. Most of the studies, suggest that energy diplomacy should play a role in the energy transition process, Huda (2024) underscoring that diplomacy will play a crucial role in meeting the 2050 aims. Using a linear regression model, Nassar (2024) exposed the discrepancies faced by the Gulf Cooperation Council countries in the green energy progress: while the UAE is advancing quickly and effectively, maintaining a strong alignment with its targets, Bahrain and Kuwait are taking more time to reach their desired objectives.

Considering the ongoing shifts in global energy markets, Downie (2019) considers that Australia should focus on the energy governance through The Group of Twenty (G20).

Analysing Asian energy diplomacy, Huda and Ali (2017) have focused on the implications of the major regional energy infrastructure project, Turkmenistan-Afghanistan-Pakistan-India/ TAPI pipeline, indicating that the attempts to address the obstacles in this case have been too simplistic. Authors advocate for a multi-stakeholder approach, that requires the

involvement of different external actors, stressing that the TAPI project is serving as a tool for peace-building (Huda & Ali, 2017).

The limited availability of domestic energy resources, apart from coal, is becoming an increasingly pressing challenge for China (Gueldry & Liang, 2016). The attention on the energy diplomacy of China, one of the largest energy consumers in the world, has also increased progressively in the last decades, as the country has been focusing on building its bilateral relations with the energy superpowers (Wu, 2015). China is facing a growing energy demand, importing substantial quantities of fuels such as oil, coal or natural gas, being at the same time an important actor on the energy market (Liang et al., 2023). Moreover, Chinese diplomatic efforts aim to enhance the country's reputation as a rising nuclear energy power (Sun et al., 2022). Undoubtedly, as Moghani and Maleki (2024) underscored, China requires a reliable energy supply to support its economic development, consequently Chinese decision makers are constantly making efforts to improve energy security (Mahmood et. al, 2022) and to diminish fossil fuels usage (Liang et al., 2023), energy diplomacy being a fundamental element of its energy security policy (Mahmood et al, 2022). However, Wang's (2020) study concluded that the Chinese energy diplomacy is not strategically focused, having a predominantly mercantile approach in response to the encountered challenges. To study the Chinese energy diplomacy, Li et al. (2025) used a fixed-effects model to analyse the bilateral relations with 43 states, for the 2000-2023 period. The results of the study emphasize the importance of the bilateral diplomacy, revealing that, in this case, it is more effective than the multilateral one.

In the energy sector, the Russian Federation is one of the key players, with an important asymmetrical advantage over energy resources (Ozhurt Donduncu, 2024) and a dominant position as an energy supplier in Europe (Chun, 2009). Furthermore, the Russian energy diplomacy involves a combination of factors that empower the country to leverage these vast resources as an influent tool in this field. Concerning the relation with the EU and East Asia, Wang (2020) appreciates that the foremost objective is maximizing business profits, Russia's approach being a genuinely mercantile one. In their study on the Russian nuclear energy diplomacy, the authors Aalto et. al. (2017) identified that the diplomatic efforts are being shaped by three key interests such as the energy sector and its related benefits, the economic development of Russia and the foreign policy objectives, especially in response to challenges in EU-Russian Federation energy relations. Dusciac and Robu (2019) consider that the Russian energy strategy is not limited to the commercial interests, in the last 25 years being an important and prevailing instrument in exercising political pressure against the former soviet countries. In Wang's (2020) opinion, regarding the energy cooperation, Russia deliberately maintained a low political profile, fostering a collaborative environment with the European states, a stronger influence on the former Soviet countries and a rising interest in East-Asian markets.

Results and discussions

Undoubtedly, a stable and secure energy sector is essential for ensuring resilience at national and global level, as energy security is one of the key pillars of national and international security.

Energy diplomacy, central component of economic diplomacy (Chaban & Knodt, 2015) is mainly focused on strengthening resilience in the energy sector, possessing the appropriate tools to achieve objectives such as securing energy supplies and promoting sustainable energy transitions and to navigate geopolitical uncertainties, through diplomatic instruments like international agreements and negotiations. Shaw et al. (2024) underscored the importance of understanding the connection between energy, sustainability and resilience.

Energy diplomacy represents a multifaceted phenomenon that incorporates various complex elements in its development, identified in different dimensions, parties involved or communication strategies (Chaban & Knodt, 2015).

In the contemporary global context, the primary challenges facing energy diplomacy stem from two major fronts: the transition process on the one hand and the geopolitical developments on the other hand.

Challenges arising from the transition process

Diplomacy is essential in addressing the challenges of the global energy transition. Concerning this process, Huda (2024) has observed the following issues and potential threats: the insufficiency of resources, that may lead to tension and competition among actors, cyber threats, social-economic disruptions determined by the decline in fossil fuel revenue and the intentional power outages. Kivimaa et. al. (2022) draw attention to the security implications that may occur in case of economic losses in the hydrocarbon producing actors, that can also lead to the weakening of these states, increasing the dependence on other states or increase internal tensions. In facing the consequences of the transition from fossil fuels to the renewable energy, Griffiths (2019) has highlighted the crucial role that the bilateral diplomacy holds, noted that, in his view, the relationship between its key actors, producers and consumers will also face challenges. Rudiany et al. (2022) argue that substate players enhance the energy policies that have been previously regulated at the national level, through a bilateral cooperation with other similar entities, they can contribute to building a more efficient approach regarding energy utilization, ensuring the alignment with broader regulatory frameworks, while fostering collaboration and innovation in this sector. Boyuan et al. (2015) highlighted that, in the case of promoting crude oil trade, the bilateral dimension of diplomacy is more effective and that trade cooperation could be enhanced by conducting more visits and adopting a proactive approach towards this kind of diplomacy. Griffiths (2019) also emphasised that if the number of actors is a limited one, it is more cost-effective and aligning interests is simpler, however the large-scale transition to a low carbon system will undoubtedly imply coordinating the interest of various stakeholders through the multilateral diplomatic

activities. Similar results have been disclosed in the study on the Chinese crude oil trade of Li et al. (2025), authors suggesting an increase in the foreign visits and a more proactive approach, actively engaging with other countries, considering that it is advisable to adhere to the principle of doing more and speaking less.

In the current rapidly evolving digital environment, Kivimaa et al. (2022) bring to attention potential security risks that should not be overlooked, meaning the ones related to technology, given the dependence between the new energy systems and digital devices. Also related to technology, Fattouh et. al (2018) draw attention to the endgame leader, the innovation that will prevail, as the transition process will yield different results among the regions. In this new paradigm, the oil companies and the exporting nations have to wisely choose their position and their next steps, while governments should adapt and update their diplomatic initiatives.

Challenges arising from geopolitical tensions

Diplomacy is also indispensable for navigating the challenges arising from the geopolitical tensions within the energy sector. The geopolitical events, such as the Ukrainian and the Syrian crises have intensified market-driven impact, making the arena for the Russian energy diplomacy even more complex and complicated (Proedrou, 2016).

Studies published before the invasion of Ukraine, suggested the need for a renewed approach to energy diplomacy (Cardinale, 2019), that would help the EU advance its strategic objectives, such as ensuring energy security. Nevertheless, the invasion compelled the EU to implement new initiatives aimed at building resilience, particularly in areas such as energy security and autonomy. Moghani and Maleki (2024) stated that in order to face the security challenges of the war conducted by the Russian Federation against Ukraine it is mandatory for the EU to build and maintain a sustainable energy supply, an opportunity being consolidating the energy diplomatic relations with Azerbaijan and Iran (Bocse, 2018). Following the invasion of Ukraine, the oil and gas prices became the highest in over ten years (Moghani & Maleki, 2024). Despite facing sanctions, a form of diplomatic pressure, the Russian Federation rapidly adapted, maintaining at the same time its influence on the global energy dynamics. However, regarding its foreign policy objectives in the Asia-Pacific region, Xu and Reisinger (2018) appreciate that the progress has been a modest one, that yielded only partial success and limited results. Even though the invasion and the activities in the energy sector damaged its image, Russian Federation remains a strong player on the international stage (Szulecki & Overland, 2023).

Energy relations are not always impacted by the geopolitical tensions among countries. An example in this case are the diplomatic issues between United Arab Emirates and Qatar, which unfolded between 2017-2021, when despite the blockade on Qatar, the gas flows to UAE remained largely uninterrupted (Gokce et al., 2024).

Nevertheless, the geopolitical factors also have a significant effect on the transition process, shaping new directions and diplomatic approaches in order to achieve sustainable development goals. For example, the war between Russian Federation and Ukraine has had an impact on the necessary resources for the development of the renewable energy technology, as

the prices of nickel, neon gas, palladium, have increased significantly (Huda, 2024) and it also increased the fossil fuels demand (Nassar, 2024).

Another factor that can significantly impact the energy sector and must not be overlooked is the corruption within the energy industry. Dusciac and Robu (2019) for example, mention a case in which oligarchs engaged in this practice by procuring gas at below-market prices and then reselling it to the Ukrainian authorities at a competitive rate, artificially creating benefits for the parties involved.

Considering the multidimensional energy diplomacy, Moghani and Maleki (2024) added that geopolitical factors, cooperation, international entities, together with the global organizations, political systems and national strategies have an impact on this type of diplomacy. Boyuan et al. (2015) highlighted the important role of diplomatic interactions in securing ensuring energy security. In their paper, the authors analysed the role of diplomacy by concentrating on the official visits, diplomatic relations and the level of diplomatic activities, suggesting that these interactions have a significant impact in encouraging collaboration between states and safeguarding energetic security (Boyuan et al. (2015). Focusing on diplomatic interactions and exploring whether energy relationships between countries influence their foreign policy choices, the findings of the study of Gokce et. al. (2024) provided significant evidence supporting the idea that energy interdependence fosters greater alignment in foreign policy between countries.

National-level challenges are distinct from those arising at the supranational level, partly due to the complex interaction between domestic priorities and overarching regional and international frameworks. In the particular case of the European energy diplomacy, challenged by the entity's supranational character and the multilayered characteristics of its international discourse, literature suggests that this model of diplomacy combines the inclusive stakeholder-driven and the state focused mechanisms, and in terms of its actors, there is also a mix between state and non-state ones (Chaban & Knodt, 2015). An issue observed at the European level is that the multiple players do not always operate in coordination, the transparent communication approach can lack coherence and the tensions between the EU institutions further entangle this framework (Chaban & Knodt, 2015). The lack of alignment among the member states has also been emphasized by Ozhurt Donduncu (2024), considering that this feature is weakening the European energy diplomacy, that has yet to fulfil its whole potential.

Soft power or hard power in energy diplomacy?

In pursuing their interests in the energy sector, studies highlight the deployment of both soft power and also hard power strategies, a dual approach that allows decision makers to shape global energy dynamics. EU exercises significant influence over the global energy markets, by leveraging its economic dimension (Stoddard, 2016), rather than through hard power. An example of soft power is the case of the Hanhikivi-1 nuclear power plant, where the Finnish companies with interests in the Russian Federation, had the motivation to invest, due to their existing business relationship (Aalto et al., 2017). However, energy diplomacy is not limited

to soft power and can also imply the use of hard power. A study on Turkey, an actor that is aiming at reducing the dependence on imported energy (Kilic et al., 2019) is revealing four different situations, from 2015 to 2022, in which Turkish decision makers have had a tendency to use coercion or aggressive tactics in the energy related diplomatic efforts, shaped by political ideas and domestic considerations (Ipek, 2025).

Introducing significant obstacles to diplomatic engagement in the energy sector, the current crises that have been taken place in the middle east region or east Europe, together with the energy transition process underscore the necessity for renewed strategies in this sector (Ipek, 2023). For example, Ozhurt Donduncu (2024) considers that the geopolitical consequences of external energy disagreements are the ones that undermine the effectiveness of energy diplomacy within the EU. The international scene is experiencing an energy supply shortage coupled with excessive demand, that is driving energy commodity prices to record highs, impacting inflation, economic development, the quality of daily life and at the same time the global efforts to reduce carbon emissions (Moghani & Maleki, 2024). As Gokce et al. (2024) demonstrated, the international energy trade, that is playing an important role for both parties, importers and exporters, can strongly impact the global politics, therefore a better understanding of the current energy dynamics and foreign policy stances is crucial in the decision-making process of the present geopolitical environment.

Conclusions

One of the means to foster resilience is by ensuring a stable and secure energy sector. However, the energy sector has permanently been dominated by transitions, from coal fuels to oil or nuclear, and nowadays to the renewable energy sources, as an alternative to the fossil fuels, in order to reduce the carbon emissions and combat climate change issues. These shifts have historically shaped the global economies, having an impact on the technological and industrial advancement, international relations, foreign trade or foreign direct investments.

In the last decades, the international energy system has been fronting significant multifaceted challenges that are exerting a growing influence in the energy security dynamics and economic stability. Now, energy diplomacy is primarily challenged by the transition process and the geopolitical tensions, dynamics that necessitate a reassessment of diplomatic priorities. For example, after Russian Federation invaded the Ukrainian territory, the EU took swift action to revise its energy security strategy, expediting energy related initiatives through energy diplomacy measures. However, geopolitical tensions between countries do not always affect energy relations (ex. UAE and Qatar case), which can continue due to mutual dependencies and strategic interest.

In the current global context, the geopolitical evolutions and the energy transition that aims to build a more sustainable and cleaner future do not come without drawbacks, however, this situation could also serve as a catalyst to strengthen the worldwide energy security and create new economic opportunities, consolidating global resilience. Undoubtedly, energy

diplomacy, through its key instruments, such as negotiation and strategic partnerships, and use of soft power or hard power, can foster cooperation among the state and non-state actors and play a role in managing the energy related interest, supporting the development of resilient energy markets, contributing not only to national energy security, but also to sustainable development and stability at the international level.

References

Aalto, P., Nyyssonen, H., Kojo, M., & Pal, P. (2017). Russian nuclear energy diplomacy in Finland and Hungary. *Eurasian Geography and Economics*, *58*(4), 386-417. https://doi.org/10.1080/15387216.2017.1396905.

Bayne, N., & Woolcock, S. (2017). The Future of Economic Diplomacy. In N. Bayne & S. Woolcock (Eds.), *The New Economic Diplomacy*: *Decision Making and negotiation in international economic relations* (4th ed.). Routledge.

Boyuan, L., Zhingyuan, R., & Pina, G. (2015). A Study on the Impact of Energy Diplomacy on China's Crude Oil Trade. *Energies*, *18*(4), art. 851. https://doi.org/10.3390/en18040851

Bocse, A. M. (2018). EU Energy Diplomacy: Searching for New Suppliers in Azerbaijan and Iran. *Geopolitics*, *24*(1), 145-173. https://doi.org/10.1080/14650045.2018.1477755.

Cardinale, R. (2019). The Profitability of Transnational Energy Infrastructure: A Comparative Analysis of the Greenstream and Galsi Gas Pipelines. *Energy Policy*, *131*, 347-357. https://doi.org/10.1016/j.enpol.2019.03.040.

Chaban, N., & Knodt, M. (2015). Energy Diplomacy in the Context of Multistakeholder Diplomacy: The EU and BICS, Nordic International Studies Association. *Cooperation and Conflict*, *50*(4), 457-474. https://doi.org/10.1177/0010836715573541.

Chatterjee, C. (2020). *Economic Diplomacy and Foreign Policy-making*. Macmillan.

Chun, H. C. (2009). Russia's energy diplomacy toward Europe and Northeast Asia: a comparative study. *Asia Europe Journal*, *7*(2), 327-434. https://doi.org/ 10.1007/s10308-008-0206-y

Conlin, J. (2024). Fouled by Oil? Oil Diplomacy and the Lausanne Conference, 1914-1928. *International History Review*, *47*(3), 448-466. https://doi.org/10.1080/07075332.2024.2393642.

Downie, C. (2019). Australian Energy Diplomacy. *Australian Journal of International Affairs*, *73*, 119-225. https://doi.org/10.1080/10357718.2018.1534941

Dusciac, D., & Robu, A. (2019). Economic Diplomacy in the Energy Sector in the EU's Eastern Vicinity, *Politicke Vedy*, *22*(2), 42-60. http://doi.org/10.24040/politickevedy.2019.22.2.42-60

Fattouh, B., Poudineh, R., & West, R. (2018). The Rise of Renewables and Energy Transition: What Adaptation Strategy for Oil Companies and Oil-Exporting Countries. *The Oxford Institute for Energy Studie*s, OIES Paper. https://doi.org/10.26889/ 9781784671099

Gokce, O. Z., Hatipoglu, E., & Belaid, F. (2024). Navigating Energy Diplomacy in Times of Recovery and Conflict: A Study of Cross-Border Energy Trade Dynamics, *Resources Policy*, *90*, art. 104850. https://doi.org/10.1016/j.resourpol.2024.104850

Griffiths, S. (2019) Energy Diplomacy in a Time of Energy Transition. *Energy Strategy Reviews*, *26*, art. 100386. https://doi.org/10.1016/j.esr.2019.100386

Gueldry, M., & Liang, W. (2016). China's Global Energy Diplomacy: Behavior Normalization

Through Economic Interdependence or Resource Neo-mercantilism and Power Politics? *Journal of Chinese Political Science*, *21*(2), 217-240. https://doi.org/10.1007/s11366-016-9405-3

Herranz-Surralles, A. (2015). An Emerging EU Energy Diplomacy? Discursive shifts, enduring practices. *Journal of European Public Policy*, *23*(9), 1386-1405. https://doi.org/10.1080/13501763.2015.1083044

Huda, S. M., & Ali, S. H. (2017). Energy Diplomacy in South Asia: Beyond the Security Paradigm in Accessing the TAPI Pipeline Project. *Energy Research & Social Science*, *34*, 202-213. https://doi.org/10.1016/j.erss.2017.07.013

Huda, S. M. (2024). Renewable energy diplomacy and transitions: An environmental peacebuilding approach. *Environmental Innovation and Societal Transitions*, *50*, art. 100815. https://doi.org/10.1016/j.eist.2024.100815

Ipek, P. (2023). Energy Dynamics in Turkiye's Relationship with BRICS countries, *Turkish Policy Quarterly*, *22* (4), 34-40. https://doi.org/10.58867/JPFX7559

Ipek, P. (2025). Turkey's energy diplomacy and instrumentalization of hard power, *Southeast European and Black Sea Studies*, *25*(1), 141-161. https://doi.org/10.1080/14683857.2024.2445353

Kilic, F. C., Kilic, M. K., Eydogan, M., & Kaya, D. (2019). A General Evaluation of Turkey's Energy Diplomacy and the Latest Climate Change Studies. *International Journal of Ecosystem and Ecology Science*, *9*(1). https://doi.org/10.31407/ijees9104

Kivimaa, P., Brisbois, M. C., Jayaram, D., Hakala, E., & Siddi, M. (2022). A socio-technical lens on security in sustainability transitions: Future expectations for positive and negative security. *Futures*, *141*, art. 102971. https://doi.org/10.1016/j.futures.2022.102971

Liang, L., Jin, L., Selopal, G. S., & Rosei, F. (2023). Peace Engineering in Practice: China's Energy Diplomacy Strategy and Its Global Implications. *Sustainability*, *15*(2), art. 1442. https://doi.org/10.3390/su15021442

Liao, J. (2021). China's Energy Diplomacy towards Central Asia and the Implications on its "Belt and Road Initiative". *Pacific Review*, *34*(3), 490-522. https://doi.org/10.1080/09512748.2019.1705882

Li, B., Ren, Z., & Gao, P. (2025) A Study on the Impact of Energy Diplomacy on China's Crude Oil Trade. *Energies*, *18*(4). https://doi.org/10.3390/en18040851

Mahmood, A., Khan, M. I., Ali, S., Abbas, Z., & Khan, N. (2022). The Role of Chinese Regimes of Asian Infrastructure Investment Bank and the Belt and Road Initiative in the Transformation of its Energy Diplomacy: Quest for Economic Sustainability, *Sustainability*, *14*(24), art. 16997. https://doi.org/10.3390/su142416997

Massaro, M., Dumay, J., & Guthrie, J. (2016). On the shoulders of giants: undertaking a structured literature review in accounting. *Accounting, Auditing & Accountability Journal*, *29*(5), 767-801. https://0t10y53ft-y-https-doi-org.z.e-nformation.ro/10.1108/AAAJ-01-2015-1939

Moghani, A. M., & Maleki, A. (2024). China's Energy Diplomacy in the Caspian Basin and its Impact on the Energy Security of Europe. *Energy Reports*, *11*, 2279-2294. https://doi.org/10.1016/j.egyr.2024.01.070

Nassar, A. K. (2024). Strategic energy transition in the Gulf Cooperation Council: Balancing economic, social, political and environmental dynamics for sustainable development. *International Journal of Green Energy*, 1570-1586,

https://doi.org/10.1080/15435075.2024.2435434

Okano-Heijmans, M. (2012). Japan's 'Green' Economic Diplomacy: Environmental and Energy Technology and Foreign Relations. *Pacific Review*, *25(*3), 339-364. https://doi.org/10.1080/09512748.2012.685090

Ozkurt Dorduncu, F. Z. (2024). The EU's Future Under Scurtiny: Foreign Policy Implications of the EU Energy Diplomacy in the Eastern Mediterranean. *Ankara Avrupa Calismalari Dergisi-Ankara Review of European Studies*, *23*, 199-228. https://doi.org/I10.32450/aacd.1439566

Proedrou, F. (2016). Why Russian Gas Diplomacy Fails: the Geopolitics-energy nexus in Ukraine and Turkey. *Asia Europe Journal*, *15*, 21-37. https://doi.org/10.1007/s10308-016-0460-3.

Prontera, A. (2017). Forms of State and European Energy Security: Diplomacy and Pipelines in Southeastern Europe. *European Security*, *26*(2), 273-298. https://doi.org/10.1080/09662839.2017.1313233

Rubio M., & Folchi, M. (2012) Will small energy consumers be faster in transition? Evidence from the early shift from coal to oil in Latin America. *Energy Policy*, *50*, 50-61. https://doi.org/10.1016/j.enpol.2012.03.054

Rudiany, N. P., Anggraeni, S. D., Nurhidayah, G. M., & Firmansyah, M. (2019). The Role of Cities in Energy Diplomacy: Indonesia, Japan and the Surabaya-Kitakyushu Partenership. *Hague Journal of Diplomacy*, *17*(1), 64-90. https://doi.org/ 10.1163/1871191X-BJA10082

Sanchez Perez-Castejon, P. (2013). La diplomacia comercial en el centro de la diplomacia economica espanola = The primacy of commercial diplomacy in spanish economic diplomacy strategy. *Anuario Juridico y Economico Escurialense*, *46*, 345-362.

Shaw, R., Silva, K., & Chollacoop, N. (2024). Energy, Sustainability and Resilience, A futuristic Vision from Asia, Disaster Risk Reduction. Springer. https://doi.org/10.1007/978-981-97-4174-8

Stoddard, E. (2016). Tough Times, Shifting Roles: Examining the EU's Commercial Diplomacy in Foreign Energy Markets, *Journal of European Public Policy*, *24*, 10148-1068. https://doi.org/10.1080/13501763.2016.1170190.

Sun, D. G., Xu, H. Y., & Tu, Y. C. (2022). In with the New: China's Nuclear-Energy Diplomacy in the Middle East. *Middle East Policy*, *29*(1), 41-60. https://doi.org/10.1111/mepo.12619.

Szulecki, K., & Overland, I. (2023). Russian Nuclear Energy Diplomacy and its Implications for Energy Security in the Context of the War in Ukraine. *Nature Energy*, *8*(4), 413-421. https://doi.org/ 10.1038/s41560-023-01228-5

Wang, X. (2020). Leadership-building dilemmas in Emerging Powers Economic Diplomacy: Russia's Energy Diplomacy and China's One Belt One Road. *Asia Europe Journal*, *18*, 117-138. https://doi.org/10.1007/s10308-019-00536-4

Wu, F. (2015). China's Puzzling Energy Diplomacy toward Iran. *Asian Perspective*, *39*(1), 47-69. https://doi.org/ 10.1353/apr.2015.0009

Xu, B., & Reisinger, W. M. (2018). Russia's Energy Diplomacy with China: Personalism and Institutionalism in its Policy-Making Process. *The Pacific Review*, *32*(1), 1-19. https://doi.org/10.1080/09512748.2018.1428675

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THE IMPACT OF AUTOMATION AND DIGITALIZATION ON THE COMMERCIAL MARKET IN THE REPUBLIC OF MOLDOVA

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Abstract: *The purpose of this study is to analyze the effects of automation and digitization on the commercial sector of the Republic of Moldova, with particular attention to the benefits and challenges associated with technological transformation. The study emphasizes the ways in which digital tools and automation affect market accessibility, trade efficiency, and general economic dynamics. The uniqueness of this study lies in its multidisciplinary methodology, which combines technological and policy perspectives on digitalization with economic analysis. The article looks at how digital tools can improve business operations, lower transaction costs, and boost competitiveness. It also examines how automation transforms business models, increases productivity, and fosters innovation in the Republic of Moldova's trade sector. The study finds that SMEs in Moldova show a 40% adoption rate of digital payment tools, compared to 95% in large enterprises, highlighting the digital divide. The global reliance on automation and digitalization in economic activity underscores the relevance of this study. In order to stay competitive and guarantee long-term economic resilience, the Republic of Moldova must incorporate these technologies into its trade policies and business plans. The report offers information on how the Republic of Moldova can use digital transformation to support long-term development and increase its market share abroad. The methodology combines policy evaluation, statistical interpretation of digital trade data, and bibliographic analysis to assess the effects of automation and digitalization. These approaches give a thorough assessment of how automation and digitization have affected the Republic of Moldova's business environment and offer practical suggestions for companies and policymakers. In summary, the interaction of automation, digitization, and trade growth highlights the need for the Republic of Moldova to enact progressive policies that encourage technological advancement. The nation will be able to improve trade efficiency, encourage innovation, and fortify its economic resilience in the face of international challenges by adopting a strategic approach to automation and digital tools.*

Keywords: *digitalization, automation, trade, competitiveness, economic development, Republic of Moldova.*

JEL Code: *O33, L81, F63.*

UDC: *004:339.5(478)*

Introduction

Digitalization and automation are irreversible global processes that redefine economic models and competitiveness strategies, influencing both operational efficiency and consumer behavior, as well as business competitiveness. As an emerging economy, the Republic of Moldova faces specific challenges in implementing digitalization but also considerable opportunities for trade modernization.

The digitalization of the economy contributes to the streamlining of commercial processes, increased access to international markets, and improved business productivity. The interaction between digitalization and trade requires a detailed analysis of how emerging

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technologies influence the country's economic performance. In recent literature, the study by Coban (2023) reveals that the adoption of digital technologies in EU enterprises is correlated with increased productivity and innovation capacity, as evidenced by indicators such as cloud computing and AI in SMEs. Based on these premises, the current study analyzes to what extent these transformations are also reflected in the structure of the commercial market in the Republic of Moldova. The strategic geographical position of the Republic of Moldova, along with its progressive integration into European economic networks, creates favorable conditions for accelerating digitalization and automation in various sectors. However, underdeveloped digital infrastructure, limited access to financing, and gaps in the adoption of modern technologies remain major challenges for the country.

The purpose of the research is to analyze the impact of automation and digitalization on the commercial market of the Republic of Moldova, focusing on the transformation of commercial processes, changes in consumer behavior, and the adaptability of companies to new technologies. The methodology used includes the analysis of academic literature, relevant case studies, and the interpretation of statistical data on trade digitalization at the national level.

This study contributes to the literature by providing an integrative approach to the impact of automation and digitalization on the commercial market, highlighting Moldova's specific context in a regional comparative perspective.

The article is structured into four main sections: theoretical framework introduction, research methodology, analysis of results, and conclusions with practical recommendations.

Materials and Methods

The materials used in this study include statistical data on digital trade, public policy documents, international studies on the impact of digitalization and automation on commerce, and economic reports. These sources provide an overview of the trends and evolution of the digital economy in the Republic of Moldova.

The research employed in this article is both qualitative and quantitative, including: statistical analysis of data on the digitalization of trade in the Republic of Moldova; a case study on the impact of automation implementation in retail and e-commerce; and a comparative analysis of commercial markets in neighboring countries - Romania and Ukraine - to identify best practices.

The case study focuses on the modern retail and e-commerce sectors in the Republic of Moldova. The analysis centers on the effects of introducing automated technologies such as self-checkout systems, digital inventory management solutions, and contactless payments. The objective is to highlight how these tools influence operational efficiency, customer experience, and sales dynamics. The sources used include economic policy reports, specialized studies, and relevant official statistical data.

The indicators analyzed include the volume of electronic transactions, adoption of digital payment solutions, the rate of commercial process automation, and the impact on

employment in the trade sector. For data analysis, relative frequencies, percentage comparisons, and age-group distributions were used, based on data from XPLANE Research (2024). The applied methodology enabled the collection and interpretation of relevant data on the digitalization of trade. The results reveal significant changes generated by automation and digitalization in the commercial market - developments that will be detailed in the following section. The analysis period covers the years 2019–2024, corresponding to the most recent data available in official statistics and thematic studies. Sources include reports from the National Bureau of Statistics, AmCham Moldova, ACETI, and the OECD.

Based on the outlined methodology, the following section presents the main findings on the impact of digitalization on trade in the Republic of Moldova.

Results and Discussion

Technological advancement has transformed the structure of the global economy, changing both how companies operate and how they interact with markets. Digitalization is reshaping business models, optimizing processes, and reducing costs, while also raising challenges related to infrastructure and workforce adaptation.

Critically reflecting on global economic digitalization processes, Canadian economist and theorist Don Tapscott (1996), in his seminal work The Digital Economy: Promise and Peril in the Age of Networked Intelligence, introduced the concept of the "New Economy," defined as a "phenomenon of networked intelligence." This concept underscores how digital technology transforms the economic structure through the convergence of three fundamental domains: 1) Communications (telephony, internet, satellite, wireless); 2) Computing technology (hardware, software, computer networks); 3) Digital content (publications, entertainment, information services).

In the Republic of Moldova, the transition toward the New Economy is evident in the development of the IT sector and digital commerce. For instance, the growth of local e-commerce platforms and the implementation of fintech solutions reflect digitalization trends. However, the lack of robust digital infrastructure and technological education continues to hinder progress.

The components of the "New Economy" as described by Tapscott are clearly reflected in the digitalization process of commerce in Moldova. Digitalization promotes innovation, yet the development of necessary competencies remains a major challenge for the country's human capital. In terms of technologies, electronic payments and online commerce are on the rise, but SMEs struggle to integrate them. Business models are migrating to digital platforms, although many enterprises lack the resources to make this shift. Remote work and freelancing are expanding, particularly in the IT sector. Digitalization reduces trade barriers and facilitates access for Moldovan companies to international markets, allowing producers to sell directly to consumers, even as traditional retail remains dominant.

Accelerating digitalization is essential for the economic integration of the Republic of Moldova into the European Union. Digitalization programs help enhance economic competitiveness, and Moldovan users are actively contributing to the creation of digital content, even though infrastructure remains underdeveloped. Online commerce is growing, and SMEs can access international markets, but infrastructure still poses a challenge. Additionally, digital disparities between advanced tech adopters and traditional companies lead to market polarization (Tapscott, 1996).

Analyzing Tapscott's highlighted transformations, we observe that they are highly relevant for Moldova, where digitalization represents both an opportunity and a challenge for economic competitiveness. The accelerated integration of new technologies and the development of digital infrastructure are essential success factors for trade (Tapscott, 1996).

In the context of digital transformation, the Republic of Moldova exhibits defining characteristics of the New Economy: digital commerce reduces dependency on intermediaries, and the labor market becomes more flexible through automation. However, existing gaps in digital infrastructure and the low level of technological education slow down this progress.

Given the significant growth of e-commerce at the national level, companies in the Republic of Moldova are investing in the use of automated solutions and the integration of existing artificial intelligence tools to optimize the shopping experience.

Among the most relevant examples of the impact of digitalization in commerce are:

- The introduction of automated inventory management systems in supermarkets, which optimize supply processes and reduce losses through demand forecasting;
- The use of contactless and mobile payments, which has accelerated transaction speed and enhanced payment security;
- The development of e-commerce, where online platforms have revolutionized the shopping experience by offering fast and diversified options for consumers;
- The integration of artificial intelligence solutions and data analytics, enabling personalized offers and improved customer relationships;
- The automation of distribution centers, which shortens delivery times and reduces logistics costs.

Thus, digitalization contributes to both the enhancement of operational efficiency and the transformation of the traditional commercial model by promoting accessibility and personalized customer experiences.

Consumer behavior in the Republic of Moldova has also changed significantly in recent years, along with the rise of online commerce and the adoption of digital solutions. The growing preference for online shopping is driven by factors such as accessibility, product diversity, and delivery speed - elements that directly influence the development of digital retail. Alongside this transition, e-commerce platforms play a crucial role in reshaping shopping habits, highlighting the need for retailers to invest in automated solutions and offer personalization technologies. This change in consumer preferences leads to a reconfiguration of commercial strategies and stimulates the development of e-commerce. As consumers

become more demanding, optimized digital experiences, flexible payment methods, and efficient logistics become critical factors for maintaining competitiveness in the e-commerce market. Traditional retailers who do not adapt their business models to digital demands risk losing market share to online platforms and competitors prioritizing digital innovation.

In the context of the expanding e-commerce market, a key factor is the digitalization of commercial processes, which facilitates consumer access to a wide range of products and services. More and more retailers are implementing automated inventory systems, digital payment options, and omnichannel sales platforms, offering consumers faster and more efficient shopping experiences. Another important aspect is the evolution of consumer preferences, increasingly oriented toward convenience, diversity, and delivery speed. In this regard, both local and international e-commerce platforms are adapting their strategies through offer personalization and delivery optimization. The growing number of contactless and mobile payments indicates a strong shift toward digital transactions, contributing to the consolidation of the e-commerce sector. This evolution is supported by the legal framework governing payment services and electronic money, regulated by Law No. 114/2012.

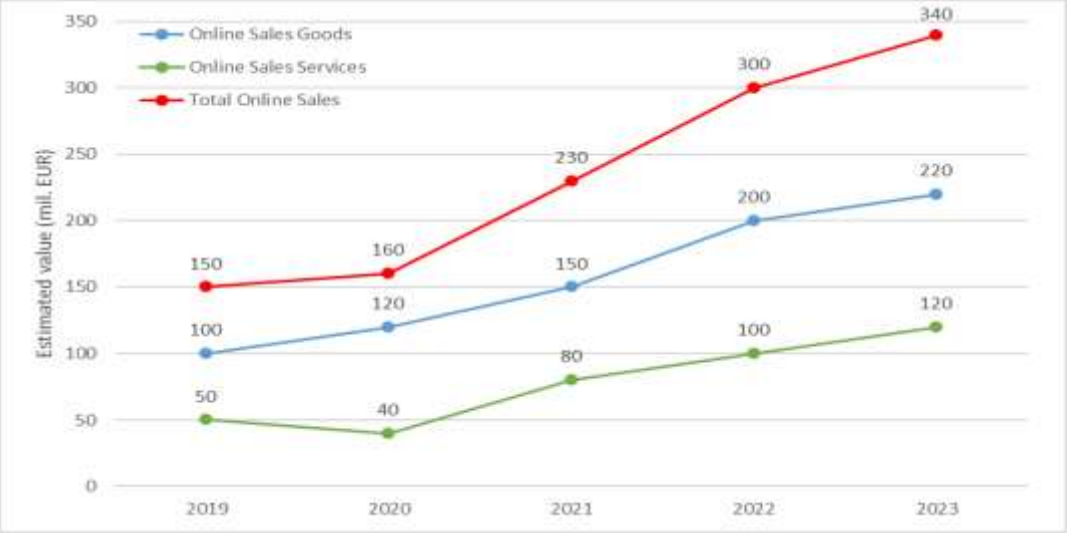

Figure 1. Evolution of the E-commerce Market in the Republic of Moldova (2019–2024)

Source: Developed by the author based on Law No. 114/2012 on Payment Services and Electronic Money and the Digital Transformation Strategy 2023–2030, e-Governance Agency[2]

Overall, these developments confirm that the e-commerce market in the Republic of Moldova is in a phase of expansion but still requires additional investments in digital infrastructure, logistics, and cybersecurity. Thus, companies adopting an integrated strategy of digitalization and automation will be better positioned to meet consumer expectations and strengthen their long-term competitive advantage.

2 *The data from the cited sources were supplemented with estimates made by the author, based on trends from policy documents and statistical studies published between 2019 and 2024*

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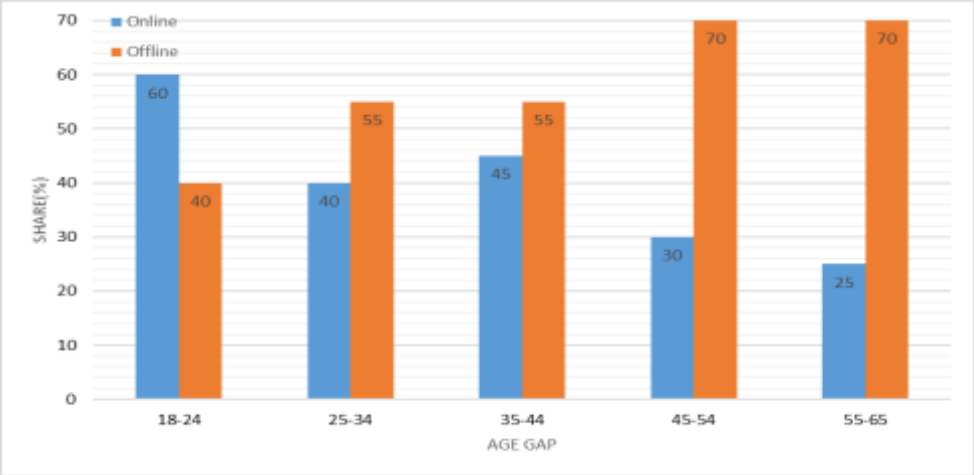

Figure 2. Preferences for Online vs. Offline Purchasing of the Same Product in the Republic of Moldova, by Age Group (2023)

Source: Developed by the author based on XPLANE Research, AmCham Moldova Report – The E-Commerce Market in the Republic of Moldova (2024)[3]

There are significant differences among age groups regarding the adoption of e-commerce. Young people aged 18–24 prefer online shopping, with 62% choosing this method compared to only 38% who shop in physical stores. In contrast, among individuals aged 55–65, 70% prefer offline shopping, while only 30% opt for e-commerce.

Intermediate age groups show a relatively balanced preference: in the 25–34 age category, 45% of consumers choose online channels, and 55% offline - similar trends are observed in the 35–44 group. However, in the 45–54 segment, the preference for traditional shopping becomes even more evident, with 70% of purchases made offline. For clarity, the presented percentages were rounded and supported by interpretations based on the age group structure in the original report. This trend compels retailers to balance investments in digitalization with the maintenance of physical stores, adapting to the preferences of various consumer segments.

The automation of commercial processes significantly impacts the labor market, reducing jobs in retail and logistics while creating new opportunities in IT, data analysis, and digital management. The implementation of digital technologies not only alters business models but also reshapes labor requirements, necessitating an effective transition through reskilling programs.

3 *The data from the cited sources were supplemented with author-generated estimates based on trends from policy documents and statistical studies published between 2019 and 2024. The values presented in Figure 2 were adjusted and interpreted by the author using rounded percentage estimates and interpolated age group data from the original report to ensure a clear comparative representation.*

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In the physical retail sector, the introduction of self-service point-of-sale systems and automated inventory management reduces the need for cashiers and administrative staff. Meanwhile, the digitalization of supply chains and the use of automated sorting systems affect demand for low-skilled labor in logistics. Conversely, the demand is increasing for e-commerce specialists, online platform administrators, cybersecurity experts, and data analysts - fields that require advanced digital competencies.

According to the Expert-Grup report (2023), Moldova's economic growth is being driven by the service sector, supported by the recovery of retail commerce and the continuous expansion of the IT industry. Moreover, the growing emphasis on retechnologization and automation has stimulated investment flows, thereby reinforcing the country's upward economic trend (Expert-Grup, 2023).

The following table illustrates the impact of automation across major sectors in Moldova, showing how digitalization transforms business processes and alters labor market demands.

The transition in the structure of the labor market affects not only employees but also the way businesses adopt new technologies. The differences between large enterprises and SMEs in the digitalization process are becoming increasingly visible, significantly impacting operational efficiency and market competitiveness. In the Republic of Moldova, the adoption of digital technologies in the commercial sector is uneven, with large enterprises and SMEs facing distinct challenges.

Table 1. The Impact of Digitalization and Automation on Occupations in the Republic of Moldova

Sector	Declining Occupations	Transitional Occupations	Emerging Occupations
Retail & Commerce	Cashiers, checkout operators, customer support staff	Digital sales specialists, customer relationship managers	E-commerce specialists, online platform designers
Logistics & Transport	Manual sorters, warehouse workers, stock supervisors	Digital logistics operators	AI specialists for transport, drone delivery developers
Finance & Accounting	Junior accountants, bank cashiers	Fintech consultants, AI auditors	Blockchain specialists, financial data analysts
Media & Entertainment	Traditional video editors, manual proofreaders, translators	Digital content producers, media strategy managers	Augmented reality specialists, AI-generated content creators
Education & Training	Standardized course instructors	Digital learning facilitators, online mentors	Developers of digital educational content, VR specialists in education

Source: Developed by the author based on data from the OECD Report (2023) on digital business skills in the Republic of Moldova

While large retail chains invest in automation to improve internal processes and increase efficiency, SMEs face financial constraints and a lack of technological expertise, which undermines their competitiveness. Large companies implement solutions such as self-

checkout systems and ERP platforms to better manage inventory and reduce personnel costs, while SMEs continue to rely on traditional methods and have limited resources to invest in digitalization. In the long term, insufficient digital adoption may lead to increased market polarization, favoring large enterprises and diminishing the competitiveness of SMEs.

An analysis of the degree of digital technology adoption among small and medium-sized enterprises (SMEs) versus large companies in the Republic of Moldova reveals significant discrepancies between the two groups. Large companies show much higher levels of integration of digital solutions. These differences directly affect operational efficiency, competitiveness, and the capacity to adapt to market demands. By optimizing resource management, digitalization becomes a catalyst for the transformation of commercial strategies - a critical condition for adapting to new economic realities.

Digitalization and automation bring significant benefits to Moldova's trade sector. However, the implementation process is slowed by multiple challenges that impact business competitiveness. A major issue is the underdeveloped digital infrastructure in rural areas, where limited access to high-speed internet and the absence of modern electronic payment solutions reduce commercial opportunities for SMEs.

Additionally, the absence of a clearly defined legislative framework and the lack of effective cybersecurity measures increase the risk of losing financial data and sensitive customer information. For many SMEs, investing in cybersecurity is expensive and difficult to implement, making them more vulnerable to digital threats.

Another essential challenge is resistance to change and the lack of digital education among entrepreneurs. Many business owners, especially those from older generations, prefer traditional methods of operation and are hesitant to adopt new technologies. At the same time, the digital skills deficit hampers the transition to automation, leading to a slow and difficult integration of technological solutions.

Table 2. Level of Digital Technology Adoption in SMEs and Large Companies in the Republic of Moldova

Technology / Process	Adoption in SMEs (%)	Adoption in Large Companies (%)	Impact on Efficiency
ERP Systems (Enterprise Resource Planning)	18%	85%	Optimization of inventory and internal processes
Self-checkout and Automated Payments	10%	75%	Reduced personnel costs and increased processing speed
E-commerce (Own Online Sales)	35%	90%	Market expansion and improved consumer accessibility
Digital and Contactless Payments	40%	95%	Increased security and efficiency of financial transactions
Artificial Intelligence for Data Analysis	5%	60%	Offer personalization and improved commercial strategy
Logistics and Supply Chain Automation	15%	80%	Reduced operational costs and faster deliveries

Source: Developed by the author based on data from the National Bureau of Statistics of the Republic of Moldova

Moreover, the workforce in the trade sector is not always prepared to operate complex digital systems, which makes professional training and reskilling programs a necessity. If these challenges are not addressed effectively, the digitalization of commerce in the Republic of Moldova risks advancing unevenly, benefiting large companies while leaving behind SMEs that lack the resources to quickly adapt to new market demands.

The analysis conducted highlights both the benefits and the challenges that digitalization brings to Moldova's commercial market. For these processes to be implemented efficiently and equitably, strategic measures are necessary - elements that will be detailed in the article's conclusions and recommendations. The integration of digital technologies must be supported through effective public policies, investments in digital infrastructure, and digital education programs, so that all businesses can benefit from the opportunities brought by automation.

For digitalization in Moldova's trade sector to be effectively implemented, viable strategies are needed to support both large enterprises and SMEs in adapting to new technologies. The main action directions include:

- Investments in IT infrastructure and SME digitalization – developing high-speed internet networks, especially in rural areas, and facilitating SME access to advanced technological solutions. Providing grants, subsidies, or tax incentives for the digitalization of small and medium-sized enterprises can help reduce the gap with large companies;
- Implementing public policies to support e-commerce, along with establishing a clear legislative framework for digital payments, data protection, and cybersecurity, is fundamental to promoting the development of online businesses (Law No. 60/2023);
- Public–private sector collaboration can facilitate the integration of innovative solutions and the development of digitalization support programs;
- Professional training programs for digital skills development – reskilling employees in areas such as e-commerce platform management, data analysis, and the use of artificial intelligence in business processes can ensure effective adaptation to new market realities. Creating training centers or partnerships with educational institutions for specialized program development can accelerate this process.

Supporting Moldova's integration into European digital ecosystems – aligning with European Union standards and partnering with international organizations can facilitate local companies' access to emerging technologies and international markets (Coretchi, B., Onofrei, A., & Rencheci, D., 2017). Innovation is a key factor in Moldova's socio-economic development process, playing a vital role in diversifying the economic structure, increasing sectoral efficiency, and improving global competitiveness. An integral part of the "new economy" in the age of "networked intelligence" is the creation and use of "digital capital," resulting from the interaction between human capital, consumer capital, and a company's structural capital (Tapscott, D., Lowy, A., & Ticoll, D., 2000).

To assess Moldova's position in the trade digitalization process, a comparative analysis with Ukraine and Romania - two neighboring states with similar economic and trade structures

but different digital adoption rates - is appropriate. This approach helps identify strengths and specific challenges in each country and provides a relevant framework for developing strategies to accelerate digital transformation in Moldova.

Table 3. Comparison of Trade Digitalization in the Republic of Moldova, Ukraine, and Romania

Indicator / Country	Republic of Moldova	Ukraine	Romania
Level of SME Digitalization	Low level, most SMEs operate traditionally.	Accelerated growth due to conflict-related necessities.	Advanced integration into European digital ecosystems.
IT Infrastructure and Internet Access	Uneven development, significant urban-rural gaps.	Rapid expansion of 4G/5G networks.	Extensive coverage, high-speed internet, low costs.
Public Policies for Digital Trade	Limited initiatives, lack of a clear strategic framework.	Proactive policies, conflict-driven digitalization.	Integrated national strategy, EU support.
Digital Payment Integration	Moderate growth, cash still predominant.	Rapid adoption of electronic payments.	High level, digital payments are widespread.
E-commerce and Marketplaces	Dominated by international platforms, SMEs face barriers.	Rapid expansion of online trade.	Strong local marketplaces, regional integration.
Digital Education and Professional Training	Deficit of digital reskilling programs.	Accelerated development of online courses.	Advanced programs supported by EU funding.

Source: Developed by the author based on the ACETI Study on SME Digital Transformation Needs (2024), EU4Digital and the Romanian Ministry of Research, Innovation, and Digitalization.

Trade digitalization varies significantly between Moldova, Ukraine, and Romania, influenced by factors such as access to financing, public policies, and digital infrastructure.

Romania has benefited from multiple EU funding programs dedicated to digitalization, which facilitated the accelerated adoption of digital payments, the development of robust e-commerce platforms, and support for SMEs in transitioning to digital operations. Through initiatives funded by the European Union, such as the Competitiveness Operational Program, Romanian SMEs received assistance in implementing ERP systems and automating business processes, giving them a competitive edge in the regional market.

Ukraine, on the other hand, was compelled to accelerate digitalization due to the armed conflict, which led to the rapid implementation of e-commerce and online payment technologies as part of an economic resilience strategy. The Ukrainian government, together with international partners, launched initiatives to support entrepreneurs through digital programs, including national platforms for selling local products and services facilitating access to financial systems without traditional banking infrastructure. The growth of digital banking applications like monobank enabled continued economic activity despite infrastructure disruptions caused by the conflict.

Although Moldova has made some progress in digitalization, it faces major challenges stemming from its underdeveloped IT infrastructure and limited access to financing for SMEs. While Romania and Ukraine have implemented proactive strategies for economic digitalization, Moldova still needs clearer and better-defined policies to support SMEs in adopting digital technologies. In this regard, the country must accelerate efforts through investments in digital infrastructure and supportive policies for SMEs, following Romania's example in attracting EU funding.

Currently, national initiatives such as the Digital Transformation Strategy 2023–2030 are in the implementation phase, but their success will depend on investments in digital education, infrastructure, and incentives for SME digitalization (Ministry of Economic Development and Digitalization, 2025).

Although the gaps with neighboring economies are evident, Moldova has the potential to close this gap through strategic measures and effective policies. To support digital commerce and economic competitiveness, Moldova must accelerate the adoption of public policies for digitalization, align with European best practices, and attract external funding sources to reduce disparities with neighboring economies.

The Government of the Republic of Moldova has implemented a series of strategies to accelerate digitalization, including the digitalization of public services and support for SMEs in adopting modern technologies. The country's Digital Transformation Strategy for 2023–2030 represents a fundamental initiative aimed at developing an innovative and sustainable digital economy, contributing to the strengthening of Moldova's economic and technological resilience.

The strategy includes a number of essential measures for the development of the digital economy. These include the development of digital infrastructure, which involves expanding essential public services for businesses, with digitalization targets of 75% by 2024 and 100% by 2030. Another important aspect is supporting the local IT industry and promoting the adoption of digital products in the domestic market, especially by stimulating electronic payments at the national level. Furthermore, the strategy envisages the creation of a program for the digitalization of SMEs and their integration into the e-commerce ecosystem, while international trade facilitation for SMEs will be supported through the simplification of customs procedures. The strategy also includes the development of the ICT sector and the digital economy, along with the promotion of cooperation between universities, the public sector, and the private sector to improve digital competencies. In addition, increasing consumer trust in online payments is targeted through the implementation of high digital security standards (e-Governance Agency, 2023).

The Republic of Moldova is also set to benefit from support under the "Digital Europe" Program to develop a European Digital Identity Wallet - an important step toward the digitalization of public services and integration into the European digital space. This wallet will allow citizens and companies to authenticate their identity and manage documents in digital format, thus facilitating interaction with both public and private services.

Furthermore, in 2021, the government established the position of Deputy Prime Minister for Digitalization, responsible for coordinating digital transformation activities, including public services and IT infrastructure. This position emphasizes the authorities' commitment to supporting trade digitalization and creating a favorable environment for the development of the digital economy.

The importance of e-commerce as a driver of economic and socio-economic growth in Moldova is particularly relevant, given the digital transformations that are reshaping market structures and stimulating innovation across sectors. Digital commerce opens important opportunities for SME development, facilitating their expansion both domestically and internationally. Online platforms provide companies with access to new consumer segments, allow for diversification of product and service offerings, and enable the implementation of modern solutions for supply chain management. Moreover, trade digitalization reduces geographical barriers and operational costs, thus increasing the competitiveness of Moldovan enterprises on the global stage. It also improves transaction transparency and efficiency, creating a favorable business climate and contributing to the modernization of the national economy (Ministry of Economic Development and Digitalization, 2025).

To fully capitalize on the potential of digital commerce, Moldova must ensure the consistent implementation of its national strategy, stimulate innovation, and improve SME access to digital resources. Integration into European digital ecosystems and investments in digital education will play a key role in enhancing the country's economic competitiveness (Economic Council, 2021).

Conclusions

In line with the directions analyzed above, Moldova's integration into the European digital space and alignment with EU standards become strategic imperatives for strengthening trade competitiveness. To remain competitive in the digital age, the Republic of Moldova must accelerate investments in IT infrastructure, implement digital training programs for entrepreneurs, and adapt its legislative framework to the new realities of electronic commerce and cybersecurity. Law No. 60/2023 represents an important starting point in stimulating electronic commerce and creating a favorable legislative framework for the development of the digital sector.

However, the analysis reveals that the success of digitalization in the Republic of Moldova largely depends on the effective integration of emerging technologies and the promotion of a business ecosystem aligned with new market requirements. In this context, collaboration between public authorities and the private sector is crucial for creating a favorable environment for innovation and supporting SMEs, which represent a vital segment of the national economy.

Moldova's integration into the European digital space and alignment with EU standards are strategic directions with a major impact on sustainable economic development. The

modernization of technological infrastructure, together with the implementation of effective policies in e-commerce and cybersecurity, can strengthen the national economy's competitive capacity. This will create the necessary conditions for expanding access to international markets and adopting emerging technologies, contributing to the digital transformation of Moldova's business environment. In the future, research could further investigate the impact of artificial intelligence and blockchain technologies on the security of commercial transactions in Moldova's digital economy.

References

e-Governance Agency. (2023). *Digital Transformation Strategy 2023–2030*. https://www.egov.md/sites/default/files/document/attachments/strategia_de_transformare_digitala_2023-2030.pdf

ACETI – Association for the Development of Electronic Communications and Innovative Technologies. (2024). *Study on the Digital Transformation Needs of SMEs*. https://aceti.md/wp-content/uploads/2024/08/Necesitatile-IMM-final.pdf

National Bureau of Statistics of the Republic of Moldova. (2025). https://statistica.gov.md/ro

Coban, M. (2023). The Role Of Digital Technology In The Development Of Enterprises In The European Union. *Eastern European Journal for Regional Studies, 9*(2), 142–155. *https://csei.ase.md/journal/files/issue_92/10_EEJRS_Issue92_142-155.pdf*

Economic Council. (2021). *Proposals to Update the Roadmap*. https://consecon.gov.md/wp-content/uploads/2021/06/PROPOSALS-TO-UPDATE-THE-ROADMAP-.pdf

Coretchi, B., Onofrei, A., Corețchi, B., & Rencheci, D. (2017). The Importance of Innovation in the Socio-Economic Development of the Republic of Moldova. In *Proceedings of the International Scientific Conference The Global Competitive Environment: Development of Modern Social and Economic Systems* (pp. 41–44). USM.

EU4Digital. (2025). *EGOV4Ukraine*. https://eufordigital.eu/discover-eu/egov4ukraine/

Expert-Grup. (2023). *The Digital Transformation of Moldova's Economy.* https://www.expert-grup.org/ro/

Lege pentru modificarea unor acte normative (stimularea comerțului electronic) Nr. 60

din 17-03-2023 [Law No. 60/2023 on Amending Certain Normative Acts (Stimulating Electronic Commerce)]. (2023). *Monitorul Oficial al Republicii Moldova, Nr. 113-116*, art. 184. https://www.legis.md/cautare/getResults?doc_id=136266&lang=ro

Lege cu privire la serviciile de plată şi moneda electronica Nr. 114 din 18-05-2012 [Law No. 114 of May 18, 2012, on Payment Services and Electronic Money]. (2012). *Monitorul Oficial al Republicii Moldova, Nr. 193-197,* art. 661. https://www.legis.md/cautare/getResults?doc_id=110338&lang=ro

Ministry of Research, Innovation and Digitalization (Romania). (2025). https://www.mcid.gov.ro/

Ministry of Economic Development and Digitalization (Moldova). (2025). *Digital Economy*. https://mded.gov.md/content/economia-digitala/

OECD. (2023). *Promoting Digital Business Skills in the Republic of Moldova*. https://www.oecd.org/content/dam/oecd/ro/publications/reports/2023/06/promoting-

digital-business-skills-in-the-republic-of-moldova_dc179cd2/e31fc713-ro.pdf

Tapscott, D. (1996). The digital economy: *Promise and peril in the age of networked intelligence.* New York: McGraw-Hill, 1996, p. 60-63. ISBN 978-0070633421.

Tapscott, D., Lowy, A., & Ticoll, D. (2000). *Digital Capital: Harnessing the Power of Business Webs.* Harvard Business School Press.

XPLANE Research. (2024). AmCham Moldova Report: *The E-Commerce Market in the Republic of Moldova*. https://www.amcham.md/st_files/2024/07/15/AmCham%20Moldova%20Raport%20pia%C8%9Ba%20comer%C8%9Bului%20electronic%20din%20Republica%20Moldova%20RO.pdf

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THE INTEGRATION OF THE REPUBLIC OF MOLDOVA INTO THE EU GREEN ENERGY SYSTEM THROUGH HYDROGEN PRODUCTION

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Abstract: *In the context of heightened regional instability and rising energy insecurity triggered by the Russia–Ukraine conflict, the Republic of Moldova faces severe challenges, including surging natural gas and electricity prices that have significantly constrained its economic resilience. As a candidate country for European Union (EU) membership, Moldova's strategic energy realignment aligns with the EU's "Energy Transition and Strategic Autonomy" agenda, which prioritizes the development of green electricity and green hydrogen to reduce dependency on imported fossil fuels. This paper conducts a comprehensive techno-economic assessment of Moldova's potential to participate in the EU green energy system by investing in green hydrogen production. Using the Levelized Cost of Hydrogen (LCOH) model, the study evaluates the financial and regulatory feasibility of constructing a 5 MW electrolysis facility under different technological and market scenarios. The findings suggest that Moldova possesses both economic and infrastructural conditions conducive to producing tradable renewable hydrogen, in accordance with EU standards. Furthermore, the development of a domestic hydrogen industry could stimulate demand for renewable electricity, catalyze investment in green infrastructure, and contribute to Moldova's long-term energy independence and economic diversification. This research offers both theoretical insight and policy guidance for small transitioning economies seeking to integrate into regional green energy markets.*

Keywords: *Hydrogen, EU, Republic of Moldova, European Integration, LCOH (Levelised Cost of Hydrogen)*

JEL Code: *Q42, Q48, Q56, O13, F15.*

UDC: 620.9(478):061.1EU

Introduction

Against the backdrop of the global push for sustainable energy transformation, the EU has consistently been at the forefront of green energy development, committed to building a low-carbon, environmentally friendly, and efficient energy system in alignment with the Paris Agreement (McCollum et al., 2018). Hydrogen, due to its versatile characteristics and its ability to be used directly or stored like natural gas, is regarded as one of the key contemporary solutions for decarbonizing the energy system. The EU's experience in this area has had a significant global impact (Pleshivtseva et al., 2023; Zhao & Wang, 2023).

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The Russia-Ukraine conflict has had a significant impact on the energy systems across Europe, particularly in Central and Eastern European countries (Sabbaghian & Rasooli, 2021; Liu et al., 2022). Against this backdrop, the EU proposed "Energy Transition and Strategic Autonomy" (European Economic and Social Committee, 2022), a core component of which is to reduce its dependence on Russian fossil fuels (Ryon, 2020). R. Moldova is one of the countries severely affected by the conflict. The disruption of the energy supply chain has led to a sharp increase in overall prices. The Government of the Republic of Moldova, with the support of the European Union, provides financial assistance to households across the country to mitigate the impact of rising electricity prices (Government of the Republic of Moldova, 2025). Financial support from the European Union has also deepened the cooperation between the two sides.

In the face of crisis, the reform of R. Moldova's energy sector, bolstered by financial support from the European Union (EEAS, 2024), demonstrates significant strategic synergy with the EU's "The REPowerEU Plan". This EU energy independence initiative aims to accelerate the green transition and reduce reliance on fossil fuels (European Commission, 2022). Such policy convergence has created a historic opportunity for R. Moldova to systematically integrate into the European Energy Union, particularly in renewable energy infrastructure development and cross-border energy market coordination (EFREMOV et al., 2022).

The successful implementation of this energy integration strategy may propel R. Moldova's transformation from an energy aid recipient to a renewable energy hub in Central Europe, especially regarding hydrogen exports to the Central and Eastern European market. This transformation not only aligns with the EU's strategic goal of energy diversification and autonomy but also resonates with R. Moldova's strategic aspiration to deepen European integration through functional cooperation mechanisms (European Commission, 2025; Sandu, 2022).

Current status of the hydrogen energy industry

Overview of EU hydrogen energy development

In terms of the development trend of the hydrogen energy market, the EU has clearly outlined in the REPowerEU Energy Plan that by 2030 the production and import of renewable hydrogen will each reach 10 million tons (European Commission Directorate-General for Energy, 2022). In 2020, Europe's hydrogen demand stood at 8.2 million tons. Driven by carbon tax policies, the demand for green hydrogen has shown an upward trend. However, at that time, the production capacity for hydrogen through water electrolysis was only 30,000 tons, resulting in a significant supply-demand gap. In terms of industrial layout, the European Hydrogen Bank (EHB) specifically aims to boost hydrogen production and transportation across Europe (H2InfraMap, 2024). Between 2024 and 2026, the EU plans to establish 21 "Hydrogen Valley" industrial cluster demonstration projects in fields such as oil refining and steelmaking. These projects will be operational, effectively advancing the industrialization process of green hydrogen (Yao 2024,). In 2024, Europe's investment in

hydrogen energy was expected to increase by 140% (European Commission. 2024), with electrolyzer investment accounting for nearly one-third of the global total. Simultaneously, the EU is actively promoting the development of the hydrogen energy industry through various policy measures, including public funding assistance (IEA, 2024).

In terms of building standards and regulatory systems, the EU continues to enhance its hydrogen energy regulations and policy framework. The EU Hydrogen and Gas Decarbonization Plan, adopted in May 2024, comprises two regulations (EU, 2024/1788; EU, 2024/1789). The plan not only updates the EU's natural gas market rules and introduces a regulatory framework for hydrogen energy infrastructure but also revises the natural gas directive to establish a low-carbon hydrogen certification system. In terms of technical standards, the "Hydrogen Energy Standardization Roadmap" comprehensively addresses the standardization needs across the entire hydrogen energy value chain (European Commission, 2023).

Overview of R. Moldova's Energy Situation

For a long time, R. Moldova's energy supply has been heavily reliant on fossil fuels, particularly oil and natural gas imported from Russia. Over the past decade, R. Moldova has actively promoted the diversification of its natural gas supply by establishing interconnected pipelines with Romania, which has partially alleviated its energy challenges (Pamfile, 2024). Following the outbreak of the Russia-Ukraine conflict in 2022, R. Moldova accelerated its efforts to reduce dependence on Russian energy and vigorously pursued energy diversification and green production initiatives (Figure 1).

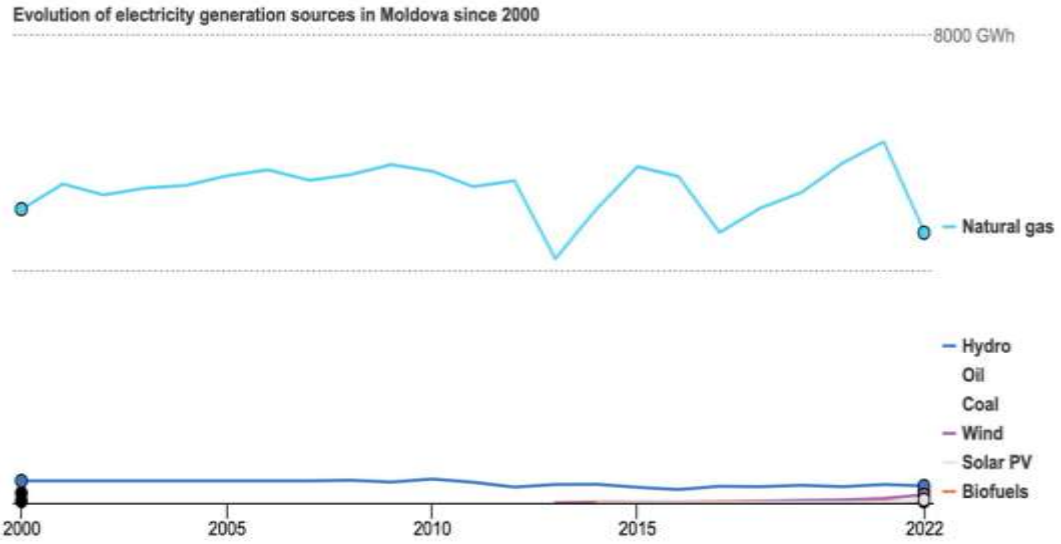

Figure 1: Evolution of R.Moldova's electricity sources (2000-2022)

Source: IEA (2022). https://www.iea.org/reports/moldova-2022, Licence: CC BY 4.0

However, in 2023 - 2024, its electricity consumption remained dominated by fossil fuels. Fossil energy, primarily natural gas, accounted for approximately 87.1% of electricity

generation, while renewable and green energy sources represented only 5.6%. An additional 6.7% of electricity was net imports. Such an energy structure not only exacerbates climate change and air pollution but also hinders R. Moldova's integration into the European green energy system. Increasing the share of low-carbon energy and achieving a diversified power generation structure have become urgent priorities (National Bureau of Statistics of the Republic of Moldova, 2024). By January 2025, Moldova's energy crisis had intensified, with electricity price increased by 75% (consumers have to pay 4.10 MDL/KWh, price increase of 1.76 MDL), compared to the previous period (ANRE, 2025).

As a European country, R. Moldova's energy security is not only a concern for itself but also for the EU and the global community. International financial institutions such as the World Bank, the European Bank for Reconstruction and Development (EBRD), and the European Investment Bank (EIB) have all provided funding for its energy security projects. The United States Agency for International Development has also pledged $370 million in support (U.S. International Trade Administration, 2024). In recent years, R. Moldova has strategically utilized these funds to advance its energy transition. Externally, in collaboration with Romania, it has increased investment in upgraded energy infrastructure to facilitate integration into the European energy system and alleviate the energy crisis. Internally, it has supported large-scale renewable energy projects and promoted the diversification and greening of its energy structure. R. Moldova plans to increase the share of renewable energy in electricity consumption to 30% by 2030 and has approved the construction of a 105 MW wind farm and a 60 MW solar park project in 2025 (Ministry of Energy of the Republic of Moldova, 2025).

Additionally, the implementation of the third round of energy plans for R.Moldova's gas industry has created opportunities for natural gas supply and hydrogen trade. In July 2024, the "Moldova Hydrogen" conference was held, during which Ukraine Hydrogen Limited Liability Company (H2U) and Moldova Global Assistance Limited signed a memorandum of understanding to launch the Hydrogen Valley project (Hydrogen Ukraine LLC., 2023). This project aims to assess the potential of renewable energy, ensure compliance with European standards, confirm the availability of water resources for green hydrogen production, coordinate the use of infrastructure, learn from European best practices, promote the application of hydrogen energy, and facilitate the construction of "green hydrogen" facilities and transportation infrastructure.

Raise of the Question

Currently, R.Moldova has initiated the construction of photovoltaic and wind energy projects (Ministry of Energy of the Republic of Moldova, 2025). However, it cannot be overlooked that these types of renewable natural energy sources inherently exhibit instability in their production processes. On the one hand, exploring the use of electricity-to-hydrogen technology to achieve high-value energy conversion, storage, and sales holds significant research value and practical economic importance. On the other hand, whether the

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development of the hydrogen energy industry can drive investment in green energy power generation is also worthy of in-depth exploration. The ultimate goal of addressing these two issues is to alleviate R. Moldova's energy and financial pressures and to integrate the country into the EU's green energy system through measures such as hydrogen exports. These are critical directions that require thorough analysis and comprehensive demonstration.

Literature Review

European academic circles have conducted extensive research on R.Moldova's energy issues from multiple perspectives, including the feasibility of green energy development, integration into the EU market through energy trade, and the study of hydrogen valleys in neighboring countries. These studies provide valuable multi-dimensional references for R. Moldova's energy transition; however, many practical challenges remain unresolved.

C. Efremov, V. Arion and M. Sanduleac (2021) conducted a detailed analysis of hydrogen energy facility construction in R. Moldova. They explored the supply and demand dynamics within the framework of the Paris Agreement and provided an assessment. Their findings indicated that R. Moldova could only achieve energy system transformation if it reached a photovoltaic energy penetration rate of 30%–50%. While this assessment serves as a technical reference for R. Moldova's transition towards a carbon-neutral energy sector, the study also highlighted the country's extremely weak green power generation infrastructure. Three years later, the slow development of renewable energy in R. Moldova continues to hinder the large-scale adoption of hydrogen energy facilities. Expanding on this, Efremov C., Cernei M., and Leu V. (2022) pointed out that R. Moldova has taken key steps in energy transformation by designing an energy transition roadmap, including strengthening policy guidance and resource allocation. They has argued that R. Moldova possesses significant green energy potential, but as of now, several critical factors, the main being the insufficient development of renewable energy, remain obstacles to achieving energy transition goals. Regarding the economic feasibility of building hydrogen energy facilities, Comendant, I. Prepelita and L. Turcuman (2019) predicted how R. Moldova could achieve the basic requirements for 100% renewable energy transformation, the core issue was the constraints of technology and electricity prices.

Another key pillar of R. Moldova's energy strategy is integrating into the EU market through green energy trade. Sandu, M. (2022) focused on analysis of the R. Moldova's energy security within the context of international economic relations. The study emphasized that R. Moldova should actively engage in energy cooperation with EU countries to enhance energy security and diversify its supply sources. By expanding energy trade, R. Moldova could leverage the EU's technical and financial support to accelerate its energy transition. However, the study did not detail specific implementation plans for hydrogen energy - particularly how hydrogen energy technology could be optimized within energy cooperation to improve the country's energy structure. This gap highlights the need

for further research, and this paper will analyze the issue from a hydrogen energy perspective to refine the existing framework.

In the field of hydrogen energy applications, Stoicescu V., Vrabie C., and Bitoiu T. (2023) examined Romania's approach to industrial and value chain transformation toward sustainable practices. Their study proposed a conceptual framework for building a sustainable smart community through the "Hydrogen Valley" model. Romania's experience in utilizing regional resources to develop a hydrogen energy industry chain underscores the potential of hydrogen valleys in driving green economic growth and technological innovation. However, these studies do not address fiscal issues - such as how the construction of hydrogen plants could help alleviate financial pressures. R. Moldova lacks the necessary policy support to effectively promote its green energy transition.

Collectively, these studies explore R. Moldova's green energy development potential and strategic direction from multiple perspectives, yet they largely overlook the economic benefits associated with these transitions. One of R. Moldova's biggest challenges is the lack of national financial support and the long-term fiscal impact of such projects once they become operational. Additionally, the country's underdeveloped green energy infrastructure directly affects its power supply. Whether the construction of hydrogen energy plants can effectively stimulate demand for green energy remains an open question, highlighting significant research gaps in these two key areas.

Problem Discussion

Power-to-hydrogen (P2H) enables high-value energy conversion. Hydrogen energy trading is subject to EU regulations, which determine how R. Moldova produces hydrogen and whether it can participate in trading on the European Energy Exchange (EEX). If Moldova's hydrogen production does not comply with these regulations and cannot be traded, all investments and efforts will be ineffective.

The Key points to pay attention to: EU hydrogen energy trading regulations, technical methods for producing green hydrogen, electricity cost prices, hydrogen energy exchange prices and trends.

4.2 Can the hydrogen energy industry drive investment in green energy generation? To stimulate investment in green electricity through hydrogen energy, the first issue to address is the investment required for electrolysis plants - how much capital is needed, at what scale, and how long it will take to generate returns. These factors must be carefully calculated to ensure feasibility. Secondly, the amount of green electricity demand generated by hydrogen energy investments will determine how effectively private investment in green electricity can be encouraged and how much it can alleviate the financial burden on the Moldovan government.

The Key points to pay attention to: the scale of hydrogen energy plant investment, the profits generated by hydrogen energy investment, and how much green electricity demand is generated.

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Methodology

Regarding the above two issues, the study adopts an integrated techno-economic assessment that combines both **quantitative and qualitative methods** to evaluate the feasibility of the Republic of Moldova's integration into the EU green energy system through green hydrogen production. The core analytical tool is the Levelized Cost of Hydrogen (LCOH) model, which calculates the average lifecycle cost of hydrogen production per unit of energy (€/MWh). The model incorporates capital expenditures (CAPEX), operational expenditures (OPEX), and electricity costs, discounted over the expected lifespan of the electrolyzer system.

The analysis focuses on a comparative evaluation of two mainstream electrolysis technologies - Alkaline Water Electrolysis (AWE) and Proton Exchange Membrane Electrolysis (PEM) - assessed in terms of energy efficiency (ranging from 60% to 90%), energy consumption, and technological maturity. A standardized 5 MW hydrogen plant serves as the reference scenario, utilizing regionally relevant electricity price data from Moldova's domestic market and average rates under European Power Purchase Agreements (PPAs). In assessing market viability, the study incorporates real-time hydrogen trading prices from the European Energy Exchange (EEX) to establish a benchmark for potential returns on investment.

In addition to cost analysis, the methodological framework includes qualitative content analysis of EU policy documents, particularly a regulatory compliance review based on Directive (EU) 2023/2413. This directive outlines eligibility criteria for green hydrogen to be traded within the EU internal market. This dual-path approach - combining cost-effectiveness modeling with institutional and regulatory alignment - offers a multidimensional foundation for understanding Moldova's strategic potential to integrate into the EU hydrogen economy.

Problem Solving and Data Collection

EU Green Hydrogen Trading Regulations

The EU's Renewable Energy Directive-related bill, issued on February 13, 2023, clarifies the standards for tradable green hydrogen (EU, 2023/2413). In terms of production scenarios, it covers three modes: direct connection between renewable energy facilities and hydrogen production equipment, grid-powered production in areas with a high proportion of renewable energy, and grid-powered production after signing power purchase agreements in areas with low carbon dioxide emissions (Table 1). In terms of quantitative assessment, the renewable hydrogen fuel threshold must not exceed 28.2 grams of carbon dioxide equivalent per megajoule (3.4 kilograms of carbon dioxide equivalent per kilogram of hydrogen), and the calculation method for greenhouse gas emissions from co-production in fossil fuel facilities is specified.

R. Moldova currently meets the first and third requirements for the production of "renewable hydrogen." Specifically, hydrogen production is achieved by directly connecting renewable energy facilities with hydrogen production equipment. This means that wind and

photovoltaic power generation facilities can be directly linked to water electrolysis equipment to produce green hydrogen. Although this method is technically feasible, Moldova's green power generation capacity is insufficient to meet domestic demand, let alone the electricity required for hydrogen production.

Table 1. EU regulation conceptualization of green hydrogen production scenario standards

Production scenario	Regulation conceptualization
Direct connection to new energy power generation facilities to produce hydrogen	Hydrogen produced by direct connection between renewable energy production facilities and hydrogen production equipment can be counted as "renewable hydrogen". For example, hydrogen produced by direct connection between wind power facilities and water electrolysis hydrogen production equipment.
Hydrogen production using power grid in areas with a high proportion of renewable energy	In areas where the proportion of renewable energy exceeds 90%, hydrogen produced using power grid power also meets the standards.
Signing an agreement for power supply and production in restricted emission areas	In areas with low CO2 emission restrictions, after signing a renewable energy power purchase agreement, using grid power to produce hydrogen can also be considered "renewable hydrogen"

Source: developed by the authors with accordance to regulations (EU, 2023/2413)

The gap in renewable energy generation significantly limits the possibility of large-scale adoption in the short term. However, hydrogen energy plants can create demand for green electricity and potentially stimulate private investment. The third method can be implemented through the European Green Power Purchase Agreement (PPA). Given its economic feasibility, this approach is preferred in the following discussion as a means of supplying green electricity.

European Green Power Purchase Agreement (PPA)

As a key mechanism in Europe's renewable energy sector, the European Green Power Purchase Agreement (PPA) is of great significance to promoting energy transformation (Acer, 2024). It is defined as an agreement reached between the developer or operator of a renewable energy power generation project and the green power purchaser, under which the purchaser buys green power at a uniform price within a specified period. PPA is mainly divided into direct or physical power purchase agreement (DPPA) and virtual or financial power purchase agreement (VPPA). From the transaction process, it involves the power purchaser's request for proposal, the power seller's quotation, the drafting of the terms list, contract negotiation, signing and project implementation. The latest data shows that in the third quarter of 2024, the price of solar and wind power fell month-on-month to 63.64 euros/MWh and 88.7 euros/MWh, with an average of 76.17 euros/MWh (LevelTen Energy, 2024). It is expected that in the future, due to the grid connection of newly commissioned power generation units, prices will fall further (Figure 2).

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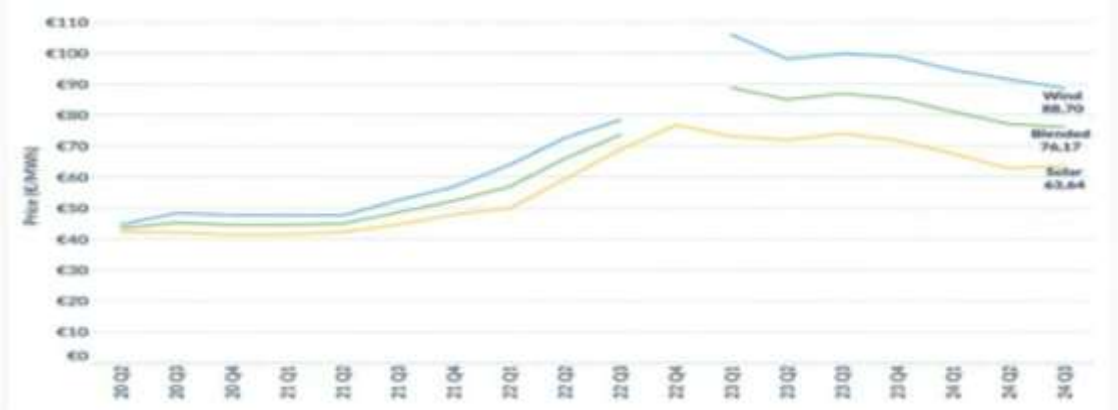

Figure 2. European green power purchase agreement prices (PPA) - Q3, 2024

Source: LevelTen Energy. (2024). https://www.leveltenenergy.com/post/levelten-u-q3-2024-ppi

Methods for producing green hydrogen

Hydrogen production technology includes three main methods: alkaline water electrolysis to produce hydrogen (AWE), using an electrolyzer to separate the positive and negative electrodes, with high maturity, low cost, and an efficiency of 60%-75%; proton exchange membrane water electrolysis (PEM) to produce hydrogen, using proton exchange membrane as electrolyte, with an efficiency of 70%-90%, high hydrogen purity, but high cost; solid oxide water electrolysis (SOEC) to produce hydrogen, using the oxygen ion conductivity characteristics at high temperatures of 700-1000℃, with a theoretical efficiency of more than 90%, but the technology is complex and is still in the laboratory stage (Table 2) (Ni 2022; Wang, 2023; Davies et al., 2021).

Table 2. Comparison of electrolysis hydrogen production technologies

	Alkaline (AWE)	**Proton exchange membrane (PEM)**	**Solid oxide (SOEC)**
Purit	≥99.8	≥99.999	Laboratory researching
Electrolyte	20%-30% (mass fraction) KOH/NaOH	PEM	Y2O3/ZrO2
Operating temperature	70-90 ℃	70-80℃	600-1000℃
Electrolysis efficiency	60-75 %	70-90 %	≥90 %
Energy consumption	4.5-5.5 kWh/Nm³	3.8-5.0 kWh/Nm³	2.6-3.6 kWh/Nm³
Operation characteristics	Quick start and stop	Quick start and stop	Difficulty in starting and stopping
Commercial features	Most mature, large-scale production, high degree of commercialization, no precious metal catalysts, low cost	High cost (proton exchange membrane, metal catalysts such as platinum and iridium), no pollution, low level of industrialization	R&D and demonstration phase

Source: developed by the authors based on Ni, Z. (2022, Wang, W. (2023), Davies, J., Dolci, F., & Weidner, E. (2021)

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Cost of producing green hydrogen

The cost assessment of European electrolyser technologies in 2023 shows distinct financial characteristics. The capital expenditure (CAPEX) of alkaline electrolysers is estimated at 1666 EUR/kW and the operating expenditure (OPEX) is 43 EUR/kW/year. In contrast, the cost structure of proton exchange membrane (PEM) electrolysers is relatively high, with capital expenditure (CAPEX) estimated at 1970 EUR/kW and operating expenditure (OPEX) at 64 EUR/kW/year (Figure 3).

Figure 3. Electrolyser maintenance costs and fixed costs in comparison, 2023

Source: European Hydrogen Observatory (2024).

The electrolyser capital expenditure (CAPEX) costs of both technologies are divided into three categories, including the electrolyser itself, auxiliary facilities (BoP) and other engineering, procurement and construction costs (Other EPC) (Figure 4).

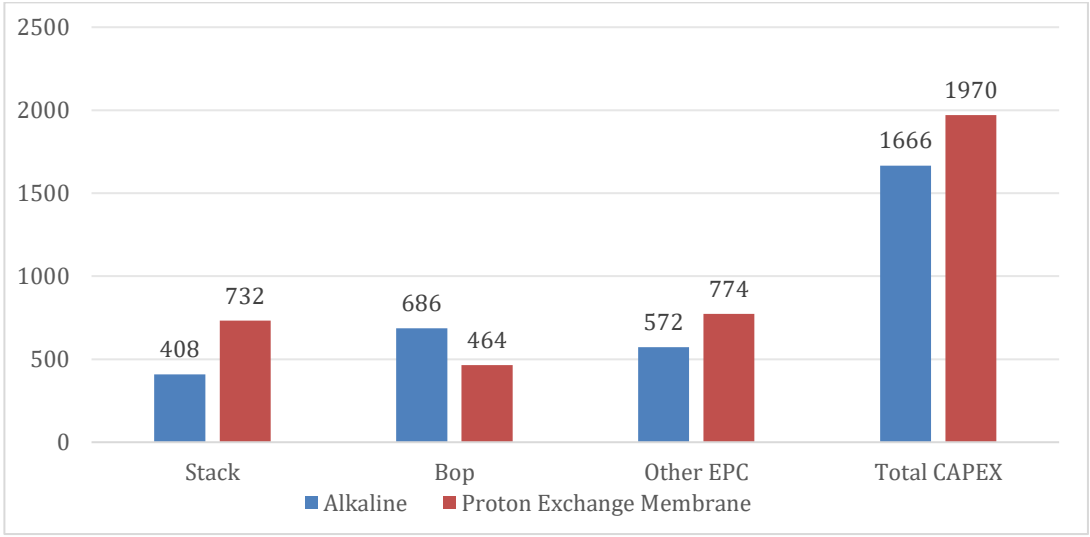

Figure 4. Capital expenditure costs of electrolyzers in 2023, €/kw

Source: European Hydrogen Observatory (2024).

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Hydrogen Energy Exchange

Founded in 2002 and headquartered in Leipzig, Germany, the European Energy Exchange (EEX) is one of the leading energy trading platforms in Europe and even the world. The EEX provides trading services for a variety of contracts such as electricity, natural gas, carbon emission rights, freight and agricultural products for the international commodity market. As part of the EEX Group, EEX is committed to building a safe, successful and sustainable global green energy commodity market. In the field of hydrogen energy, EEX is the first exchange in the world to launch hydrogen commodities to promote competition among enterprises, reduce the cost of hydrogen energy manufacturing, and popularize the use of hydrogen energy. The hydrogen trading market is operated by Hintco (market maker), which consists of more than 50 European companies, including ArcelorMittal and BNP Paribas. The EEX is expected to provide operating system support, which will strongly promote the green energy transformation in Europe (Hintco, 2024).

The EEX Hydrogen Index is based on a supply and demand model. Since the launch of the index, price volatility has increased, and as of January 24, 2025, the price has reached 286 euros/MWh (Figure 5).

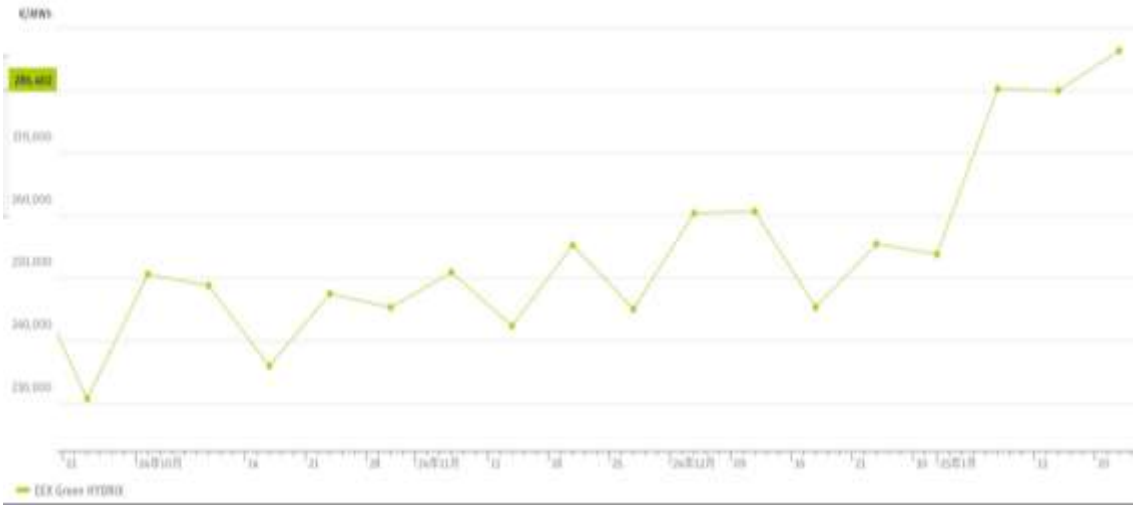

Figure 5. EEX - Hydrogen Energy Trading Price, January 24, 2025 (Euro/MWh)

Source: EEX Exchange. (2025).

It is expected that as the hydrogen energy gap continues to expand in the future, prices will rise further (Figure 6).

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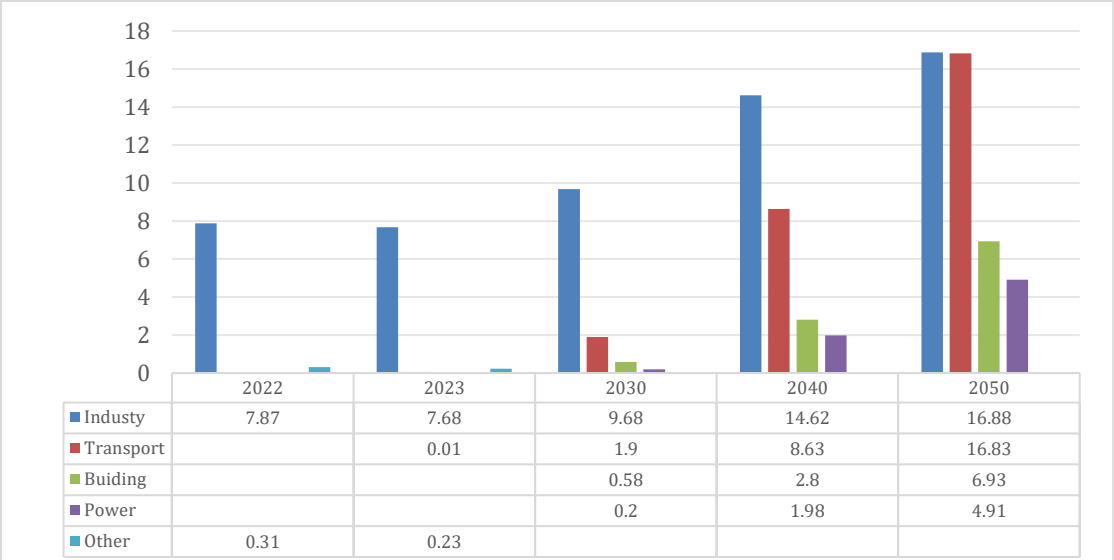

	2022	2023	2030	2040	2050
Industy	7.87	7.68	9.68	14.62	16.88
Transport		0.01	1.9	8.63	16.83
Buiding			0.58	2.8	6.93
Power			0.2	1.98	4.91
Other	0.31	0.23			

Figure 6. Average projected hydrogen demand by industry in 2030, 2040 and 2050 under different scenarios, Mt/year

Source: European Hydrogen Observatory (2024).

Global electrolysis plant installed capacity

Across Europe, water electrolysis projects are of different sizes. It is worth noting that there are 3 projects with a capacity of 10 MW or more, which together account for 21% of the total water electrolysis capacity, totaling 50 MW. In addition, there are 12 projects with an electrolysis capacity of 5-10 MW, which together account for 33% of the total electrolysis capacity in the region, with a cumulative capacity of 77.8 MW (European Hydrogen Observatory, 2024). In addition, there are 51 projects with an installed capacity of 1-5 MW, which contribute significantly to the total installed capacity, accounting for 40% (95.19 MW), so 1-5 MW is the mainstream (Figure 7).

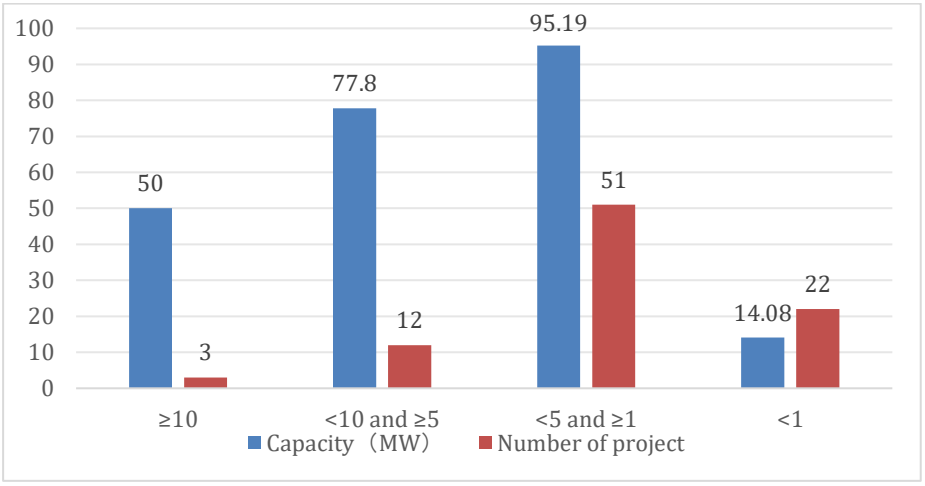

Figure 7. Electrolyser capacity and number of projects, *MW-Number of Project*

Source: European Hydrogen Observatory (2024).

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However, as the gap between hydrogen demand and supply in Europe widens, hydrogen energy plants with an installed capacity of 100MW and above are being planned and started, such as the Reni Hydrogen Valley in Odessa, Ukraine. Because it is close to R. Moldova, it has important reference significance (Figure 8). Therefore, according to the trend, it is planned to be more than 100MW in the future.

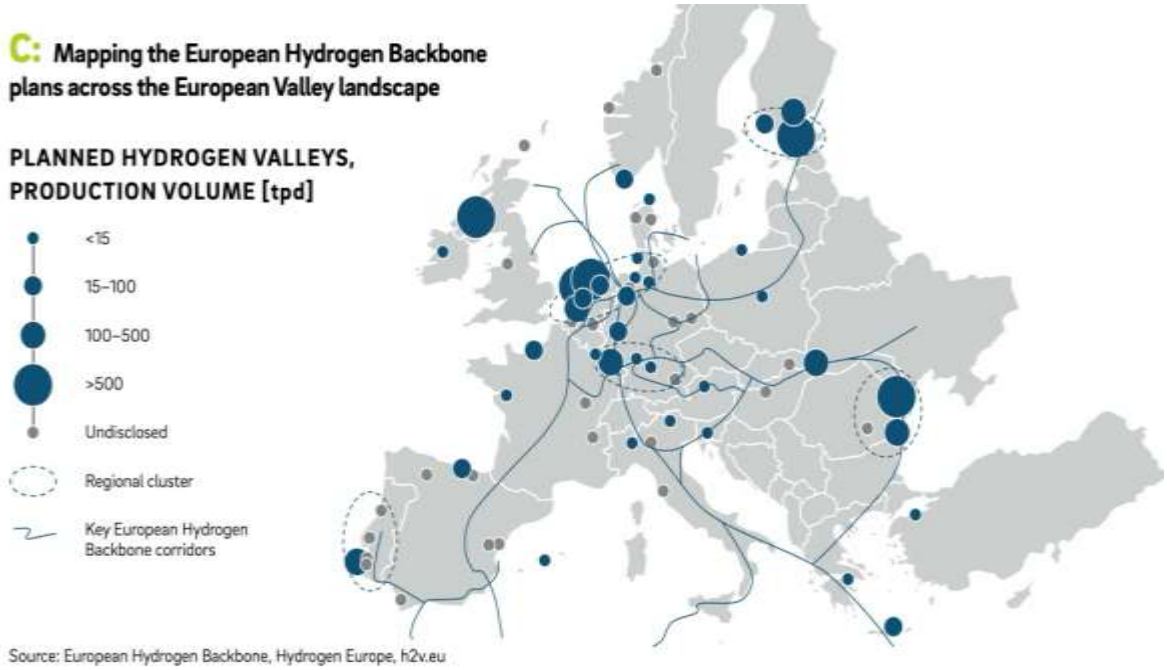

Figure 8. European Hydrogen Backbone Map

Source: Weichenhain et al (2024)

The significance and enlightenment of Ukraine's Reni H_2 Valley

H2U Hydrogen Valley - Reni is a strategically important hydrogen energy project in Odessa, Ukraine, located around the city of Reni in the Odessa region. It was supported by the Ukrainian Ministry of Energy. The project has joined hands with Bilfinger Tebodin and other professional institutions to conduct feasibility studies on hydrogen production, hydrogen transmission pipelines, and wind and solar farm construction (Hydrogen Ukraine LLC, 2023).

The project plans to build a renewable hydrogen plant with an initial electrolysis capacity of 100 MW and an output of 210 tons/year. The long-term goal is to increase the production capacity to 3 GW, when the annual hydrogen production is expected to reach 210,000 tons. In terms of industrial chain layout, hydrogen is produced through proton exchange membrane electrolyzers (PEM), involving multiple storage and transportation methods. At present, the project has completed technical and economic calculations and front-end engineering design, and is currently conducting feasibility studies. The Odessa Reni Hydrogen Valley project has a far-reaching impact on Ukraine's energy transformation, economic development, energy security and environmental protection, and is a key measure

to promote regional sustainable development (Hydrogen Ukraine LLC, 2023). Because of many similarities such as Odessa's geographical location, it provides a reference for Moldova's hydrogen energy construction.

Data collection and calculation

The difference between high calorific value and low calorific value of hydrogen is mainly due to the different states of the generated product water. In the case of high calorific value, the combustion product water is liquid, while in the case of low calorific value, the water is gaseous. It takes heat to change from liquid water to gaseous water, so the high calorific value is bigger than the low calorific value. High calorific value (liquid water) is 142 kJ/g, low calorific value (gaseous water) is 120 kJ/g (Aravindan et al., 2023).

$$2H_2 + O2 \rightarrow 2H_2O \quad (1)$$

In actual application, 1 kg of hydrogen is often taken as equivalent to 33.33 kWh, which is a more practical approximate value obtained after comprehensive consideration of various practical factors (Singh et al., 2021). The following table is obtained by sorting out the above text and related data. (Table 3).

Table 3. Hydrogen physical data, Production technology and cost, Electricity price

Average calorific value of hydrogen	120MJ/KG (approximate value for general engineering)	
H2 Numeric conversion	1 MWh =30 Nm3	
	Alkaline (AWE)	Proton exchange membrane (PEM)
Fixed costs (CAPEAX)	1666 € / KW	1970 € / KW
Maintenance cost (OPEX)	43 € / KW / Year	64 € / KW / Year
Electricity costs	Electricity price in R. Moldova: 3.29 MDL / KWh ≈ 167€/MWh European PPA price: 76 € / MWh	
Technology life	About 10 Years (Approximately 90,000 hours at full load)	
Construction scale	5 MW (Authors' selection: current global average)	
Electrolyzer efficiency	60-75%	70-90%
Energy consumption (kWh·Nm3)	4.5-5.5 (Authors' selection: 5)	3.8-5.0 (Authors' selection: 4.5)
Hydrogen price (EEX)	286 € / MWh	

Source: composed by the authors based on references from Figure 3, Figure 7; Singh et al.(2021), Wei et al. (2024); Gerloff. (2021), Smolinka et al. (2022), Gao et al (2021); Monitorul Oficial al Republicii Moldova. (2025);AVIC Securities Research Institute (2024).

The levelized cost of hydrogen (LCOH) is an economic indicator that measures the average cost of hydrogen production over the entire life cycle, covering initial investment, operation and maintenance, fuel, depreciation and other costs, and helps compare the economic feasibility of different hydrogen production technologies. LCOH is obtained by dividing the total cost by the total hydrogen production after discount (see the formulas (2) and (3) (Clean Hydrogen Observatory, 2024; China Industrial Development Promotion Association, 2021). In Table 4, there is the analysis and calculation results of AWE and PEM by the LCOH method with the formulas, in comparison.

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$$\text{LCO（Levelized cost of hydrogen）} = \frac{\text{Fixed costs （CAPEX）}}{\text{H}_2\text{（capacity）} \times \text{Lifetime}} + \text{Maintenance cost (OPEX)} \quad (2)$$

$$\text{Maintenance cost (OPEX)} = \text{Energy consumption（KWh} \cdot \text{Nm}^3\text{）} \times \text{Price} + \text{Other cost} \quad (3)$$

Table 4. Levelized cost analysis LCOH - life 87,600 hours (10 years)

	Alkaline (AWE)		Proton Exchange Membrane (PEM)	
Power Consumption	4,380,000 MWh			
Electricity costs (76 € / MWh)	76 € / MWh 33,288,000 €			
Fixed costs (CAPEAX)	8,330,000 €		9,850,000 €	
Maintenance cost (OPEX)	2,150,000 €		3,200,000 €	
Total Cost	43,768,000 €		46,338,000 €	
	η=60%	η=75%	η=70%	η=90%
Hydrogen production	1,752,000 MWh	2,190,000 MWh	2,271,888 MWh	2,920,988 MWh
LCOH	24.98 € / MWh	19.99 € / MWh	20.40 € / MWh	15.88 € / MWh

Source: Authors' calculation

The levelized production cost of hydrogen energy is compared with other energy costs (Table 5) to estimate the range of construction costs (X) that need to be controlled. Finally, the cost-effectiveness of Moldova's entry into the European market through hydrogen energy and the possibility of replacing other energy sources are predicted.

Table 5. Comparison of the hydrogen LCOH with other fuel costs (1€ = 0.924 $)

Energy Name	Unit conversion	Price fluctuation range in 2024	Average price
Alkaline - LCOH		19.99-24.98 € / MWh	22.49 € / MWh
PEM – LCOH		15.88-20.40 € / MWh	18.14 € / MWh
Construction costs (land, plant)		X € / MWh	
International Energy Agency：3.0 - 4.3 $ / Kg		96.5-138.3 € / MWh	117.4€ / MWh
EEX Hydrogen Price		230-286 € / MWh	258 € / MWh
Average green electricity prices under European Power Purchase Agreements (PPA)		76-82 € / MWh	79 € / MWh
Brent Crude Oil Average Price: 68 - 93 $ / B	≈ 1.7 MWh / B	43.28-59.22 € / MWh	51.25 €/ MWh
ICE Newcastle Coal Price: 127-140 $ / T	≈ 6.7 MWh / T	20.54-22.65 € / MWh	21.60 €/ MWh
Natural gas main prices: 7.5-16 $ / MMbtu	≈ 0.293 MWh / MMBtu	27.7-59.1 € / MWh	43.4 €/ MWh

Source: Authors' calculation based on IEA (2022), MacroMicro. (2024), Revolut Ltd. (2025).

Compared with other energy sources, it can be seen that the production cost of hydrogen has a huge cost advantage, but the construction cost X (land cost, plant cost, etc.) directly affects the total cost of hydrogen, and further affects the sales profit of hydrogen. On this basis, the formulas (4) and (5) for building hydrogen costs (Y) and profits (Z) are:

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Total Cost: Y = LCOH H_2 (AWE or PEM)+ X (Construction cost) (4)

Total Profit: Z=Line (EEX-H_2) - Y (5)

Note: The X-axis is the construction cost (X) . The Y-axis is the price (€), (Figure 9).

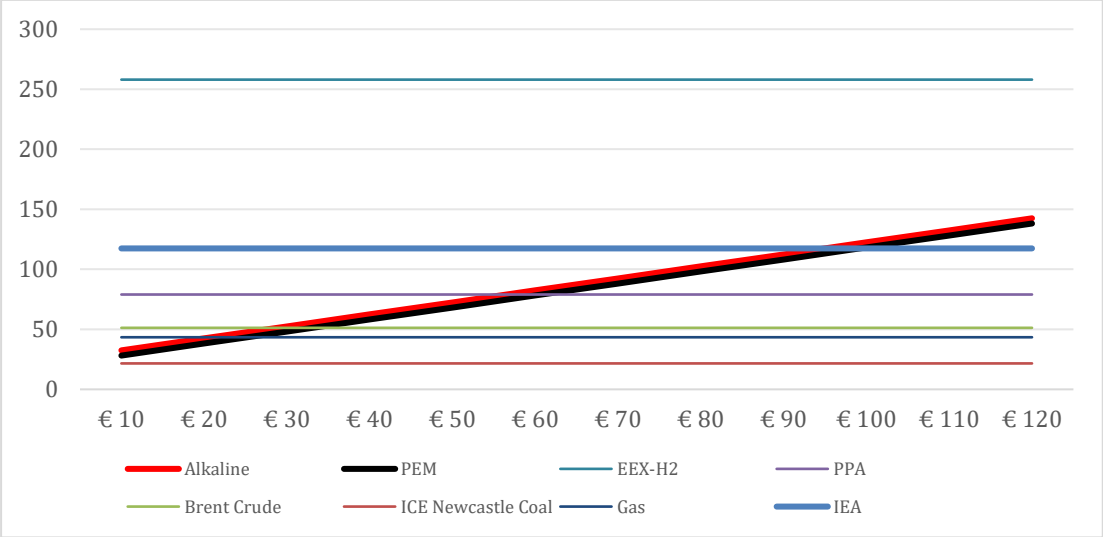

Figure 9. Impact of hydrogen plant construction costs (X)

Source: created by the authors

Based on Moldova's superior geographical endowment (dense rivers and flat terrain), its renewable energy infrastructure construction has significant cost advantages. This geographical feature not only improves the economic feasibility of the hydrogen energy industry by reducing the fixed cost investment threshold, but also strengthens the competitiveness of green hydrogen compared to traditional energy, providing key economic support for the transformation of the energy structure.

Conclusion

Under the global energy transition framework, R. Moldova is confronting severe energy shortages, with soaring prices of natural gas and electricity exerting significant pressure on its national economy. However, the EU's "Energy Transition and Strategic Autonomy", which drives member states to strengthen energy infrastructure development and accelerate energy transition while actively pursuing international cooperation to reduce dependence on Russian fossil fuels, has created strategic opportunities for R. Moldova. The EU's provision of financial assistance for green energy development offers R. Moldova a crucial pathway to align with the EU's green energy system. By advancing hydrogen energy technologies, expanding hydrogen production facilities, and engaging in the EU's green energy market through hydrogen fuel exports, R. Moldova could potentially achieve dual objectives of energy self-sufficiency and

economic stabilization. The following four considerations are the basis for achieving the goal of energy independence:

1. Economic feasibility and feasibility of hydrogen energy technology: By analyzing the costs in the production process through LCOH (levelized cost of hydrogen), R. Moldova has a certain degree of economic feasibility when using alkaline electrolyzer (AWE) and proton exchange membrane electrolyzer (PEM) technology to produce green hydrogen. However, fixed capital (X) investment directly affects the economic benefits of hydrogen energy. Therefore, the site selection and plant construction of hydrogen energy plants need to be considered, and reference can be made to the construction of different hydrogen valleys around the world to select reasonable standards. At the same time, reasonable maintenance can also increase the life of the electrolyzer and reduce depreciation costs.

2. The driving effect of hydrogen energy on the demand for green electricity: The demand for green electricity from hydrogen energy plants is huge. The construction of plants can not only directly produce green hydrogen, but also create demand for green electricity, thereby driving investment in renewable energy in R. Moldova. Through the electrolysis of water to produce hydrogen, R. Moldova can convert unstable wind and solar energy into storable hydrogen, thereby achieving efficient utilization and storage of energy. This will not only help alleviate the problem of energy shortage, but also promote the development of the domestic green energy industry and reduce dependence on imported fossil energy.

3. Potential for integration into the EU green energy system: R. Moldova can gradually integrate into the EU green energy system by developing hydrogen energy, especially green hydrogen production. The EU's demand for green hydrogen is growing, and its hydrogen energy trading market (such as EEX) provides R. Moldova with the opportunity to export hydrogen. At the same time, it makes profits for the Moldovan government and alleviates fiscal and energy pressures. Although Moldova's green power infrastructure is currently weak, through the construction of hydrogen energy plants, its green energy production capacity can be gradually improved, thereby meeting the EU's demand for green hydrogen.

4. R. Moldova will face the challenge of high requirements of hydrogen regulations: The EU has strict regulations on hydrogen energy trading. R. Moldova can only meet the requirement of directly connecting renewable energy production facilities with hydrogen production equipment to qualify as producing "renewable hydrogen." However, due to the low proportion of renewable energy in its power grid, it fails to meet the other two criteria. If the hydrogen produced does not comply with EU standards, it will be ineligible for trading on the European Energy Exchange (EEX), rendering the initial investment futile.

Suggestion

Based on the above four considerations, strong policy support and international cooperation are essential for R. Moldova's hydrogen energy development. The EU's "Energy Independence Plan REPowerEU" and "European Hydrogen Bank Plan" offer financial and technical support opportunities. Additionally, by strengthening energy infrastructure and

collaborating with neighboring countries such as Romania, R. Moldova can accelerate the development and utilization of green energy. Based on the author's thinking, the development of hydrogen energy in the Republic of Moldova should consider the long-term timeline, so the author makes the following suggestions:

Short-Term Recommendations:

- Launch a 5MW hydrogen demonstration project through fiscal subsidies and competitive public tenders;
- Introduce Green Power Purchase Agreements (PPAs) to ensure a stable electricity supply for hydrogen production;
- Upgrade renewable energy infrastructure to increase the share of green electricity in the national energy mix.

Long-Term Strategies:

- Promote domestic development of hydrogen technologies by encouraging R&D activities in universities and industrial enterprises;
- Align national hydrogen production and regulation frameworks with the EU's hydrogen trading standards, particularly those outlined in Directive (EU) 2023/2413;
- Develop an export-oriented hydrogen economy by enabling participation in the European Energy Exchange (EEX), thereby establishing Moldova as a regional green fuel supplier.

Thus, with the growing global demand for green energy, hydrogen - as a clean and efficient energy carrier - is expected to play a crucial role in the future energy system. By developing hydrogen energy technology, R. Moldova can not only mitigate its current energy crisis but also lay the foundation for a long-term green energy transition, securing a place in Europe's green energy landscape. The construction of hydrogen production facilities in R. Moldova will drive demand for green electricity, stimulate domestic renewable energy investment, and accelerate Moldova's integration into the EU's green energy system. Despite technical and financial challenges, with policy support, international cooperation, and technological innovation, R. Moldova has the potential to establish a significant presence in the future green energy market while achieving energy independence and sustainable economic growth.

References

Agency for the Cooperation of Energy Regulators. (2024, October 10). *No need for more power purchase agreement templates (PPAs).* https://www.acer.europa.eu/news/no-need-more-power-purchase-agreement-templates

Aravindan, M., Hariharan, V. S., Narahari, T., Kumar, A., Madhesh, K., Kumar, P., & Prabakaran, R. (2023). Fuelling the future: A review of non-renewable hydrogen production and storage techniques. *Renewable and Sustainable Energy Reviews, 188,* Article 113791. https://www.sciencedirect.com/science/article/abs/pii/S1364032123006482

Clean Hydrogen Observatory. (2024, June). *Levelised cost of hydrogen (LCOH) calculator manual.* https://observatory.clean-hydrogen.europa.eu/sites/default/files/2024-06/Manual%20-%20Levelised%20Cost%20of%20Hydrogen%20%28LCOH%29%20Calculator.pdf

Comendant, I., Prepelita, I., & Turcuman, L. (2019, October). Identifying the opportunity to meet the Republic of Moldova electricity demand by combining renewable energy sources and energy storage systems. In *2019 International Conference on Electromechanical and Energy Systems (SIELMEN)* (pp. 1–6). IEEE.

Davies, J., Dolci, F., & Weidner Ronnefeld, E. (2021). *Historical analysis of FCH 2 JU electrolyser projects* (EUR 30648 EN). Publications Office of the European Union. https://doi.org/10.2760/951902

Efremov, C., Arion, V., & Sanduleac, M. (2021, October). Short-term daily storage need assessment for a large PV deployment scenario: Preliminary case study for Republic of Moldova. In *2021 10th International Conference on Energy and Environment (CIEM)* (pp. 1–5). IEEE.

Efremov, C., Cernei, M., & Leu, V. (2022). Sustainable energy transition roadmap to 2050 for Republic of Moldova. *EMERG, 8*(3). https://emerg.ro/wp-content/uploads/2022/10/1-SUSTAINABLE-ENERGY-TRANSITION-ROADMAP-TO-2050-FOR-REPUBLIC-OF-MOLDOVA.pdf

European Commission. (2022). *REPowerEU: Affordable, secure and sustainable energy for Europe.* https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en

European Commission. (2023). *European Clean Hydrogen Alliance road map on standardisation.* Publications Office of the European Union. https://ec.europa.eu/docsroom/documents/53721

European Commission. (2024a, November 7). *Speech by President von der Leyen at the Fourth Edition of the Renewable Hydrogen Summit (video message).* https://ec.europa.eu/commission/presscorner/detail/en/speech_24_5725

European Commission. (2024b, February 2). *Roadmap for energy market reforms agreed and support for Moldova reaffirmed: 5th EU–Moldova high-level energy dialogue.* European External Action Service. https://www.eeas.europa.eu/delegations/moldova/roadmap-energy-market-reforms-agreed-and-support-moldova-reaffirmed-european-commission-5th-eu_en

European Commission. (2025, February 4). European Commission and Moldova agree on a 2-year comprehensive strategy for energy independence and efficiency. https://enlargement.ec.europa.eu/news/european-commission-and-moldova-agree-2-year-comprehensive-strategy-energy-independence-and-2025-02-04_en

European Commission Directorate-General for Energy. (2022). *Hydrogen in the EU's energy system.* European Union. https://energy.ec.europa.eu/topics/eus-energy-system/hydrogen_en

European Economic and Social Committee. (2022). *Strategic vision for the energy transition to enable the EU's strategic autonomy* (Opinion No. NAT/849). https://www.eesc.europa.eu/en/our-work/opinions-information-reports/opinions/strategic-vision-energy-transition-enable-eus-strategic-autonomy

European Energy Exchange AG. (2025). *About EEX*. https://www.eex.com/en/about-eex/eex-ag

European Hydrogen Observatory. (2024, November). *The European hydrogen market landscape*. https://observatory.clean-hydrogen.europa.eu/sites/default/files/2024-11/The%20European%20hydrogen%20market%20landscape_November%202024.pdf

European Union. (2023). *Directive (EU) 2023/2413 … promotion of energy from renewable sources. Official Journal of the European Union, L 2023/2413*. https://eur-lex.europa.eu/eli/dir/2023/2413/oj

European Union. (2024a). *Directive (EU) 2024/1788 … internal markets for renewable gas, natural gas and hydrogen. Official Journal of the European Union, L 2024/1788.* https://eur-lex.europa.eu/eli/dir/2024/1788/oj

European Union. (2024b). *Regulation (EU) 2024/1789 … internal markets for renewable gas, natural gas and hydrogen. Official Journal of the European Union, L 2024/1789.* https://eur-lex.europa.eu/eli/reg/2024/1789/oj

Gao, X., Zheng, K., Cai, C., Fan, Y., & Kuang, J. (2021). 氢储能用于核电调峰经济性研究 [Economic analysis of hydrogen energy storage for nuclear power peak shaving]. *南方能源建设*, 8(4), 1–8.

Gerloff, N. (2021). Comparative life-cycle-assessment analysis of three major water electrolysis technologies while applying various energy scenarios for a greener hydrogen production. *Journal of Energy Storage*, *43*, Article 102759. https://www.sciencedirect.com/science/article/abs/pii/S2352152X21004874

Government of the Republic of Moldova. (2025, February 26). Moldovan government approved electricity compensation, included directly in bills, starting from February 2025. https://gov.md/en/content/moldovan-government-approved-electricity-compensation-included-directly-bills-starting

Hintco. (2024, September). *Creating clean commodity markets to accelerate the energy transition.* https://cdn.sanity.io/files/u4w9plcz/production/8506bc6f24909ba96b6748f3fb0b28ab914607da.pdf

H2InfraMap. (2024, Q4). *Hydrogen infrastructure map*. https://www.h2inframap.eu/#map

Hydrogen Ukraine LLC. (2023). *Projects – Odesa*. https://uabio.org/wp-content/uploads/2023/09/S2_9_Riepkin-Kryl_POWERING-THE-FUTURE_UKRAINES-HYDROGEN-INITIATIVES.pdf

Hydrogen Ukraine LLC. (2023, September 18). Hydrogen energy in the Republic of Moldova: The plan for the development of the industry and prospects for strengthening the country's energy security. https://h2u.ua/en/hydrogen-energy-in-the-republic-of-moldova-the-plan-for-the-development-of-the-industry-and-prospects-for-strengthening-the-countrys-energy-security

International Energy Agency. (2022). *Global hydrogen review 2022*. OECD Publishing. https://www.iea.org/reports/global-hydrogen-review-2022

International Energy Agency. (2024, June 6). Hydrogen and CCUS investment to soar in 2024, risks remain: IEA. *S&P Global Commodity Insights.* https://www.spglobal.com/commodity-insights/en/news-research/latest-news/energy-transition/060624-hydrogen-and-ccus-investment-to-soar-in-2024-risks-remain-iea

Liu, Z., Yan, Z., & Hou, Y. (2022). 俄乌冲突对世界能源发展的影响与启示 [Impact and

implications of the Russia–Ukraine conflict on global energy development]. *全球能源互联网*, 5(4), 309–317.

MacroMicro. (2024). *Different energy price chart.* https://sc.macromicro.me/charts/889/commodity-brent

McCollum, D., Zhou, W., Bertram, C., De Boer, H., Bosetti, V., Busch, S., Després, J., Drouet, L., Emmerling, J., Fay, M., Fricko, O., Fujimori, S., Gidden, M., Harmsen, J., Huppmann, D., Iyer, G., Krey, V., Kriegler, E., Nicolas, C., … & Riahi, K. (2018). Energy investment needs for fulfilling the Paris Agreement and achieving the Sustainable Development Goals. *Nature Energy, 3*(7), 589–599. https://publications.jrc.ec.europa.eu/repository/handle/JRC108794

Ministry of Energy of the Republic of Moldova. (2025, March 14). Ministry of Energy launched the first auction for the construction of wind and solar parks with a total capacity of 165 MW. https://energie.gov.md/ro/content/ministerul-energiei-lansat-prima-licitatie-pentru-constructia-parcurilor-eoliene-si

National Bureau of Statistics of the Republic of Moldova. (2024). *Energy balance of the Republic of Moldova, editions 2007–2024.* https://statistica.gov.md/files/files/publicatii_electronice/balanta_energetica/Balanta_energetica_editia_2024_en.pdf

National Energy Regulatory Agency of the Republic of Moldova. (2025, January 3). *Board of Directors Decision No. 13: Approval of regulated prices for electricity supply to S.A. "Furnizarea Energiei Electrice Nord".* https://anre.md/storage/upload/administration/hcareports/3876/HCA%20nr.%2013%20din%2003.01.2025.pdf

Ni, Z. (2022). *Public utility industry-Hydrogen energy industry series report (III): In-depth analysis of hydrogen production costs and investment opportunities in the hydrogen era.* Topsperity Securities Research Institute. https://pdf.dfcfw.com/pdf/H3_AP202210071578934755_1.pdf

Pamfile, L. V. (2024). Prospects for Romania to become the main energy exporter to the Republic of Moldova. *EMERG: Energy. Environment. Efficiency. Resources. Globalization, 10*(1), 1–12.

Pleshivtseva, Y., Derevyanov, M., Pimenov, A., & Rapoport, A. (2023). Comparative analysis of global trends in low-carbon hydrogen production towards the decarbonization pathway. *International Journal of Hydrogen Energy, 48*(83), 32191–32240.

Poladyan, A., Baghdasaryan, L., & Trchounian, A. (2018). *Escherichia coli* wild-type and hydrogenase mutant cells growth and hydrogen production upon xylose and glycerol co-fermentation in media with different buffer capacities. *International Journal of Hydrogen Energy, 43*(33), 15870–15879.

Prețuri reglementate. (2025). [Regulated prices]. *Monitorul Oficial al Republicii Moldova*, 5–7. https://premierenergy.md/wp-content/uploads/2025/01/Preturi_reglementate_2025.pdf

Revolut. (2025, March). USDT to EUR exchange rate. https://www.revolut.com/crypto/price/usdt/eur/?amount=10000

Ryon, E. (2020). European strategic autonomy: Energy at the heart of European security? *European View, 19*(2), 238–244.

Sabbaghian, A., & Rasooli, R. (2021). Stability analysis of Russia-EU energy relations after the Ukraine crisis: An interdependence theory perspective. *Central Eurasia Studies, 14*(1), 177–201.

Sandu, M. (2022). The need for integration of the energy complex of the Republic of Moldova into the European energy system in the context of energy security. *Journal of Research on Trade, Management and Economic Development, 17*(1), 50–62.

Singh, R., Singh, M., & Gautam, S. (2021). Hydrogen economy, energy, and liquid organic carriers for its mobility. *Materials Today: Proceedings, 46*, 5420–5427.

Smolinka, T., Bergmann, H., Garche, J., & Kusnezoff, M. (2022). The history of water electrolysis from its beginnings to the present. In *Electrochemical power sources: Fundamentals, systems, and applications* (pp. 83–164). Elsevier.

Stoicescu, V., Vrabie, C., & Bitoiu, T. (2023). Energy ecosystems layered over hydrogen valleys for sustainable smart communities: Strategic framework for the Green Deal Industrial Plan implementation in Romania. In *Smart Cities International Conference (SCIC) Proceedings* (Vol. 11, pp. 443–498). Pro Universitaria Publishing House.

U.S. International Trade Administration. (2024, March 8). *Moldova country commercial guide.* https://www.trade.gov/country-commercial-guides/moldova-energy

Wang, W. (2023). 氢能产业专题研究报告（III）：**制**氢电解槽，绿电制氢快速发展，电解槽产业化加速 [Hydrogen energy industry special research report (III): Hydrogen production electrolyzers, rapid development of green power hydrogen production, and accelerated industrialization of electrolyzers]. ***国信****证券研究所.* https://pdf.dfcfw.com/pdf/H3_AP202307071592103693_1.pdf

Wei, X., Sharma, S., Waeber, A., Wen, D., Sampathkumar, S. N., Margni, M., & Maréchal, F. (2024). Comparative life-cycle analysis of electrolyzer technologies for hydrogen production: Manufacturing and operations. *Joule, 8*(12), 3347–3372.

Weichenhain, U., Kaufmann, M., Pfister, J., Scheiner, M., & Rubio Redondo, M. (2024, June). *Hydrogen valleys: Progress in an evolving sector.* European Commission. https://horizoneuropencpportal.eu/sites/default/files/2024-06/chju-hydrogen-valleys-progress-in-an-evolving-sector-2024.pdf

Yao, Y. (2024). **海外**氢能专题之行业篇（一）欧洲：制储运用政策完**善**，**碳税落地加速**绿氢平价 [Overseas hydrogen energy special report (I) – Europe: Comprehensive policies for production, storage, transportation, and utilization; carbon tax accelerates green hydrogen parity]. ***国金****证券研究所.* https://pdf.dfcfw.com/pdf/H3_AP202406241636809538_1.pdf

Zhao, Z., & Wang, G. (2023). **美欧**氢能发展战略及对我国的启示 [Development strategies of hydrogen energy in the US and Europe and their implications for China]. ***南方能源建****设*, 10(3), 97–103.

中国氢能促进会. (2021). **探究**绿氢降本之路 [Exploring the cost-reduction path of green hydrogen]. ***中国****氢能源产业促进联盟.* https://www.cn-heipa.com/newsinfo/1927440.html

中航证券研究所. (2024, July 30). **行**业报告：氢能产业深度报告（1）[Industry report: In-depth report on the hydrogen energy industry (1)]. *AVIC Securities Research Institute.* https://pdf.dfcfw.com/pdf/H301_AP202407301638485316_1.pdf

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THE DEVELOPMENT OF SOLAR ENERGY AND ITS EFFECTS ON REDUCING IMPORT DEPENDENCY IN THE REPUBLIC OF MOLDOVA

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Abstract: *The purpose of this study is to analyze the evolution and current state of solar energy development in the Republic of Moldova, with a particular focus on its role in reducing dependence on imported energy resources. The study identifies two key findings: (1) the implementation of 434 MW of solar capacity could reduce electricity imports by approximately 16.5%, and (2) domestic production could increase from 27% to 39% of national consumption, strengthening energy security. A review of recent literature highlights that while Moldova has made progress in developing solar energy capacities, practical applications of decentralized and hybrid systems remain limited, with significant potential for expansion. The actual level of research and achievements in the field shows that Moldova is at an early-to-intermediate stage, with ongoing pilot projects, emerging regulatory frameworks, and increasing public and private investments. This research evaluates Moldova's solar energy potential based on climatic and geographic data, examines existing policies and regulatory frameworks, and analyzes current investments and projects in the photovoltaic sector. The paper proposes concrete measures to stimulate the expansion of solar infrastructure, including financial incentives, public-private partnerships, and technological innovation. Ultimately, this study contributes to the development of a more sustainable, resilient, and energy-independent future for the Republic of Moldova*

Keywords*: solar energy, energy independence, energy imports, sustainability, energy efficiency, climate change.*

JEL Classification*: Q42, Q43, Q48, O13, H54*

UDC: 620.92(478)

Introduction

In the current context of climate change and growing concerns about energy security, the development of renewable energy sources has become a global priority. The Republic of Moldova, being a state with a significant dependence on energy imports, faces major challenges in ensuring a sustainable and resilient energy system. In this sense, solar energy represents a viable solution for diversifying the national energy mix, reducing economic vulnerabilities and increasing energy independence.

Diversification of the national energy mix. The integration of solar energy into the energy mix of the Republic of Moldova contributes to reducing the share of imported fossil sources (currently about 70-73% of electricity comes from imports) and to increasing the share of renewable sources. By the end of 2024, solar energy accounted for 68% of the total

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renewable energy sources in the country, with a capacity of 394.90 MW. Thus, solar energy adds a domestic, renewable, and stable component to the national energy mix.

Reducing economic vulnerabilities. Solar energy helps reduce costs associated with energy imports, thereby lessening the negative impact on the trade balance and the national budget. For example, the implementation of photovoltaic mini-parks with a capacity of 434 MW would reduce electricity imports by approximately 16.5%, lowering dependence on international price fluctuations for gas and electricity. As a result, the economy becomes more resilient to external shocks.

Increasing energy independence. By increasing domestic production capacity from solar sources (from 27% to 39% of national consumption, according to the analyzed scenario), the Republic of Moldova reduces its dependence on external sources, strengthening its energy security. Solar energy, being local and inexhaustible, provides a greater degree of national control over the energy source, reducing exposure to external geopolitical and economic risks.

The massive dependence on imports constitutes a considerable financial burden: the costs of purchasing natural gas, petroleum products and electricity from abroad have a direct impact on the trade balance and the national budget.

The massive dependence on imports constitutes a considerable financial burden: the costs of purchasing natural gas, petroleum products and electricity from abroad have a direct impact on the trade balance and the national budget. For example, in 2023, the Republic of Moldova consumed approximately 4.33 TWh of electricity, of which only 1.17 TWh (around 27%) was produced domestically, while the remaining 3.16 TWh (approximately 73%) was covered through imports. Assuming an average import price of 100 EUR per MWh, this resulted in an annual expenditure of about 316 million EUR solely for imported electricity.

In addition, natural gas imports represented an even larger financial burden. During the 2022–2023 period, Moldova paid prices that sometimes exceeded 1,000 USD per 1,000 cubic meters of natural gas. Given the country's annual consumption of around 1 billion cubic meters, the total cost for imported gas alone could reach approximately 1 billion USD per year.

These expenditures contribute significantly to the trade deficit. In 2023, Moldova's trade balance deficit exceeded 4 billion USD, with energy imports (including electricity, gas, and petroleum products) accounting for an estimated 25% to 30% of this deficit. As such, the reliance on imported energy sources not only strains the national budget but also amplifies the country's economic vulnerability to external price fluctuations and geopolitical risks.

Reducing imports by replacing part of consumption with domestically produced energy (from solar sources) could reduce national energy expenditure and vulnerability to the volatility of external markets.

Recent energy crises have demonstrated how exposed the Moldovan economy is to international price shocks; for example, record gas price increases in Europe in 2022 have generated major pressures. By diversifying energy sources by adding photovoltaic

capacities, Moldova can gradually decouple the economy from fluctuations in fossil fuel prices and increase the resilience of the energy system (Tetra Tech ES, Inc.,2023).

In addition, the costs of solar technology have fallen globally over the past decade, making photovoltaics increasingly affordable and competitive. Thus, from an economic point of view, investments in solar energy can lead in the medium and long term to lower local production costs compared to energy imports, especially if advantageous international support schemes and financing are capitalized.

From a strategic perspective, the development of solar energy directly responds to the need to improve the energy security of the Republic of Moldova. The more intensive use of a locally abundant resource, solar radiation, can gradually diminish the critical dependence on external sources and the risks associated with it. A national energy strategy that includes the expansion of photovoltaic capacities will lead to a more diversified and robust energy mix in the face of disruptions. As long as three-quarters of the energy needs are imported, any external shock (economic or geopolitical) poses a threat to the country's stability (Tetra Tech ES, Inc., 2023).

By contrast, domestically produced solar energy provides a safe and inexhaustible source that is nationally controllable. This takes on increased geopolitical importance in the current context, in which the security of energy supply has become a central element of the economic defense strategy. Moreover, Moldova's alignment with EU practices and standards in the field of renewable energy (through the treaties concluded within the Energy Community and the Association Agreement with the EU) also has a strategic component: the integration of the Moldovan energy market with the European market. Investments in solar energy facilitate this integration by reducing the domestic production deficit and can transform the Republic of Moldova from a simple importer into a potential seasonal exporter of green energy on the regional market, in the long term.

The use of solar energy in the Republic of Moldova has seen a significant increase in recent years, due to technological advances, decreasing implementation costs, and support from public policies and private investments. This renewable energy source not only reduces greenhouse gas emissions, but also contributes to stabilizing energy prices and creating a more self-sufficient energy sector. However, there are still barriers related to storage infrastructure, legislation and access to finance, which require effective solutions for an accelerated energy transition (Ministry of Energy of the Republic of Moldova, 2025).

The present study analyzes the impact of solar energy development on reducing dependence on energy imports in the Republic of Moldova. The research is based on updated data on solar energy production, the country's potential in this field and the measures necessary to increase the contribution of this resource to national energy security. Also, the paper explores the existing challenges and opportunities in the process of implementing photovoltaic technologies, providing recommendations for optimizing development strategies.

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Materials and methods

This study is based on a diverse set of materials, including official data on electricity production, consumption and imports in the Republic of Moldova, as well as reports from government agencies, national statistics and energy regulatory bodies. It also integrates studies and analyses carried out by international organizations, academic institutions and research centres, aimed at the development of renewable energy, the efficiency of photovoltaic technologies and global trends in the energy sector (IRENA, 2023). In addition, policy documents and strategies developed by national and international authorities are analysed to understand the regulatory framework on renewable energy and energy security. Economic reports and feasibility studies on the implementation of solar energy projects provide insight into their impact on the economy, the environment and national energy security.

The methodology of this study involves an extensive literature review to collect accurate and up-to-date information from official sources, academic literature, and policy documents. A comparative approach is used to assess the costs and efficiency of solar energy in relation to other energy sources available in Moldova, taking into account investment requirements, technological performance and environmental impact. The study also looks at existing solar energy projects to assess their contribution to reducing import dependency and identify good practices that could be scaled up at national level. In addition, mathematical modeling and statistical forecasting are applied to estimate the potential contribution of solar energy to the country's energy security in the medium and long term. An analytical and critical perspective is adopted in the evaluation of current energy policies, identifying strengths, limitations and opportunities for advancing solar energy development in Moldova. Through this approach, the study aims to provide a comprehensive understanding of the role of solar energy in reducing dependence on imports and strengthening national energy security.

Results and discussions

Analysis of renewable energy data in the Republic of Moldova reveals a significant increase in installed solar energy capacity. According to data from the National Center for Sustainable Energy (CNED), by the end of 2024 (figure 1), photovoltaic installations, with a summary installed capacity of 394.90 MW, are the most widespread technology and represent 68% of the total installed capacities. These are followed by wind farms, whose summary power reached 160.83 MW, accounting for 28% of the total. The capacities of hydro and biogas plants register values of 16.75 MW (3%) and 7.01 MW (1%) respectively (CNED, 2025).

This substantial growth was supported by investments in infrastructure and the implementation of support policies for renewables. Thus, the Republic of Moldova has made remarkable progress in the development of the solar energy sector, contributing to reducing dependence on electricity imports from external sources and increasing national energy security.

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The evolution of renewable electricity production capacities in the Republic of Moldova reflects the country's commitment to the energy transition and the integration of alternative sources of electricity production into the national energy mix.

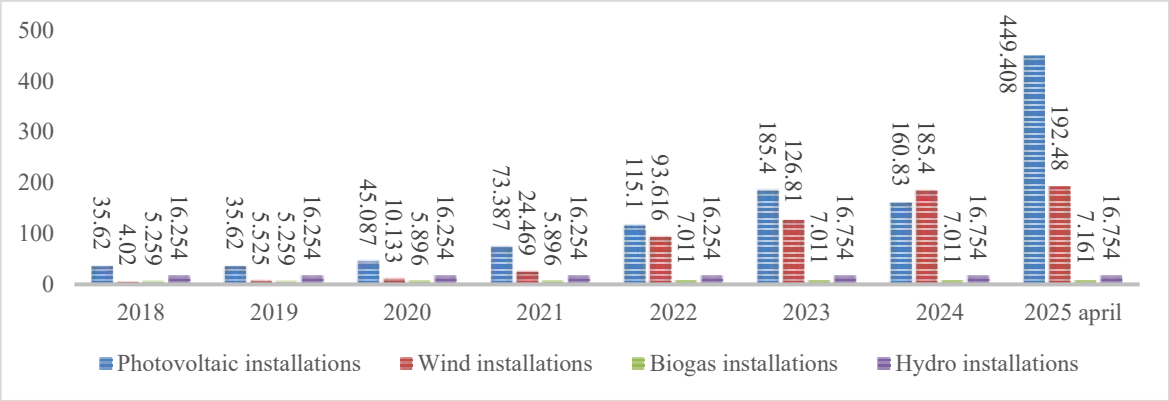

Figure 1. Annual evolution of installed capacities of renewable energy sources

Source: Developed by the authors based on the source National Energy Council of Moldova (2025).

Following this analysis, we can mention that the integration of solar energy into the national energy mix has contributed to the reduction of electricity imports. In 2023, the final energy consumption of the Republic of Moldova was 2853 thousand tons of oil equivalent, and the total imports of electricity were 88433 TJ. Compared to previous years, this represents a slight decrease in dependence on imports due to the increase in the capacity of renewable sources, including solar energy (National Bureau of Statistics of the Republic of Moldova (NBS), 2024).

The increase in the share of E-SER renewable energy confirms the progress towards achieving the target of at least 27% of renewable energy in the energy balance by 2030, an objective that aligns with both European Union policies and international agreements for reducing greenhouse gas emissions and promoting energy sustainability (CNED, 2025).

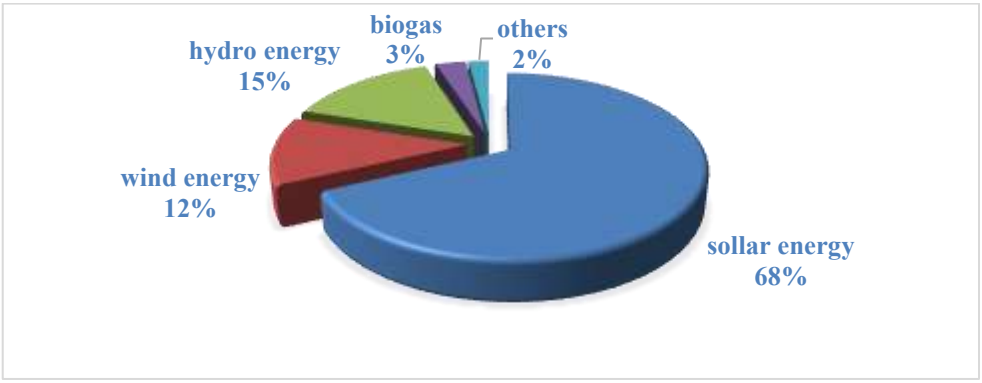

Figure 2. Weighted distribution by type of technology of the E-SER capacities installed at the end of January 2025

Source: Developed by the authors based on the source National Energy Council of Moldova (2025).

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In this context, the development of a photovoltaic power plants intended to supply 2-4 communities, totaling approximately 10000 inhabitants, represents an innovative and sustainable solution for diversifying energy sources and reducing CO_2 emissions. The implementation of such a project requires a rigorous assessment of energy requirements, implementation costs, energy storage solutions and integration into the national electricity grid.

To ensure the energy needs of these communities, it is essential to estimate the average energy consumption per household and community. According to statistics, a typical household consumes about 300 kWh per month, and the total number of households varies between 3000 and 3500. Therefore, the monthly energy requirement is between 900000 and 1050000 kWh (Corbu, 2024, p.52).

Taking into account the average annual solar radiation in the Republic of Moldova, which is about 1200-1300 kWh/m²/years, and the efficiency of modern solar panels, a photovoltaic power plants with an installed capacity of 5-6 MW would be enough to meet the energy demand of the targeted communities.

Table 1. Investment estimate and funding sources for a 5 MW photovoltaic system

Component	Estimated cost (EUR/MW)	Total estimated cost (EUR) for 5 MW
Panouri Solar	500,000 – 700,000	2,500,000 – 3,500,000
Inverters	150,000 – 200,000	750,000 – 1,000,000
Mounting structures	100,000 – 150,000	500,000 – 750,000
Storage batteries (optional)	300,000 – 500,000	1,500,000 – 2,500,000
Network connection and infrastructure	200,000 – 300,000	1,000,000 – 1,500,000
Administrative costs and installation	100,000 – 200,000	500,000 – 1,000,000
Total	1,350,000 – 2,000,000	6,750,000 – 10,000,000

Source: Elaborated by the authors based on the source Ministry of Energy of the Republic of Moldova (ME), (2025).

The investment estimate presented in Table 1 highlights the financial structure required for the implementation of a 5 MW photovoltaic system. The total cost ranges between 6.75 million EUR and 10 million EUR, depending on the chosen technologies, inclusion of optional storage systems, and specific infrastructure requirements. The detailed breakdown by components provides transparency regarding the main cost drivers, with solar panels and storage batteries representing the most significant shares of the total investment.

This analysis underlines the importance of precise project planning and cost optimization, as well as the necessity to secure diverse sources of funding (state, private investors, international grants/loans) to ensure financial sustainability. A well-balanced financing strategy, combined with careful technological choices, can significantly reduce long-term operational costs and contribute to achieving national energy security objectives through the expansion of solar energy capacities.

Table 2. Sources of funding and contribution shares

Source of funding	Possible contribution (%)	Estimated contribution (million EUR)
State	20 - 40	1.35 – 4
External funding (grants, loans)	30 - 50	2 – 5
Private investors	20 - 50	1.35 – 5

Source: Elaborated by the authors based on the source Ministry of Energy of the Republic of Moldova (ME), (2025).

The project involves the installation of high-efficiency photovoltaic panels on an area of approximately 10-12 hectares, depending on the technology used. As highlighted in the analyzed article, the land area required for installing Photovoltaic power plants varies according to the technical configuration of the system. For example, East-West oriented systems are designed so that the panels can be installed more compactly, requiring less space per unit of installed capacity compared to traditional south-oriented systems.

This approach allows for more efficient use of land, being particularly advantageous in areas where land availability is limited or where minimizing the impact on productive agricultural land is desired. The article emphasizes the importance of identifying unproductive land or distributing photovoltaic capacities across multiple communities precisely to reduce the impact on agricultural land and local ecosystems.

In addition, to ensure a continuous supply, it is necessary to implement an energy storage system, based on lithium-ion batteries or alternative technologies, such as redox flow batteries. This photovoltaic power plants can also operate efficiently without an energy storage system (batteries), relying on optimized integration into the electricity grid and alternative solutions for balancing production and consumption.

The Photovoltaic power plants planned in the Republic of Moldova, located in the localities of Negureni (Telenesti district) and Rădeni (Straseni district), (HG 83/2025, HG 84/2025) will be integrated into the national electricity grid through transformer stations and distribution lines. This infrastructure will enable an efficient integration of renewable energy into the country's energy system. In addition, an intelligent monitoring system will be implemented to optimize the production and distribution of electricity (Ministry of Energy, 2025).

To ensure the sustainability and safety of these projects, a detailed analysis of the impact on the environment and use of agricultural land is necessary. The photovoltaic power plants in Negureni will occupy an area of 44 hectares of agricultural land, and the one in Rădeni will be located on 54 hectares of arable land. Although solar energy is a renewable and environmentally friendly source, the conversion of large areas of agricultural land into areas for energy production can influence local ecosystems, biodiversity and microclimate. In this context, it is essential to adopt measures to mitigate the impact on the environment and local communities.

A more balanced solution would be to distribute these photovoltaic panels in several communities, instead of concentrating them in a single village. For example, instead of

allocating 44 hectares in a single locality, it would be more appropriate to identify 2-4 communities in which solar systems are located on smaller areas, of a maximum of 15 hectares each. There are both advantages and disadvantages in the development and integration of solar energy into the national energy system. The advantages include reducing dependency on imports, lowering long-term costs, protecting the environment, and increasing energy security. On the other hand, disadvantages relate to the intermittency of production, the need for investments in storage and distribution infrastructure, and the risk of occupying agricultural land. The management of the entire infrastructure, including the dispatchable part, falls to system operators and authorized distributors, especially Moldelectrica, in partnership with the state and private investors, with efficient coordination being essential for the optimal integration of new capacities. It is true that for the system it is better for energy to be generated where it is consumed, as this reduces transport losses and increases efficiency, which is why the net metering/billing mechanism was proposed, supporting local production and self-consumption integrated into the grid.

This strategy would reduce the negative impact on agricultural land and distribute the benefits of renewable energy more equitably among several localities. In addition, to protect agricultural resources, photovoltaic panels should be installed on unproductive land, such as hills, degraded land, or areas that are not used for agriculture. Thus, spaces that otherwise do not have a high economic return could be capitalized, avoiding the transformation of fertile land into industrial areas.

This approach would allow for the sustainable development of the energy sector, while maintaining the ecological balance and supporting local communities without negatively affecting their economic and livelihood activities.

Next, the implementation and financing costs are analyzed to estimate the costs needed to supply 20% of the population of the Republic of Moldova with solar energy, focusing on the southern districts of the country, where the solar irradiation conditions are more favorable. It is true that the wind potential is more favorable in the southern part of the Republic of Moldova, where the average wind speed and orographic conditions are more suitable for the installation of wind turbines. In contrast, the solar potential is advantageous across the entire territory of the country, due to relatively uniform solar radiation, which allows photovoltaic energy to be efficiently harnessed both in the north, center, and south. However, an important technical aspect to consider is that photovoltaic systems gradually reduce their efficiency at temperatures above 20°C. The increase in ambient temperature leads to a decrease in the performance of the panels, as solar cells are sensitive to overheating. For this reason, the design and location of installations must take into account not only solar radiation but also average annual temperatures and solutions for ventilation or technologies that mitigate thermal effects on energy production.

To calculate the installed capacity requirement, an average annual consumption of 1000 kWh per person was considered, resulting in a total need of 434 MW of photovoltaic energy.

Table 3. Distribution of the required capacity for each district, as well as estimates of minimum and maximum costs for the implementation of the project

Raion	Population	Required capacity (MW)	No. of mini-parks (5 MW each)	Maximum occupied land (ha)	Minimum estimated cost (EUR)	Maximum estimated cost (EUR)
Cahul	124600	107.0	21	252	144 450 000	214 000 000
Cantemir	62100	53.3	11	132	71 955 000	106 600 000
Causeni	90800	78.0	16	192	105 300 000	156 000 000
Cimislia	60400	51.9	10	120	70 065 000	103 800 000
Leova	53000	45.5	9	108	61 425 000	91 000 000
Stefan Voda	70700	60.7	12	144	81 945 000	121 400 000
Taraclia	43700	38.6	8	96	52 110 000	77 200 000
Total	124600	107.0	21	252	144 450 000	214 000 000

Source: Elaborated by the authors based on the source of the Institute of Energy Research of Moldova.

The implementation of mini-photovoltaic systems capable of supplying 20% of the population of the Republic of Moldova is feasible with sustainable financing and a well-planned strategy. Through efficient resource management, this project could significantly contribute to the country's energy independence and reduce CO2 emissions. It is recommended to strengthen partnerships with international financial institutions and attract private investment to accelerate the process.

Effective coordination between government authorities and renewable energy investors is also essential so that implementation is carried out in a sustainable manner, with minimal environmental impact and maximum benefits for the economy and the population (Agenția pentru Eficiență Energetică, 2021).

In 2023, the total electricity consumption of the Republic of Moldova was approximately 4.333 TWh (terawat-hours), i.e. ~4.33 billion kWh. Of this demand, domestic production covered only 1.169 TWh (~1.17 billion kWh), highlighting the limited generation capacity domestically. Therefore, the difference was ensured by electricity imports in a volume of approximately 3.164 TWh (about 3.16 billion kWh). In other words, more than 70% of the electricity consumed in 2023 came from imports, highlighting a very high external dependence and a vulnerability of national energy security (Government of the Republic of Moldova, 2024).

In order to reduce the deficit of domestic production, it is proposed to build mini-photovoltaic power plants of 434 MW in the south of the Republic of Moldova. Such solar capacity is considerable, especially considering the current level of renewable energy investment in the country.

The estimated average annual production for this project is around 520,800 MWh, equivalent to 0.521 TWh per year.

The contribution of a production of 0.521 TWh per year from the mini photovoltaic power plants would have a significant effect on the import needs. If we relate this production to the volume of imports in 2023 (approx. 3,164 TWh), we see a potential reductionin imports of

~16.5%. (Calculation: 0.521 TWh / 3.164 TWh × 100% ≈ 16.5%.) In other words, given an annual consumption similar to that of 2023, the solar energy produced by the new installation could replace about a sixth of the electricity that the country would otherwise have to import.

In terms of consumption coverage, domestic production would increase from ~1,169 TWh to ~1,690 TWh annually thanks to this project. Thus, the share of domestic productionin meeting demand would rise from about 27% (without the project) to about 39% with the implemented project.

Implicitly, dependence on imports (the proportion of consumption covered by imports) would decrease from ~73% today to about 61%. This substantial decrease in the share of imports in the energy mix would reduce the country's exposure to import-related risks (such as price fluctuations in foreign markets or supply disruptions).

The development of solar energy in the Republic of Moldova has had a significant impact on reducing dependence on imports, but the intermittent nature of photovoltaic production imposes the need to implement efficient solutions for energy storage. In this regard, capitalizing on the hydropower resources of the country's large rivers is a strategic option.

The exploitation of the hydropower potential began in 1954, with the commissioning of the Dubasari power plant, with a capacity of 48 MW. Also, the use of the Prut River for energy production was made possible by the construction of the Coste şti-Stânca hydropower complex, in collaboration with Romania, with a capacity of 16 MW.

Between 1985 and 2010, the average annual electricity production in the Republic of Moldova was approximately 59.5 GWh. In the current context, the integration of pumped storage hydropower plants (CHE-PAs) on the Prut and Dniester rivers offers an optimal solution for balancing the production fluctuations of renewable sources, such as solar energy, and ensuring a continuous supply of electricity (Nicolaev, Bînzari, 2016).

The CHE-AP plants are equipped with reversible hydro aggregates, which work through an energy storage process: outside peak hours, they use electricity from the system, at low prices, to pump water from the lower tank to the upper one. Subsequently, during peak energy demand hours, the plants generate electricity to sell it on the balancing market. Their flexibility is guaranteed by the short start-up time and the high speed of loading/unloading of the hydro aggregates, aspects that make them essential for sustaining the stability of the electricity grid.

Pumped storage hydropower plants allow the storage of surplus electricity generated by photovoltaic power plants during the day and its release at night or during periods of peak demand. This technology can perfectly complement Moldova's renewable energy production, contributing to the stability of the national energy system.

According to a study carried out, such a plant with a capacity of 100 MW could operate with an efficiency of 80% in generation mode and 70% in pumped mode (Arion & Efremov, 2021). Therefore, the location of two such plants on the Prut and Dniester rivers would bring multiple benefits:

- Reducing dependence on energy imports: Stored energy can be used during periods of high consumption, reducing the need for imports;
- Efficient integration of renewable sources: surplus solar energy during the day can be converted into stored hydraulic energy to be used at night.

The construction of a pumped storage hydropower plant involves a high initial cost, but in the long run it becomes a cost-effective solution. Studies indicate that the investment required for a 100 MW plant would be around €200 million, with a payback time of around 26 years, taking into account current energy tariffs. At the same time, the existence of already built reservoirs or favorable land near the Prut and Dniester rivers could reduce infrastructure costs.

To maximize the efficiency of the project, it is proposed to combine the CHE-AP with solar and wind energy projects, thus allowing the use of energy during periods when renewable production fluctuates. A hybrid approach, combining solar, wind, and hydropower, could reduce dependence on fossil fuels by more than 50% by 2035 (Arion & Efremov, 2021).

Another advantage of the CHE-AP is their use for irrigation in agricultural areas in the south and center of the Republic of Moldova. Pumping systems can be used not only for generating electricity, but also for transporting water in irrigation networks during periods of drought. This solution would contribute to the development of agriculture and reduce farmers' vulnerability to climate change.

The construction of these plants, in combination with the development of solar and wind energy, would allow the Republic of Moldova to become energy independent, reducing imports and creating a sustainable, stable energy system that is resistant to foreign market fluctuations.

Conclusions

The development of solar energy in the Republic of Moldova is a strategic solution to reduce dependence on electricity imports, within the global energy transition and the need to diversify energy sources. The present study highlights the positive effects of the implementation of photovoltaic technologies on the country's energy security, highlighting the long-term economic, ecological and strategic benefits.

The analysis of data on the installed capacity of solar energy in the Republic of Moldova indicates a significant increase in recent years. According to the National Center for Sustainable Energy (CNED), by the end of 2024, solar energy will account for about 68% of the total renewable energy sources in the country, reaching a total capacity of 394.90 MW. This evolution is due to both private investments and government programs that have supported access to finance for the development of photovoltaic power plants (Ministry of Energy of the Republic of Moldova (ME), 2025).

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In addition to increasing installed capacities, an important challenge remains the efficient integration of solar energy into the national distribution grid. Due to the intermittent nature of solar energy, it is necessary to implement energy storage solutions, such as high-capacity lithium-ion batteries or pumped storage hydroelectric power plants (CHE-AP). These would allow the surplus energy generated during the day to be stored and used during peak hours (International Renewable Energy Agency (IRENA), 2023).

The implementation of a program to develop mini- photovoltaic power plants with a total capacity of 434 MW could reduce dependence on imports by about 16.5%. Thus, the share of domestic production in covering consumption would increase from 27% to 39%, strengthening the country's energy security.

The use of solar energy would also help stabilise electricity prices by reducing the long-term costs associated with energy imports. Unlike fossil fuels, which are exposed to the volatility of international markets, solar energy offers a stable and predictable cost, favouring the national economy (World Bank, 2023). Another key aspect of solar energy development is the economic and environmental benefits. Economic benefits include attracting investment in energy infrastructure, creating new jobs in the renewable energy sector, and reducing government spending on purchasing electricity from external sources.

On the ecological level, solar energy contributes to the reduction of CO2 emissions and to the achievement of the environmental objectives assumed by the Republic of Moldova within the policies of the European Union and the Paris Agreement. Solar energy projects can significantly reduce air pollution and support the transition to a sustainable economic model based on renewable resources.

A concrete example of the implementation of solar energy with a positive impact is the construction of photovoltaic power plants in the localities of Negureni (Telenești district) and Rădeni (Straseni district). They will have a considerable installed capacity and will contribute to the electricity supply of several local communities.

In order for the Republic of Moldova to maximize its energy potential and become more energy independent, a series of strategic measures are needed:

- expanding photovoltaic capacities, by supporting decentralised projects for households and small and medium-sized enterprises.
- modernisation of the electricity grid, to improve the integration of renewables and reduce energy losses.
- development of efficient energy storage solutions, including the implementation of pumped storage hydroelectric power plants (CHE-PA) on the Prut and Dniester rivers, which ensure a stable supply of electricity during periods of high consumption.
- the adoption of supportive government policies, including tax incentives and subsidies for solar energy investments.
- diversifying the energy mix, by combining solar energy with other renewable sources, such as wind energy and biogas.

Through well-implemented strategic measures and effective collaboration between the government, the private sector and international investors, the Republic of Moldova can take an important step towards energy independence and a sustainable future based on renewable energy. Thus, the country will not only ensure a more stable energy system, but will also contribute to environmental protection and reducing the impact of climate change.

In conclusion, the development of solar energy in the Republic of Moldova is not only a necessity, but also an opportunity to reduce dependence on imports, stabilize energy prices and stimulate the national economy. Increasing photovoltaic capacities and implementing effective policies to integrate them into the national grid could turn solar energy into a central pillar of the country's energy system.

References

Guvernul Republicii Moldova. (2025). Hotărârea nr. 83 din 05.02.2025 cu privire la aprobarea Strategiei naționale pentru dezvoltarea energiei regenerabile 2025–2035. *Monitorul Oficial al Republicii Moldova*, *45-48*, art. 123. https://www.legis.md

Guvernul Republicii Moldova. (2025). Hotărârea nr. 84 din 05.02.2025 pentru aprobarea Planului de acțiuni privind implementarea Strategiei naționale pentru dezvoltarea energiei regenerabile 2025–2035. *Monitorul Oficial al Republicii Moldova*, *45-48*, art. 124. https://www.legis.md

Guvernul Republicii Moldova. (2024). Decision no. 820 of 11.12.2024 for the approval of the Regulation on exceptional situations in the electricity sector and the Action Plan for exceptional situations in the electricity sector. *Monitorul Oficial al Republicii Moldova*, *234–236*, art. 412. https://www.legis.md/cautare/getResults?doc_id=143455&lang=ro

Biroul Național de Statistică al Republicii Moldova. (2024). *Balanța energetică a Republicii Moldova: Culegere statistică, ediția 2024.* https://statistica.gov.md/files/files/publicatii_electronice/balanta_energetica/Balanta_energetica_editia_2024_ro.pdf

Ministerul Energiei al Republicii Moldova. (2025). *Raport de activitate al Ministerului Energiei, 2024.* https://energie.gov.md/sites/default/files/raport_de_activitate_men_2024_0.pdf

National Agency for Energy Regulation of the Republic of Moldova. (2025). *Annual Activity Report 2024.* https://www.anre.md/raport-de-activitate-3-10

Centrul Național pentru Energia Durabilă. (2025). *Installed capacities.* https://cned.gov.md/ro/content/capacitati-instalate

Corbu, V. (2024). *Innovative strategies in the operative management of power grids* (Ph.D. thesis, Academy of Economic Studies of Moldova). https://www.anacec.md/files/Corbu-teza.pdf

Corețchi, B. (2023) Securitatea economică durabilă prin inovații: un model integrat pentru Republica Moldova. In *Economic Security in the Context of Systemic Transformations*: materialele conferinței științifico-internațională (pp. 41-46). ASEM. https://ibn.idsi.md/sites/default/files/imag_file/p-41-46.pdf

Nicolaev, E., & Bînzari, A. (2016). *The contribution of renewable energy sources to the energy*

security of the Republic of Moldova. Technical University of Moldova.

Institute of Energy Research of Moldova. (2022). *Elaboration of the technical-economic models of the SERî energy projects implemented in the social institutions for the implementation of the net metering support scheme.* link

Tetra Tech ES, Inc. (2023). *PV Integration in the Moldovan Power System.* Moldova Energy Security Activity. USAID Moldova. https://www.energie.gov.md/sites/default/files/report_on_res_self-consumption_in_md_final.pdf

Ministry of Energy. (2025). *Premiere: Moldova – two photovoltaic parks with a capacity of 50 and 40 MW will be built.* https://www.energie.gov.md/en/content/first-time-two-photovoltaic-parks-capacity-50-and-40-mw-will-be-built-moldova-0#:~:text=Media-,For%20the%20First%20Time%2C%20Two%20Photovoltaic%20Parks%20with%20a%20Capacity,Will%20Be%20Built%20in%20Moldova&text=By%20the%20end%20of%202025,energy%20sources%20by%2090%20MW.

International Renewable Energy Agency (IRENA). (2023). *Renewable energy statistics 2023.* https://www.irena.org/Publications/2023/Jul/Renewable-energy-statistics-2023

World Bank. (2023). *Annual Report 2023: A new era in development.* World Bank. https://www.worldbank.org/ro/country/moldova