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CONTENTS

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ANALYSIS OF THE EVOLUTION OF THE NUMBER OF PENSIONERS AT NATIONAL AND REGIONAL LEVEL

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Abstract: *Pension systems are going through a period of crisis all over the world. Many countries in the European Union, among others, have impressive costs—generally over 8-10% of GDP—just to keep a component of the social insurance system afloat, namely that of providing the necessary income after exit from the labor market. However, the situation is much more difficult, more complex, especially in perspective. In the conditions of the "peculiarities of the inherited pension system" and the factors that inevitably affect the century we are passing through (the aging of the population, the reduction of the active population, the macroeconomic problems mainly of the countries in transition, etc.) the budget necessary to ensure the payment of pensions as a share of the GDP is anticipates that it will double in 40-50 years. Most countries have already started pension reform processes or at least are planning such changes / for the next periods. Although the problems are apparently the same, the directions of change, even if sometimes convergent, are different. A decade ago, the primary reform approach discussed and implemented was generally parametric (modification of retirement ages, replacement rates, etc.). The present study describes the framework in which previous or anticipated changes have taken place and are likely to take place in the future, in order to be able to design a coherent and effective policy in the field of pensions. Pension systems globally—across various levels of development, political experiences, and governance systems—face challenges that will inevitably become chronic in the coming years.*

Keywords: *pension categories, number of pensioners, defined contributions, social security*

JEL Classification: *H55, J32 C6, C63, G2, G23*

1. Introduction

At the moment, there is an almost explicit consensus in the Western capitalist world: at least a partial transition to the private sector is the key to the viability of pension systems. Romania has not yet taken this step, but it cannot afford to delay this reform for a long time. On the other hand, the transition, electoral interests and other objective or subjective factors have created and maintained serious inequities in Romania's public pension system.

The socio-demographic and economic processes that characterize the last period (the aging of the population, the reduction of the active population, the macroeconomic problems mainly of countries in transition, etc.) and that will be accentuated in the coming decades transform the problem of social protection of the elderly and especially the problem of administration more efficient pension systems in a fundamental challenge for both developed and transition countries.

For Romania, the problem is aggravated by the alarming delay of the reform, by the wrong decisions, by the lack of vision and coherent strategies in the field. In this context, in addition to the major problems of all ex-communist countries that have registered an economic decline and a reduction in the number of employees (those who support the pension system through contributions), Romania is also faced with the incompleteness of the pension system which is summarized below in pillar I, the privately administered occupational and voluntary components being still in the project stage and requiring several years until implementation and the appearance of effects. Also, phenomena encountered in other countries in transition (and even in Western developed countries in the last decades) such as early retirements and the decrease of the real average retirement age or the support of pillar I with budget funds were much more pronounced in our country and led to an exaggerated increase in the number of pensioners and to an alarming reduction in the real average retirement age.

2. Evolution of the number of pensioners in Romania after 1990

Romania registered spectacular increases after 1990, in terms of the number of pensioners. The dissolution of large state-owned enterprises brought a massive wave of early retirements, which led to an almost doubling of the number of retirees between 1990 and 2000 (the number of retirees increased from 3679 thousand people in 1990 to 6153 thousand people in the year 2000, the year in which a record number of pensioners was recorded - figure 1). Since 2000, the number of pensioners has registered an annual decrease, reaching the level of 5228 thousand people in 2020.

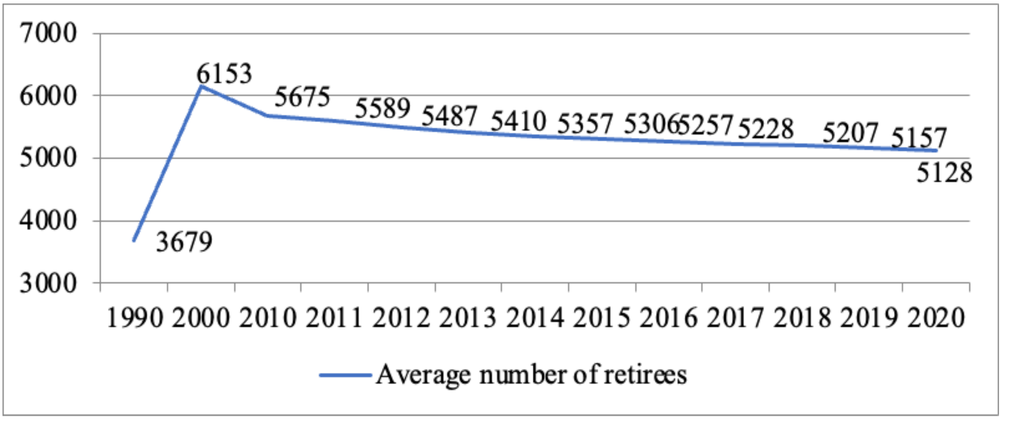

Figure 1. Evolution of the average number of pensioners (thousands of people)

Source: National Institute of Statistics, TEMPO online database, http://statistici.insse.ro:8077/tempo-online

The increase in the number of pensioners was achieved simultaneously with a decrease in the number of employees (Figure 2). If in 1990 there were 2.5 employees to one pensioner, after the year 2000 there are more pensioners than employees. The most dramatic situation occurred in 2011, since then the situation has improved somewhat, the number of employees registering an increase (by approximately 597 thousand people), and the number of pensioners a decrease (by approximately 361 thousand people).

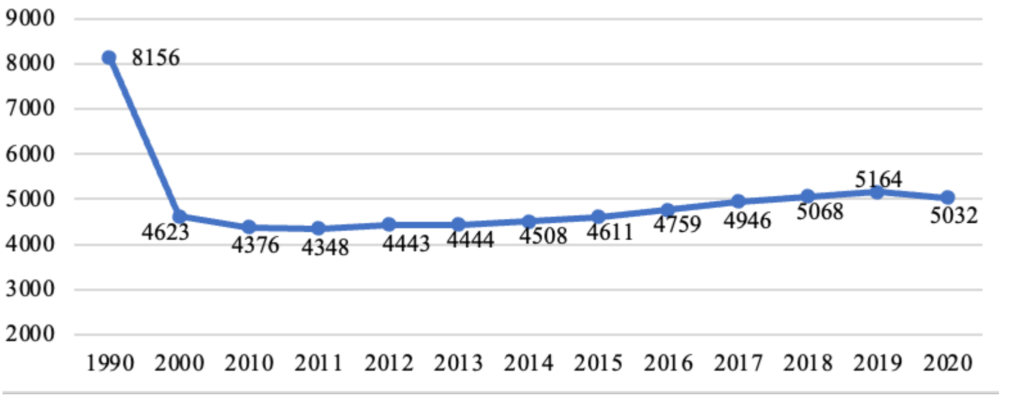

Figure 2. Evolution of the average number of employees (thousands of people)

Source: National Institute of Statistics, TEMPO online database, http://statistici.insse.ro:8077/tempo-online

Analyzing the evolution of the number of pensioners by category (figure 3), we can note that between 1990 and 2020 all four categories of pensioners: the average number of pensioners, social insurance pensioners, social insurance pensioners (without farmers), insurance pensioners social - farmers, have registered important increases. Between 2000 and 2010, three of the mentioned categories registered decreases in terms of the average number. The exception is the category of social security pensioners (without farmers), which registered a fairly significant increase. Starting from 2011 to 2020, all four categories of pensioners analyzed have registered decreases, even if these decreases are not very significant. Even if there have been decreases in the average number of pensioners, they remain numerically higher than the number of employees. This creates increased pressure on the social security budget which continues to be in deficit year after year.

For this reason, the current legislation in the field has led to the increase of the retirement age for women and to the discouraging of early retirements. All these measures were taken in order to reduce the pressure on the budget provided for the payment of pensions.

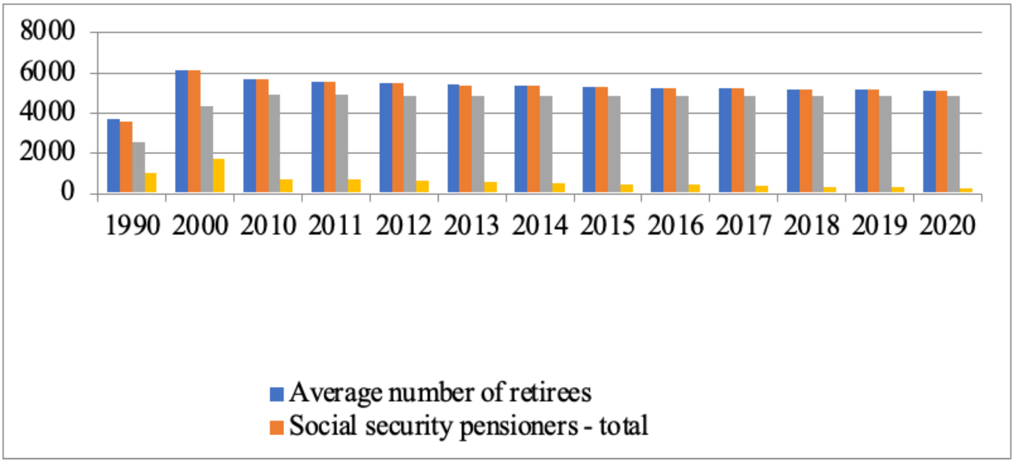

Figure 3. Evolution of the number of pensioners by category

Source: National Institute of Statistics, TEMPO online database, http://statistici.insse.ro:8077/tempo-online

Table 1 shows the percentage increase in the number of pensioners (by category), percentage calculated compared to 1990. In the categories "with early retirement" and "with partial early retirement", the percentage was calculated compared to 2010, due to the lack of data until that year. Analyzing these data, it can be seen that the category "with early retirement" had the largest increase, which registered an increase of 255.6%, followed by the category "with full contribution period", with an increase of 237, 3%. These two categories of pensioners registered an increase of more than double the existing figure at the beginning of the analyzed period. The categories "for age limit" (increase of 195%) and "with incomplete contribution period" (increase of 125.3%), recorded lower, but still numerically significant increases.

The only category that recorded a decrease was the category "with partial early retirement" where the decrease was really significant (-35.8% percentage). The decrease in this category was registered as an effect of the measures taken after 2010, to discourage and penalize this category of retirement which has become unattractive. All the evolutions of these retirement categories resulted in the increase of the total average number of retirees by 142% in 2020 compared to 1990, after having recorded a maximum of 167.2% in 2000.

Table 1. The evolution of the number of pensioners according to the contribution period

	1990	**2000**	**2010**	**2015**	**2017**	**2018**	**2019**	**2020**
Average number of retirees	3679	6153	5675	5306	5228	5207	5157	5128
Increase compared to 1990	100,0	167,2	154,3	144,2	142,1	141,5	140,2	139,4
For the age limit	1859	3087	3309	3500	3629	3685	3717	3776
Increase compared to 1990	100,0	166,1	178,0	188,3	195,2	198,2	199,9	203,1
With full contribution internship	1160	2247	2282	2602	2753	2830	2888	2973
Increase compared to 1990	100,0	193,7	196,7	224,3	237,3	244,0	249,0	256,3
With incomplete contribution period	699	840	1027	898	876	855	829	803
Increase compared to 1990	100,0	120,2	146,9	128,5	125,3	122,3	118,6	114,9
With early retirement	-[1]	-[2]	9	23	23	21	19	16
Increase compared to 2010	-	-	100	255,6	255,6	233,3	211,1	177,8
With partial early retirement	-	-	123	86	79	88	92	91
Increase compared to 2010	-	-	100,0	69,9	64,2	71,5	74,8	74,0

Source: National Institute of Statistics, TEMPO online database, http://statistici.insse.ro:8077/tempo-online

1 There is no data

2 There is no data

Figure 4 shows the evolution of the number of retirees by reason of disability, in total and by retirement levels. As can be seen, the total number of pensioners in this category had a spectacular increase until 2010, a year in which almost 8 times more pensioners were registered than in 1990. After reaching the maximum this year, the number of pensioners of invalidity registered fairly important decreases year by year until 2020, still remaining much higher compared to 1990. An increase was recorded, however, in the number of pensioners with III degree of invalidity. If until 2012, the number of pensioners with II degree of disability was much higher than the number of pensioners with III degree of disability, after this year the ratio reversed.

The decrease in the number of disability pensioners was also due to the fact that many abuses were discovered in this type of retirement. And for this type of pensions, measures were taken aimed at discouraging the registered abuses, by increasing the legal penalties given to those who did not respect the legislation and granted these pensions to people who did not fit into these categories.

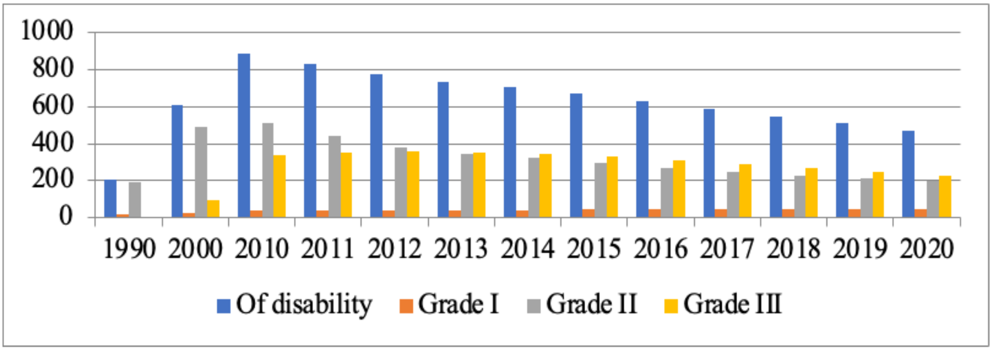

Figure 4. Evolution of the number of disability pensioners (thousands of people)

Source: National Institute of Statistics, TEMPO online database, http://statistici.insse.ro:8077/tempo-online

Figure 5 shows the evolution of other categories of pensioners: social insurance pensioners - religious and social insurance pensioners - lawyers. Data were not recorded for these two categories until 1996. These two categories registered different increases: social security pensioners - religious (increase by 181.5%) and social security pensioners - lawyers (increase by 331, 5%).

The second analyzed category "social security pensioners - lawyers", registered a very large increase due to some sets of very attractive measures for the retirement of these social categories. These measures are still in force and will, in the next period, favor the increase in the number of pensioners in this category.

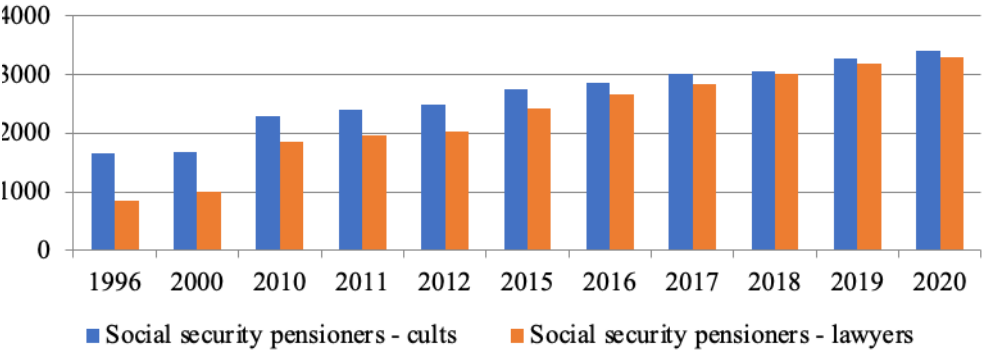

Figure 5. Evolution of the number of other categories of pensioners

Source: National Institute of Statistics, TEMPO online database, http://statistici.insse.ro:8077/tempo-online

An important analysis is also that of the evolution of the number of pensioners in the development regions of Romania (Table 2). Romania is divided into 8 development regions as follows:

1. North-West Region
2. Central Region
3. North – East Region
4. South – East Region
5. South Region – Muntenia
6. Bucharest - Ilfov region
7. South-West Oltenia Region
8. West Region

We achieved an evolution of the weight of the number of pensioners from each region in the total registered at the country level. From the analysis carried out, two types of regions are distinguished:

- regions where the share of the number of pensioners in the national total decreased, and among these regions we list: the Center, Bucharest Ilfov and West regions;
- regions in which the share of the number of pensioners in the national total has increased, and among these regions we list: North-West, North-East, South-East, South Muntenia and South-West Oltenia regions.

The regions where the total number of pensioners decreased are the most developed regions of Romania, and the regions where the share of the number of pensioners in the national total increased are the less developed regions but which have an older population than the other regions where - have registered decreases.

The region that recorded the largest decrease in the number of pensioners in the national total is the Bucharest Ilfov region with a decrease of - 4.2%, and the region that recorded the largest increase in the number of pensioners in the national total was the South region - East with an increase of + 2.4%.

Table 2. Evolution of the share of the number of pensioners on the development regions of Romania

	1990	**2000**	**2015**	**2017**	**2018**	**2019**	**2020**
TOTAL	2380038	4246061	4682624	4678090	4684479	4672043	4674927
percent of the total	100,0	100,0	100,0	100,0	100,0	100,0	100,0
NORTH-WEST region	302374	554251	614969	613348	613361	612171	613117
percent of the total	12,7	13,1	13,1	13,1	13,1	13,1	13,1
CENTER region	314094	516946	575135	578473	581455	581011	582570
percent of the total	13,2	12,2	12,3	12,4	12,4	12,4	12,5
NORTH-EAST region	293032	596839	702124	702398	704230	702280	702249
percent of the total	12,3	14,1	15,0	15,0	15,0	15,0	15,0
SOUTH-EAST region	236758	479474	570089	577144	580128	580442	582213
percent of the total	9,9	11,3	12,2	12,3	12,4	12,4	12,5
SUD-MUNTENIA region	363185	692175	727700	721277	718912	713874	711854
percent of the total	15,3	16,3	15,5	15,4	15,3	15,3	15,2
BUCHAREST - ILFOV region	383802	558416	558332	557151	557722	556698	557437
percent of the total	16,1	13,2	11,9	11,9	11,9	11,9	11,9
SOUTH-WEST OLTENIA region	211363	422882	482401	478541	478792	476512	476062
percent of the total	8,9	10,0	10,3	10,2	10,2	10,2	10,2
WEST region	275430	425078	451874	449758	449879	449055	449425
percent of the total	11,6	10,0	9,7	9,6	9,6	9,6	9,6

Source: National Institute of Statistics, TEMPO online database, http://statistici.insse.ro:8077/tempo-online

Regarding the gender distribution of the number of pensioners, it can be stated that the economic and social development of Romania in the second half of the century resulted in a higher share of men in the number of state social insurance pensioners until year 2009, in other words, during that period men were predominantly employed, women choosing the status of housewives. The change in this ratio occurred in the first half of 2009, a year in which, in addition to lower female mortality at older ages, the number of women entering retirement exceeded the number of men.

Starting from 2018, the number of male pensioners will be higher than the number of female pensioners, the difference cannot compensate for the effects of differential mortality, clearly lower for women, and the share of women in the total number of social security pensioners is to increase moderately but steadily, from 51 % how much I am today.

3. Conclusions

This paper tried to review the main aspects related to the evolution of the number of pensioners in Romania after 1990. Following the analysis of the evolution of the number of pensioners, the following conclusions can be identified:

• Romania registered spectacular increases after 1990, in terms of the number of pensioners. The dissolution of large state-owned enterprises brought a massive wave of early retirements, which led to an almost doubling of the number of retirees between 1990 and 2000;

• the increase in the number of pensioners was achieved simultaneously with a decrease in the number of employees. If in 1990 there were 2.5 employees to one pensioner, after the year 2000 there are more pensioners than employees;

• the evolution of the number of pensioners on grounds of disability, in total and by retirement levels, had a spectacular increase until 2010, a year in which almost 8 times more pensioners were registered than in 1990;

• in the category of pensioners due to disability, many abuses were discovered so that measures were taken to discourage the registered abuses, by increasing the legal penalties given to those who did not comply with the legislation and granted these pensions to people who did not fit into these categories;

• regarding the distribution of the number of pensioners by region, two situations are observed:

- regions in which the share of the number of pensioners in the national total has increased, and among these regions we list: the North - West, North - East, South - East, South Muntenia and South - West Oltenia regions;

- regions in which the share of the number of pensioners in the national total decreased, and among these regions we list: the Centru, Bucharest Ilfov and West regions;
- The region that recorded the largest decrease in the number of pensioners in the national total is the Bucharest Ilfov region with a decrease of - 4.2%, and the region that recorded the largest increase in the number of pensioners in the national total was the South region – East with an increase of + 2.4%;

Regarding the gender distribution of the number of pensioners, it can be stated that the economic and social development of Romania in the second half of the century resulted in a higher proportion of men in the number of state social insurance pensioners until in 2009, in other words, men were predominantly employed during that period, women choosing the status of housewives. The change in this ratio occurred in the first half of 2009, a year in which, in addition to lower female mortality at older ages, the number of women entering retirement exceeded the number of men.

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CAPITAL TAXATION AND ECONOMIC RESILIENCE: DECISION-MAKING PREDICTION THROUGH INFORMATION SYSTEMS IN THE NATIONAL SECURITY ARCHITECTURE

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Abstract: *The rapid transformation of the global economic ecosystem requires states to intelligently adapt fiscal policies, where technology becomes a strategic ally. This study explores how advanced information systems and artificial intelligence algorithms can be used to model the relationship between capital tax pressure and gross fixed capital formation (GFCF), a key indicator of economic resilience. Using longitudinal data from EUROSTAT (2010–2022) and machine learning techniques (REPTree model), the research identifies critical fiscal thresholds and relevant decision configurations for stimulating investment. The findings reveal that investment levels are not solely influenced by the absolute tax burden, but rather by strategic combinations of taxation forms and macroeconomic context. In this regard, AI-powered information systems enable not only real-time risk monitoring but also the simulation of fiscal scenarios geared toward resilience and economic autonomy. The integration of these technologies into the national security architecture provides valuable operational support for the formulation of intelligent and adaptive fiscal policies aimed at strengthening economic autonomy.*

Keywords: *information systems, adaptive decision, predictive modelling*
JEL Classification: *C35, C38, E27, G28, H25*

1. Introduction

The current global context is marked by financial instability, geopolitical fragmentation and the need to strengthen strategic autonomy, the ability of states to manage fiscal resources in a balanced manner becomes essential for supporting economic resilience. This article aims to investigate the impact of fiscal pressure exerted on capital through taxes on corporate income, self-employment income and capital stock on gross fixed capital formation, used here as a proxy for investment and infrastructure resilience. In this approach, the emphasis is placed on the use of information systems to support economic and fiscal decisions, with the aim of supporting the overall architecture of national security. Methodologically, the research is based on a longitudinal data set, on which decision modeling techniques are applied, to highlight conditional relationships and critical fiscal thresholds. Through this approach, significant combinations of fiscal factors that positively or negatively influence the level of national investment are identified, thus providing an empirical basis for the formulation of adaptive public policies (Antikainen, Uusitalo, & Kivikytö-Reponen, 2018; Bai, Sarkis, & Dou, 2020; Dragomir-Constantin, 2025c).

The study also highlights the importance of predictive analysis information systems in monitoring fiscal risks and anticipating economic imbalances and decision-making information systems, which, integrated into fiscal analysis processes, can significantly contribute to strengthening financial autonomy and strengthening the state's capacity to respond quickly and efficiently to emerging challenges (Chen & Wang, 2024). In an era marked by persistent geopolitical tensions, systemic crises and reconfigurations of the global economic order, economic autonomy is becoming a central pillar of the national security architecture (Liu & Chen, 2024). States can no longer rely exclusively on external trade flows or globalized capital markets to support their development, but are forced to strengthen their internal resilience through self-financing mechanisms, protection of critical infrastructure and anticipation of economic vulnerabilities. In this context, the ability to effectively manage fiscal resources, especially those derived from domestic capital, acquires major strategic relevance. Taxation, beyond its traditional function as an instrument of redistribution or economic stimulation, is thus becoming an operational instrument of economic security governance. In particular, taxes on capital—whether on corporate income (CIA), self-employment income (SIE), or capital stock taxes (SST)—can directly influence the investment behavior of economic actors, affecting the level of fixed capital formation and, implicitly, the state's ability to modernize its strategic infrastructure (Dragomir-Constantin, 2025c). Excessive fiscal pressure can generate financial disintermediation, capital relocation, and a decrease in investment self-sufficiency, while a judicious balance between collection and stimulation can provide a solid basis for economic resilience. In parallel with these conceptual transformations, digital technologies and intelligent information systems are becoming an indispensable ally of the state in the process of fiscal decision-making (Lee, Kao, & Yang, 2014). The integration of predictive analysis systems, decision-making algorithms, complex fiscal databases and Business Intelligence infrastructures allows not only the real-time monitoring of economic risks, but also the simulation of fiscal scenarios with strategic impact (Abdullah & Almaqtari, 2024). Thus, technology-assisted decision-making modeling offers an anticipatory vision of the relationship between taxation and development, facilitating a governance oriented towards stability and economic sovereignty.

2. Theoretical framework

The present paper aims to analyze this complex interdependence, by assessing how the fiscal pressure on capital influences the level of national investments and, implicitly, economic resilience. To this end, decision-making modeling techniques are used applied to a data set provided by EUROSTAT, and the dependent variable is represented by gross fixed capital formation, considered a relevant indicator for the investment capacity of states (Marković & Jemović, 2024).

Starting from this analytical framework, the research aims to answer three fundamental questions:

- What is the relationship between capital taxation and investments in the economy?
- Can financial resilience be anticipated through decision-making modeling?
- What role do information systems play in supporting fiscal decisions and strengthening economic security?

By addressing these questions, the study contributes to the outline of a theoretical-applicative framework in which fiscal policies, supported by advanced information infrastructures, become integrated components of the national security architecture, offering states a strategic self-regulation tool in the face of emerging challenges.

2.1. Dataset and source

The study uses a dataset collected from the official EUROSTAT platform, covering the period 2010–2022 for 27 European Union member states. The data are structured on the following relevant indicators for the analysis of the relationship between capital taxation and public investment:

- TKC – Capital taxes from corporate income,
- TKE – Capital taxes from self-employed activities,
- TKS – Taxes applied to the capital stock,

• GFK – Gross fixed capital formation (million euros), used as a dependent variable.

All indicators were expressed in absolute values (million euros), without initial logarithmic transformations, precisely in order to preserve the readability of the interpretation of the decision-making models. The variables year (year) and country (country) were used as segmentation attributes, being integrated into the decision-making model to capture spatial-temporal variations.

3. Methodology

3.1. Data Exploration

The descriptive statistical analysis of the dependent variable GFK shows a highly skewed distribution to the left (positively skewed), with a mean of approximately 193,391 million euros and a significant standard deviation of over 514,000. The maximum value reaches 35,550,504 million euros (EU27 case), while the minimum values are below 2,000 million euros in small states (e.g. Malta, Cyprus). This wide variation justifies the use of decision-making models capable of capturing non-linear relationships and identifying conditional logical ramifications. This image provides a detailed statistical analysis of the dependent variable GFK (Gross Fixed Capital Formation), used in the model to assess the investment capacity and, implicitly, the economic resilience of the analyzed states. The analyzed variable, representing gross fixed capital formation (GFK), is of continuous numerical type and constitutes the dependent component of the decision-making prediction model. It is composed of a total of 362 observations, each of them having a unique value, attesting to a high degree of granularity and specificity of the collected data, respectively, an increased fidelity of the records at the national and annual level. The absence of missing values strengthens the robustness of the dataset and eliminates the need for interventions through imputation or estimation. The range of values covered by this variable is extremely wide, with an absolute minimum of 1,264 million euros, most likely corresponding to a small economy such as Malta, and an impressive maximum of 35,550,504 million euros, most likely attributed to the aggregate value of the European Union as a single economic entity. The arithmetic mean of these values is around the threshold of 193,391 million euros, suggesting a high overall level of investment. However, this mean is insufficiently representative of the central tendency, as it is significantly influenced by the existence of extreme values at the top of the distribution.

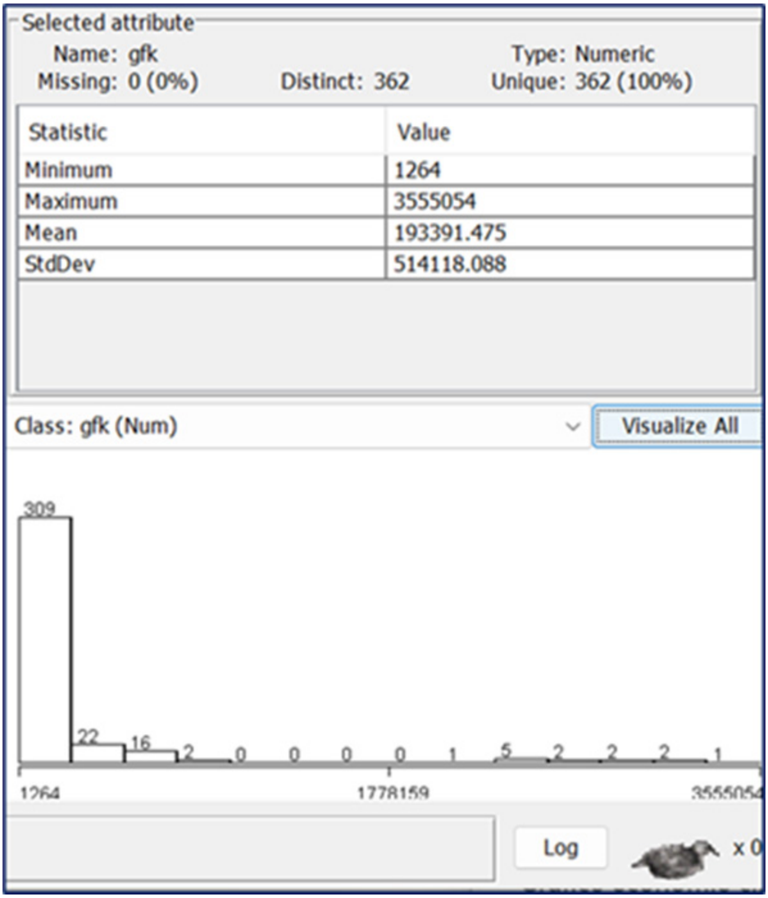

Figure 1. Data Exploration realized by the author

This observation is supported by the high value of the standard deviation, calculated at approximately 514,118 million euros, which highlights a considerable dispersion of the data from the central average and indicates the existence of significant variation between countries and years, reflecting both structural differences in economic size and fiscal and investment policy particularities. The distribution graph for the GFK variable reveals a pronounced leftward asymmetry (positive skew), with an overwhelming concentration of observations (309 out of 362) in the lower range of the scale, below the value of 177,815 million euros. Only a small number of observations – between two and five – are in the area of extreme values, corresponding to the maximum levels, which shows that massive fixed investments are characteristic of a limited number of states or economic aggregations of the size of the European Union.

This uneven distribution indicates the existence of a pronounced investment polarization at the European level, in which only a few economies have the capacity to support major investments in infrastructure and fixed capital. Consequently, the statistical average becomes an indicator with reduced interpretative value in the absence of dispersion and classification analyses, requiring the use of decision-making techniques that can effectively integrate both non-linear relationships and obvious distributional anomalies.

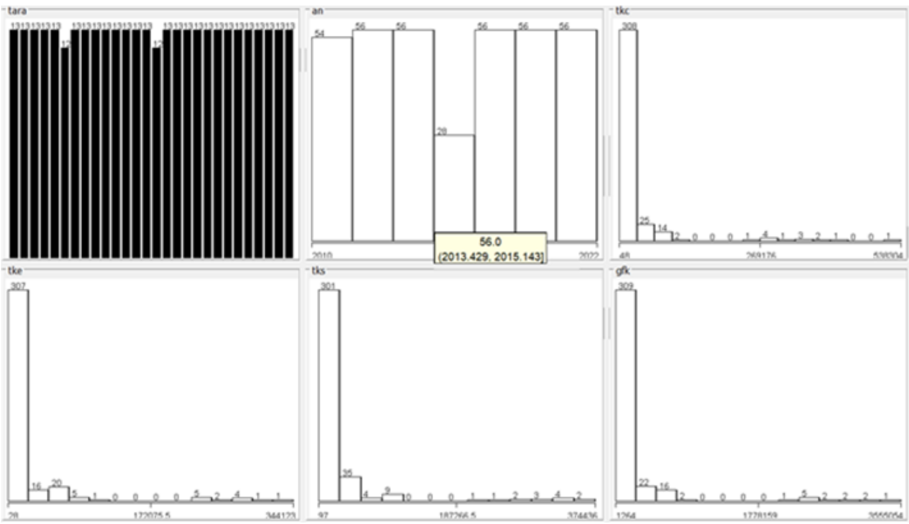

Figure 2. Data distribution realized by the author

These distributions justify the choice of robust decision models, such as REPTree or Random Forest, which handle data with extreme values and structural imbalances well. The visual distributions of the variables analyzed within the decision model reveal significant structural features, which substantiate the choice of the modeling method and provide important clues regarding the fiscal and investment behavior in the European Union member states.

First, the variable “country” (country) presents a perfectly balanced distribution, with each of the 27 states included in the sample having the same number of observations (13), most likely corresponding to each calendar year between 2010 and 2022. This symmetry of the data ensures a comparable representation across countries, eliminating possible biases induced by territorial under- or over-representation, and provides a solid framework for comparative analyses between national tax regimes. The variable “year” covers the time interval 2010–2022, with a constant frequency of observations in almost all years, except for a notable discontinuity around 2013–2015, where the frequency drops to 28 observations. This sharp drop suggests the existence of gaps in reporting or data collection in that period, which must be taken into account in the temporal interpretation of the models, especially in the analysis of trends and decision thresholds correlated with the year.

The central fiscal indicators of the analysis, namely "TKC" (taxes on capital from corporate income), "TKE" (taxes on income of independent individuals) and "TKS" (taxes on capital stock), are characterized by a strongly asymmetric distribution to the left, highlighting an overwhelming concentration of values in the lower part of the scale. This phenomenon signals that most European states collect relatively modest revenues from these tax sources, while only a small number of economies – most likely Germany, France or the European Union at the aggregate level – record significantly higher values. This fiscal polarization may indicate structural differences in the capital taxation regime, the degree of formalization of the economy or the administrative capacity to collect. As for the dependent variable "GFK" (Gross Fixed Capital Formation), used as an indicator of investment resilience, the distribution is also highly skewed, with over 300 observations in the lower ranges and only a few very high values corresponding to developed economies. This statistical configuration suggests a disproportionate concentration of infrastructure and fixed asset investments in countries with strong tax bases and high financial capacity, while smaller economies or those with suboptimal tax regimes face a limited capacity to generate public and private capital in the long term.

4. Results

The distributional analysis supports the hypothesis that the fiscal pressure on capital, in interaction with certain structural factors, can significantly influence the level of investment and, implicitly, the economic resilience of states, justifying the integration of these variables in a predictive model based on decision trees. Also, the statistical characteristics of the data require the use of algorithms that can handle scale imbalances and non-linear relationships between variables, such as the REPTree.

The tree primarily uses the "country" variable to divide the data set into distinct nodes, which indicates that the national factor has a dominant influence in determining the level of fixed investment. This reflects structural economic realities, such as the size of the economy, fiscal policies, or the level of infrastructural development, that differ significantly from one state to another.

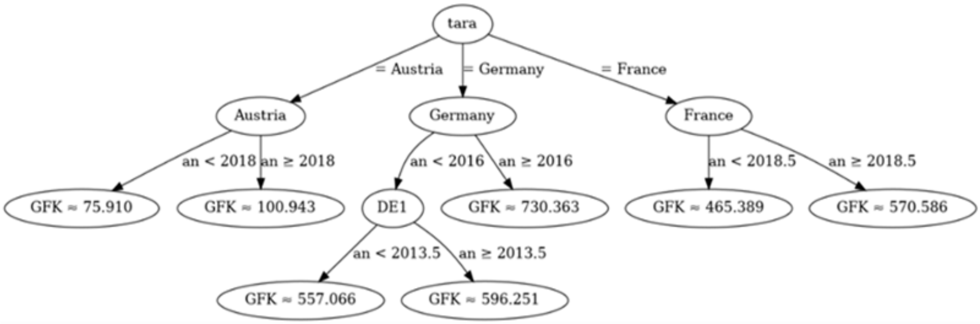

Figure 3. Relevant examples of decision segments extracted from the tree realized by the author

The analysis of the evolution of fixed capital investments in some European Union Member States highlights significant growth trends starting with 2016 and 2017, respectively, in a context marked by stimulating economic policies and post-crisis recovery initiatives. In the case of Austria, a consistent increase in the GFK value is noted after 2018, most likely as a result of alignment with European economic recovery measures. For France, the decision-making model reveals a critical threshold located around 2018.5, which delimits a transition from an average of approximately 465,388 million euros to a higher level of 570,586 million euros, associated with the intensification of public and private investments generated by digitalization and ecological transition programs. Germany presents a stratified investment evolution, with a succession of relevant time thresholds: before 2013.5, the value of GFK was around 557,065 million euros, rising to 596,250 million euros between 2013.5 and 2016, and reaching a peak of 730,362 million euros after 2016, in a possible effort to consolidate industrial capacity in the post-Brexit context. At the aggregate level of the European Union (EU27), a marked difference is observed between the period before 2017 – with an average GFK value of approximately 2,386,444 million euros – and the period after it, when investments increase significantly to 3,070,194 million euros, an evolution correlated with the launch of the Next Generation EU instrument and the targeting of funds towards strategic priorities such as the green and digital transition.

4.1. Taxation-related decision rules

Based on the REPTree analysis, several relevant decision rules were extracted that directly link the level of capital taxation to the volume of fixed investments. These rules highlight favorable or restrictive tax configurations, as follows:

- Rule 1: if TKE > 17,000 and TKS < 100, then GFK tends to be significantly low
- Rule 2: if TKC < 200,000 and TKS > 10,000, then GFK is generally medium to high.
- Rule 3: if TKE < 5,000 and TKC > 500,000, GFK tends to reach above-average values

The decision analysis based on the REPTree model allows the extraction of significant rules that highlight how combinations of forms of capital taxation influence investment behavior. The first rule indicates that, in situations where the taxation of self-employment income (TKE) exceeds the threshold of EUR 17,000 million and the taxation of the capital stock (TKS) is kept below EUR 100 million, gross fixed capital formation (GFK) tends to be significantly reduced; this configuration suggests an inhibitory effect on investment, determined by the over-taxation of entrepreneurship in the context of a poorly taxed capital base. In contrast, the second rule reveals that a low level of corporate income taxation (TKC < EUR 200,000 million), combined with a moderate taxation of the capital stock (TKS > EUR 10,000 million), is associated with medium to high levels of investment, which reflects a fiscal balance favorable to the stimulation of fixed capital. The third rule completes this logic, showing that when the tax burden on self-employment income is low (TKE < 5,000 million euros) and the taxation of corporate profits is substantial (TKC > 500,000 million euros), the GFK level tends to exceed the average, indicating a positive correlation between the efficient taxation of large companies and the capacity to generate national investments, given that the entrepreneurial sector is fiscally encouraged.

4.2. Critical fiscal thresholds

Based on the segmentation provided by the decision tree and the visual distributions, critical fiscal thresholds can be identified that function as inflection points in the investment capacity:

• TKE > 17,000 million euros → potential inhibitor for GFK in states with a weak entrepreneurial base.

• TKC > 600,000 million euros → threshold associated with consolidated economies, which allows a high level of collection without negatively affecting investments.

• TKS < 100 million euros → identified as a risk area, where the lack of taxation on the capital stock is correlated with significant investment decreases.

Interpretation of the decision rules highlights critical fiscal thresholds, which function as predictive factors in assessing the investment capacity of states. First, exceeding the 17,000 million euro level in self-employment income taxation (TKE) proves to be a potential inhibitor of gross fixed capital formation (GFC), especially in economies characterized by a low entrepreneurial base, where a strong tax pressure on the small business segment diminishes the capacity to initiate and sustain investments. Second, reaching a corporate income tax collection threshold (TKC) of over 600,000 billion euros is specific to consolidated economies, which have the necessary infrastructure and stability to support a high level of tax collection without negatively affecting the investment climate, which suggests a correlation between economic maturity and resilience to high tax pressure. Last but not least, maintaining the capital stock taxation (TKS) below the threshold of 100 million euros is identified as an area of systemic risk, in which the absence of a fiscal instrument capable of valorizing the accumulated capital generates structural imbalances and is associated with a notable decrease in investments, reflecting a vulnerability of the fiscal model that undermines the long-term self-financing capacity.

5. Conclusions

The results obtained by applying the REPTree decision model clearly highlight the fact that the fiscal pressure exerted on capital – manifested by taxation of corporate income, self-employment and capital stock – represents a relevant and sensitive determinant of investment capacity, reflected in the level of gross fixed capital formation (GFC), used in this study as a proxy for economic resilience. In a context marked by geopolitical reconfigurations and recurrent economic tensions, this relationship becomes essential for understanding the mechanisms through which states can strengthen their economic autonomy and, implicitly, the national security architecture.

More than the absolute level of the tax burden, what seems to decisively influence investment behavior is the combination of forms of taxation and their placement in a certain temporal and structural context. The interactions between taxes on capital, whether targeting corporate profits, self-employment or patrimonial assets, generate emergent effects that cannot be understood outside an integrated framework. In this sense, the decision-making model allows the identification of optimal fiscal configurations, through which both areas of fiscal capping can be anticipated – where excessive pressure discourages investment – and the risks of fiscal regression, associated with unjustified relaxations that can destabilize the public budget without producing positive economic effects. Thus, fiscal balance appears not as a fixed value, but as a dynamic benchmark, which must be continuously adjusted according to the particularities of each economy and its strategic objectives. In this complex equation, information systems become indispensable tools for anticipatory fiscal governance, providing analytical and decision-making support by integrating Business Intelligence, Big Data and artificial intelligence technologies. The ability of these systems to collect, process and analyze large volumes of data in real time gives the state a granular view of emerging fiscal risks, facilitating both the simulation of alternative scenarios and the assessment of the impact of legislative measures on economic behavior. Thus, they function as strategic sensors of fiscal stability and can contribute to the creation of proactive public policies, focused on autonomy, adaptability and resilience.

However, the conclusions of this study must be interpreted in light of inherent methodological limitations. The use of aggregated data at national and annual levels restricts the possibility of detailed analysis at sectoral or regional level, while structural differences between states – including in terms of the size of the economy, the legal system or administrative efficiency – can significantly influence the interpretation of the results. In addition, the absence of social variables, such as education level, inequality level or unemployment rate, limits the model's ability to fully capture the impact of taxation on socio-economic cohesion. Even under these conditions, the study validates the idea that capital taxation is a critical variable in understanding and modeling the investment capacity of the European Union Member States. The REPTree model applied to the data provided by Eurostat demonstrated the existence of tax thresholds and tax configurations that significantly influence investment dynamics, thus providing an empirical basis for the formulation of adapted public policies. Consequently, it is imperative to implement integrated tax monitoring IT systems, capable of providing real-time analysis and supporting evidence-based decision-making. It is also necessary to balance the tax pressure on capital through policies that stimulate investment, without compromising budgetary sustainability, as well as to correlate the tax regime with the objectives of economic autonomy, so that taxation becomes not only a collection tool, but also a pillar of structural stability.

By intelligently linking taxation, digital infrastructure and economic strategy, states can develop adaptive mechanisms for protection and development, in line with the new requirements of European economic security and in support of public governance oriented towards sovereignty, resilience and performance.

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HOW ARE ICT WORKFORCE SPECIALISTS ADJUSTING TO THE RISE OF AI?

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Abstract: *According to Eurostat data, over the last decade, the number of ICT specialists in the EU has increased nearly seven times more than the overall increase in total employment. In terms of gender distribution, the same data indicated that by the end of 2023, the number of men in this field was more than four times higher than that of women in the EU (80.60% vs. 19.40%). Approximately two-thirds of these specialists had completed tertiary education (66.7%). Due to the huge role they have in the current development process, decision-makers have an interest in tracking employment developments for ICT specialists. From this perspective, Romania appears to be facing challenges in the labor market for this sector, with data indicating a trend of decreasing specialists in software development. Essentially, AI has led to increased automation, resulting in projects being executed with smaller budgets and fewer personnel.*

Keywords: *digital challenges, digital transformation, gender balance, ICT specialists, rejuvenation of ICT specialists, tertiary education*

JEL Classification: *O3, Z10, Z13*

1. A Digital Decade - General framework

One of the European Commission's main political priorities for the coming years is to adapt Europe to the grand digital challenges. According to the Digital Decade Communication (European Commission, 2021), the document that "sets out a vision and objectives for a successful digital transformation of Europe by 2030", ICT professionals and digitally skilled citizens are one of the four essential pillars of Europe's digital future. To achieve its goals, the EU target is to reach 20 million ICT specialists employed in the EU, while also focusing on "greater convergence of gender balance in such jobs".

The road is not an easy one. According to Eurostat data, in 2023, **almost 10 million people worked as ICT specialists within the EU 27 borders**, as follows:

- 2.1 million people in Germany, that means approximately 21.5% of the total population employed in the EU 27 as ICT specialists;
- 1.3 million in France, that means approximately 13.8% of the total population employed in the EU 27 as ICT specialists;
- Almost 1 million in Italy and 0.9 million in Spain, that means approximately 9.9% and 9.6% of the total population employed in the EU 27 as ICT specialists, respectively.

According to Eurostat data , proportion of ICT specialists in total employment, in 2023, in the EU countries was the following:

- Sweden – 457.900 persons employed as ICT specialists (8.7 % of total employment in Sweden);
- Luxembourg – 25.800 persons employed as ICT specialists (8 % of total employment in Luxembourg);
- Finland – 200.700 persons employed as ICT specialists persons employed as ICT specialists (7.6 % of total employment in Finland);
- The Netherlands – 673.700 persons employed as ICT specialists persons employed as ICT specialists (6.9 % of total employment in The Netherlands);
- Estonia – 46.500 persons employed as ICT specialists persons employed as ICT specialists (6.7 % of total employment in Estonia);
- Ireland - 166.700 persons employed as ICT specialists persons employed as ICT specialists (6.2 % of total employment in Ireland);
- Denmark – 176.800 persons employed as ICT specialists persons employed as ICT specialists (5.9 % of total employment in Denmark);
- Belgium – 272.600 persons employed as ICT specialists persons employed as ICT specialists (5.4 % of total employment in Belgium);
- Cyprus - 24.700 persons employed as ICT specialists persons employed as ICT specialists (5.4 % of total employment in Cyprus);
- Austria – 237.400 persons employed as ICT specialists persons employed as ICT specialists (5.3 % of total employment in Austria).

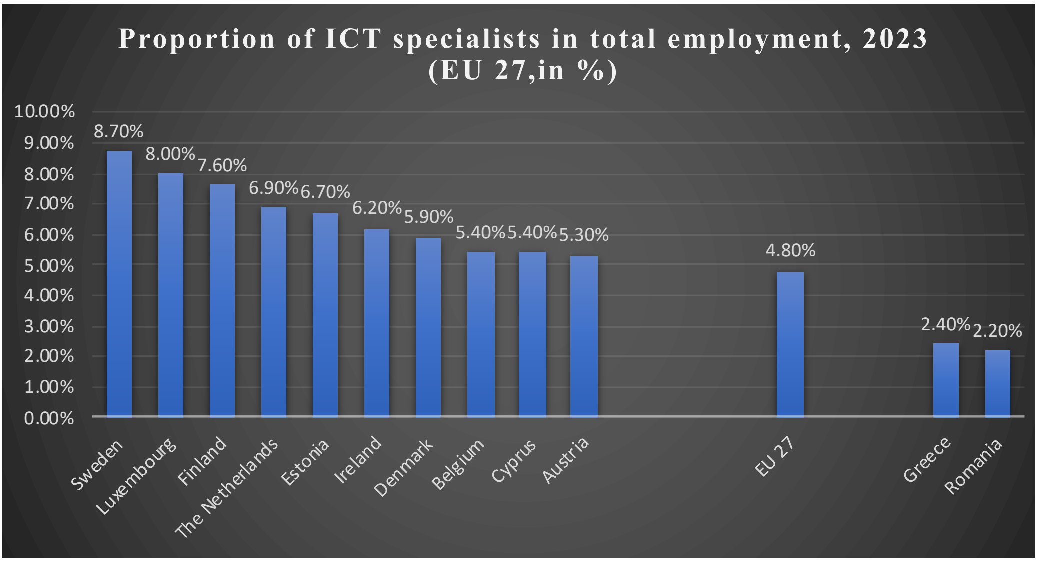

Figure 1. Proportion of ICT specialist's employment 2023 (EU 27, %)
Source: Eurostat (isoc_sks_itspt)

At the other end of the range, according to Eurostat data:

- Greece – 100.500 persons employed as ICT specialists persons employed as ICT specialists (2.4 % of total employment in Greece);
- Romania – 196.200 persons employed as ICT specialists persons employed as ICT specialists (2.2 % of total employment in Romania).

Defined as people who have the ability to develop, operate and maintain ICT systems and for whom ICTs constitute the main part of the job, ICT specialists in Romania seem to be entering a difficult period on the labor market. As Eurostat data shows, after a period of 0.6% growth in the cohort of ICT specialists between 2018-2022 (from 2.2% to 2.8% of total employees), 2023 records for the first time a decrease in the number of ICT specialists in Romania.

2. Number of ICT specialists

During the last nine years, the share of ICT specialists in total employment increased by 1.3 percentage points (pp) from 3.5 % in 2015 to 4.8 % in 2023. An increase in the number of people employed as ICT specialists from 6,551,900 to 9,789,200, which represented a corresponding increase of almost 67%.

Figure 2. ICT specialists, EU 27, 2017-2023
Source: Eurostat (isoc_sks_itspt)

As can be seen from Figure 3, after a slow increase between 2015 and 2019, the number of people employed as ICT specialists showed higher progression rates between 2019 and 2021 by 7.1% and 6.0%. In the last years of the decade, however, the progression slowed down slightly, but still revealed a higher rate than those prevailing at the beginning of the decade by 5.0% between 2021 and 2022 and 4.1% between 2022 and 2023. This general growth trend could reflect the digital transformation affecting the entire European economy, which is also observable in Romania.

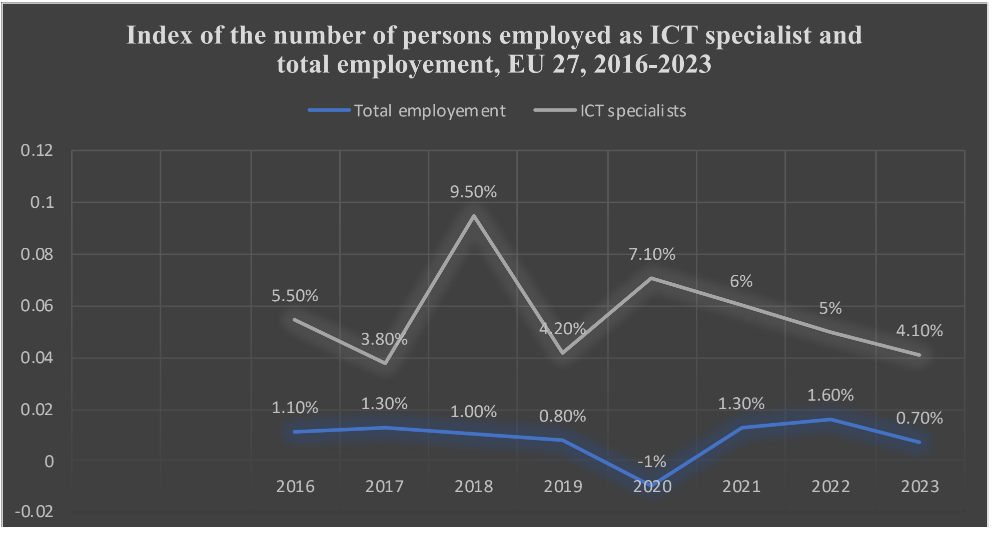

Figure 3. Index of the number of persons employed as ICT specialists and total employement. *Source: Eurostat (isoc_sks_itspt)*

As can be observed in Figure 4, in 2016-2023 annual rates of change for the number of persons employed as ICT specialists were consistently higher than those recorded for total employment across the EU economy. Whilst the number of ICT specialists in employment increased with an annual average rate of 5,65 % in the last eight years, total employment increased by 0.85 % each year on average. Notable is the 9.5% increase in 2018 (685,860 people employed as ICT specialists). Starting in 2020, the growth trend reversed, although between 2022 and 2023, ICT specialists continued to progress in the total workforce, but at a slower pace well above the growth in total employment.

3. ICT specialists by sex

Generally majority of persons employed as ICT specialists in the EU 27 are men. According to Eurostat data **the share of ICT employment in 2023 was accounted by men - 80.6 %**, practically which was 2.9 pp lower than it had been in 2015. In 2023, the most ICT men specialists were in Czechia (87.6 %), Malta (86.2 %), Italy (84.3%) and Hungary (84.3 %), while share of men ICT specialists **was lower than 75 % in Romania (74.0 %)**, Estonia (73.2 %) and Bulgaria (70.9 %).

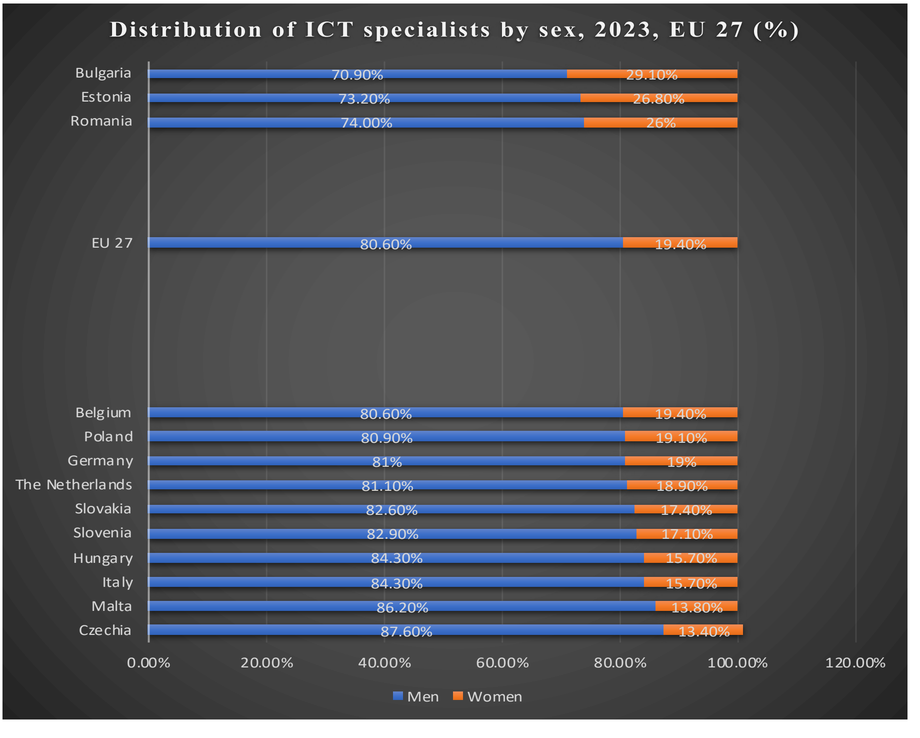

Figure 4. Distribution of ICT specialists by sex, 2023, UE 27 (%)

Source: Eurostat (isoc_sks_itsps)

The highest levels of female employment (more of 100.000 women employed as ICT specialists) were in Germany – 399 600, France - 271 500, Spain - 183 000, Italy - 152 300, Poland - 142 100, The Netherlands - 127 100 and Sweden 104 300.

There were 22 EU Member States where the share of female ICT specialists increased between 2015 and 2023, with very large advances being observed in Luxembourg (from 13.8% to 22.5% with an increase of 8.7 pp), followed by Slovakia (from 11.9% to 17.4% with an increase of 5.5 pp), Poland (from 13.6% to 19.1% with an increase of 5.5 pp), Austria (from 14.3% to 19.5% with an increase of 5.2 pp) and The Netherland (from 13.9% to 18.9%, with an increase of 5 pp).

Between 2015-2023, the share of female ICT professionals in the EU-27 increased by 2.9 pp, from 15.5% to 19.4%.

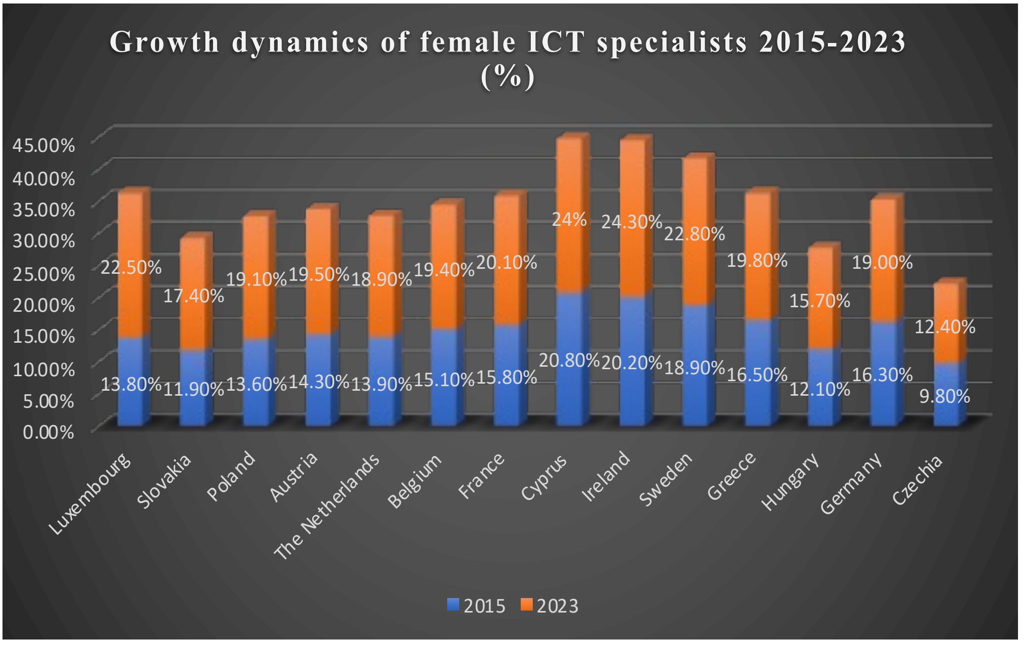

Figure 5. Growth dynamics of female ICT specialists 2015-2023 (%)

Source: Eurostat (isoc_sks_itsps)

It should also be noted that there were five countries where the share of women in the total number of ICT specialists decreased: Latvia (from 28.1% to 24% with a decrease of 4.1% pp), Malta (from 17% to 13.8%, with a decrease of 3.2 pp), **Romania (from 27.3% to 26.0%, with a decrease of 1.3 pp)**, Bulgaria (from 31% to 29.1%, with a decrease of 0.9 pp) and Lithuania (from 20.4% to 20.0%, with a decrease of 0.4 pp).

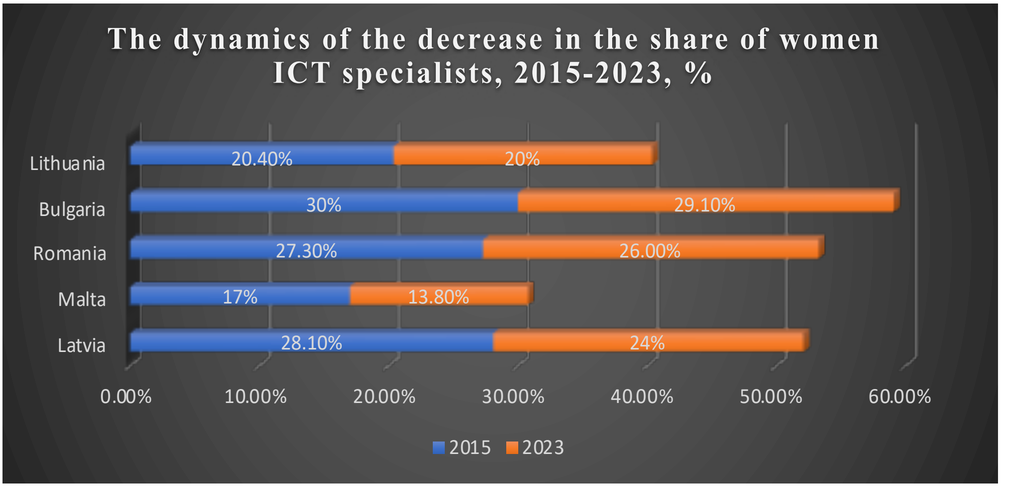

Figure 6. The dynamics of the decrease in the share of women, ICT specialists, 2015-2023 (%). *Source: Eurostat (isoc_sks_itsps)*

4. ICT specialists of EU 27- level of education

As Eurostat data shows in 2023, **two-thirds** (66.7% of those reporting their education level) **of all ICT professionals in the EU had completed a tertiary level of education.**

Generally the share of ICT specialists with tertiary education has increased between 2015-2023 increasing from 59.8% in 2015 to 66.7% in 2023 (with an increase of 6.6 pp).

The highest levels of increase in the period covering 2015 to 2023 concerning the share of ICT specialists with a tertiary level of educational was in: Sweden (from 52.5% to 66.3% with an increase of 13.8 pp), Portugal (from 52.5 % to 66.2%, with an increase of 13.7 pp), Cyprus (from 73.8% to 87.3%, with an increase of 13.5 pp), Bulgaria (from 65.2% to 76.9%, with an increase of 11.7 pp) and Denmark (from 52% to 62.2%, with an increase of 10.2%).

In 2023 the share of ICT specialists with a tertiary level of educational in **Romania was 76.2% with an increase of 6.4 pp between 2015-2023**.

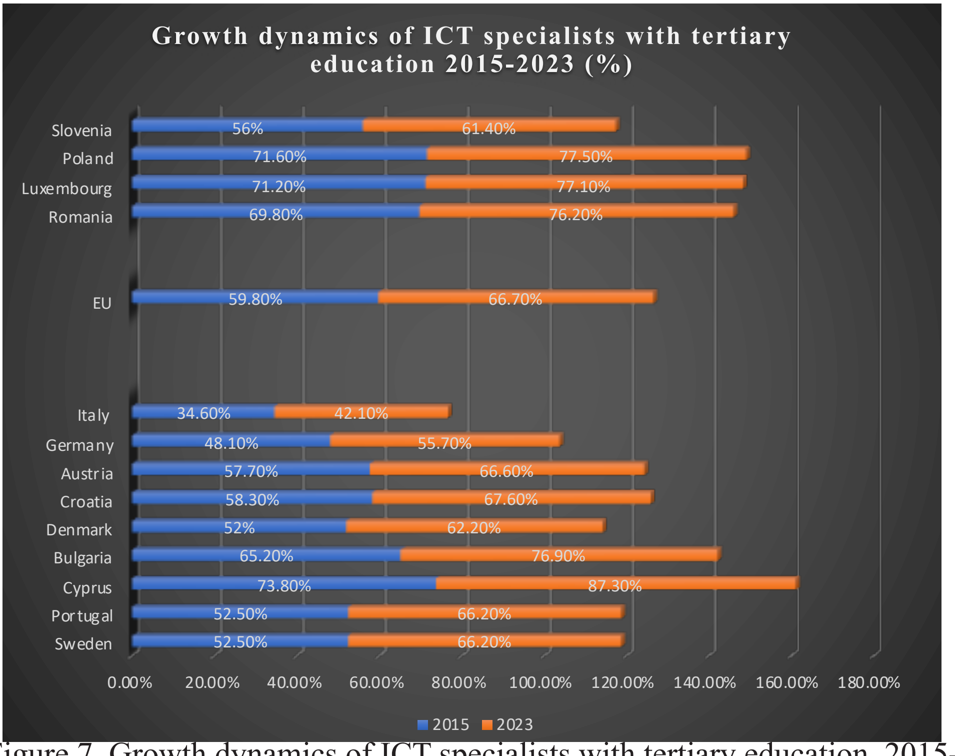

Figure 7. Growth dynamics of ICT specialists with tertiary education, 2015-2023 (%). *Source: Eurostat (isoc_sks_itsps)*

In 2023, in EU 27 the highest shares of ICT specialists with a tertiary level of educational attainment was in the following countries: **Cyprus** - 84.7%, **Spain** - 83.1%, **Ireland** - 81.7%, **France** - 81.4% and **Belgium** - 81.3%, where more than four out of every five persons had obtained such a level of education in 2023.

5. ICT specialists of EU 27 - age group

Regarding the age distribution of ICT specialists, two age groups are used: people aged 15-34 and 35 and over (limited at 74 years). As Eurostat data shows **62.7 % of all persons employed as ICT specialists in the EU, in 2023, aged 35 years and over.** Compared to 2015, is a decrease with 1% of ICT specialists aged 35 years and over (63.7% in 2015). The largest progression of ICT specialists aged 35 and over, in 2015-2023 period, was in the following countries: **Slovakia** (with a difference of 16.8 pp), **Romania** (with a difference of 10.2 pp), **Bulgaria** (with a difference of 6.7 pp), **Estonia** (with a difference of 6.5 pp), **Slovenia** (with a difference of 6.4 pp) and **Poland** (with a difference of 6.1 pp) (See Figure 8).

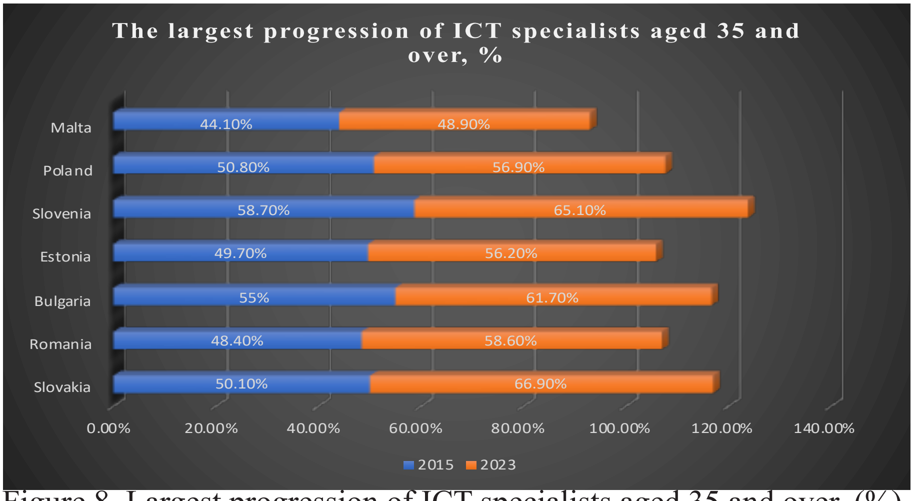

Figure 8. Largest progression of ICT specialists aged 35 and over, (%).
Source: Eurostat (isoc_sks_itsps)

In the same period (2015-2023) was noticed a completely different pattern in **Denmark, The Netherlands, Finland and Sweden (a rejuvenation of ICT specialists)**, with an increase of 9.4 pp, 4.6 pp, 3.1 pp and 3 pp (Figure 9). Another 8 countries (Portugal, Luxembourg, Italy, Germany, Ireland, Spain, Cyprus and Croatia) followed the same pattern, but with smaller differences.

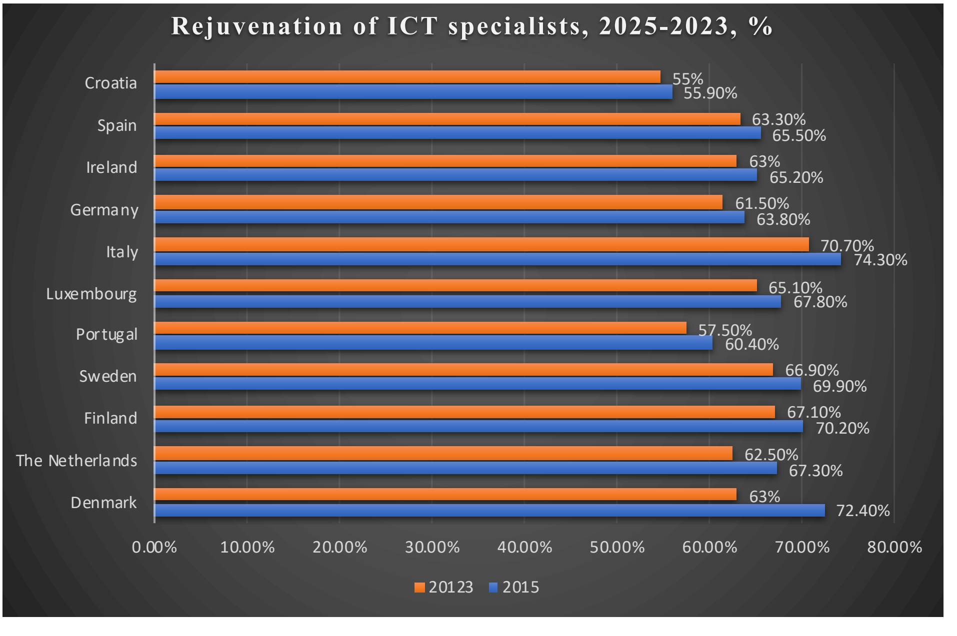

Figure 9. Rejuvenation of ICT specialists, 2015-2023 (%).
Source: Eurostat (isoc_sks_itsps)

6. Conclusions

- Digital technologies will transform the world we live and work in;
- Digital technologies will touch a lot of different aspects of our lives;
- Digital transformation is one of the most important key priorities for the EU;
- The Digital Decade initiative already established the EU targets that will guide digital transformation until 2030;
- According to the Digital Decade Communication (9 March 2021), the document that "sets out a vision and objectives for a successful digital transformation of Europe by 2030", ICT professionals and digitally skilled citizens are one of the four essential pillars of Europe's digital future.
- To achieve its goals, the EU target is to reach 20 million ICT specialists employed in the EU, while also focusing on "greater convergence of gender balance in such jobs";
- In 2023, almost 10 million people worked as ICT specialists within the EU borders;
- During the last nine years, the share of ICT specialists in total employment increased by 1.3 percentage points (pp) from 3.5 % in 2015 to 4.8 % in 2023;
- Generally majority of persons employed as ICT specialists in the EU 27 are men. According to Eurostat data the share of ICT employment in 2023 was accounted by men - 80.6 %;
- Two-thirds (66.7% of those reporting their education level) of all ICT professionals in the EU 27 had completed a tertiary level of education;
- 62.7 % of all persons employed as ICT specialists in the EU 27, in 2023, were with aged 35 years and over;
- In Romania were **196.200 persons employed as ICT specialists' persons in 2023** (2.2 % of total employment in Romania);
- Even though the share of ICT employment in 2023 was accounted by the men in the EU 27 (80.6%), **the share of male ICT specialists was 74% in Romania**;
- In the last eight years the share of women in the total number of ICT specialists decreased in **Romania (from 27.3% to 26.0%, with a decrease of 1.3 pp**);
- In 2023 the share of ICT specialists with a tertiary level of educational in **Romania was 76.2% with an increase of 6.4 pp between 2015-2023**.
- Defined as people who have the ability to develop, operate and main-

tain ICT systems and for whom ICTs constitute the main part of the job, **ICT specialists in Romania seem to be entering a difficult period in the labor market**;

- After a period of 0.6% growth in the cohort of ICT specialists between 2018-2022 (from 2.2% to 2.8% of total employees), **2023 records for the first time a decrease in the number of ICT specialists in Romania.**

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COST OPTIMIZATION IN PROFESSIONAL TRAINING: INTEGRATION OF VIRTUAL TEACHERS IN THEORETICAL EDUCATION – AN ECONOMETRIC ANALYSIS

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Abstract: *In the context of rising costs associated with professional training and the need for scalable educational solutions, the use of virtual teachers (AI-based) has become an increasingly viable alternative. This article examines the impact of integrating virtual teachers on optimizing the costs of theoretical education, employing econometric methods to assess their efficiency compared to traditional teaching models. The study is based on data collected from professional and technological education institutions, evaluating operational costs, pedagogical efficiency, and the level of acceptance among students and teachers. By employing a multiple regression econometric model, we identify the economic and pedagogical factors that influence the success of virtual teacher implementation, including their impact on academic performance and the cost savings achieved. The findings suggest that integrating these technologies can lead to a significant reduction in educational costs; however, substantial initial investments and a gradual adoption strategy are required. The conclusions provide recommendations for decision-makers regarding the sustainable use of virtual teachers in professional training.*

Keywords: virtual teacher, theoretical education, educational costs, econometric analysis, professional training, AI training

JEL Classification: *C51, I21, I22, M53, O33*

1. Introduction

Professional education is undergoing a profound transformation, driven by economic and technological changes that are shaping the labor market. In this context, the digitalization of education is not just an opportunity but a necessity. Traditional learning systems face evident limitations, ranging from high costs associated with teacher salaries to challenges in ensuring a uniform and adaptable educational process that meets the diverse needs of students. One emerging solution with the potential to optimize both costs and instructional efficiency is represented by virtual teachers—AI-based systems capable of delivering personalized, interactive, and readily accessible content.

Virtual teachers can significantly reduce educational expenses by decreasing the need for a large number of instructors to teach theoretical content, particularly in professional education. At the same time, they offer increased flexibility in the learning process, enabling personalized instruction tailored to each student's individual pace. However, integrating these technologies raises several critical questions: What is their actual impact on educational costs? Is this solution sustainable in the long run? How do virtual teachers influence students' academic performance and the general perception of education?

This study aims to examine to what extent the use of virtual teachers in theoretical education within professional training can contribute to cost optimization and an improvement in the quality of the learning process. The primary hypothesis of this research is that integrating virtual teachers can generate significant savings in educational budgets without compromising academic outcomes. To validate this hypothesis, we will conduct a comparative analysis between institutions that rely on traditional teaching methods and those that have implemented advanced digital solutions, using an econometric model to determine the actual impact of this technology on costs and educational efficiency.

The structure of this article is designed to provide a clear and detailed overview of the analyzed problem. The first section will be dedicated to a literature review, outlining the current state of AI technologies in education and identifying the main econometric models used to assess their impact. Next, the research methodology will be presented, detailing the data selection criteria, the indicators used, and the statistical techniques applied. The results analysis will highlight the cost differences between traditional teaching methods and virtual teachers, their impact on student performance, and the perception of key stakeholders in the educational process. Finally, the study will formulate conclusions and recommendations for institutions interested in implementing virtual teachers, considering both the economic benefits and the challenges associated with this technological transition.

2. Literature Review

The integration of artificial intelligence in education has become an extensively researched topic in recent decades, with studies focusing on the efficiency of virtual teachers, the impact on personalized learning, and the optimization of costs within educational systems. This section explores the specialized literature concerning the incorporation of virtual teachers into theoretical education, examining their economic and pedagogical implications.

Artificial Intelligence and the transformation of education

Artificial intelligence has demonstrated a significant impact on the educational process, particularly by enabling personalized learning tailored to each student's needs. Hasrat-Rind (2021) highlights that AI-based educational systems such as Khan Academy, ALEKS, and DreamBox Learning allow for content customization based on student progress, offering continuous and adaptive feedback.

Another major advantage of AI in education is its potential to reduce inequalities in access to quality educational resources. According to the *UNESCO (2023)* report, integrating virtual teachers can provide equal opportunities for students from diverse socio-economic backgrounds, eliminating geographical and financial barriers that often hinder educational accessibility.

Models of virtual teacher integration in education

Virtual teachers have been implemented in various educational systems with different objectives, ranging from personalized mentorship to automated theoretical instruction. The study *AI-POWERED MENTORSHIP PERSONALIZED LEARNING* demonstrates that AI can act as a digital mentor, providing personalized educational support and encouraging autonomy in the learning process.

Another approach to AI-driven education involves educational robots, as described in the work *AI teachers: AI-based robots as teachers*. This study highlights both the advantages of student-robot interaction in the learning process and the ethical and technological challenges posed by the adoption of these systems.

Economic efficiency of virtual teachers

One of the most pressing considerations in the integration of artificial intelligence (AI) into education is its economic feasibility. While AI has been recognized for its potential to improve learning outcomes and accessibility, its implementation comes with significant financial implications. The cost-benefit analysis of adopting virtual teachers must account for both short-term expenses (such as infrastructure investments and software development) and long-term economic returns (such as reductions in labor costs and enhanced resource allocation).

A key advantage of virtual teachers is the potential for cost savings, particularly in terms of human resource expenses. The study *Appraisal of Artificial Intelligence and Cost* argues that the replacement of traditional instructors with AI-driven teaching assistants can significantly reduce salary and operational costs. In traditional education systems, instructors' wages, benefits, and training contribute substantially to operational expenses. By leveraging AI-based virtual teachers, educational institutions can decrease their dependency on human instructors, especially for repetitive theoretical lessons, while maintaining high educational standards.

Moreover, virtual teachers can provide scalable solutions to educational institutions, allowing a single AI-powered system to serve thousands of students simultaneously without the need for additional hiring. This scalability is particularly relevant in vocational education, where subject-matter experts may be scarce and costly to employ across multiple locations. AI-driven systems can standardize content delivery, ensuring consistency in education quality while minimizing the need for instructor replacements or training new personnel.

Beyond teaching personnel costs, AI-driven education platforms offer opportunities for streamlining administrative operations, thereby reducing indirect expenses. The report *Quantitative Analysis of AI-Driven Security Measures* highlights how AI can contribute to budget optimization by automating various administrative processes, including:

- Student enrollment and scheduling – AI-driven platforms can efficiently allocate resources, reducing administrative workload.
- Performance tracking and evaluation – Automated grading and feedback systems reduce instructors' time investment and allow for real-time performance monitoring.
- Resource allocation – AI can predict and manage classroom capacity, ensuring optimal utilization of educational infrastructure.
- Reduction of human error – AI systems can minimize financial losses due to mismanagement, incorrect payroll allocations, and inefficient budgeting practices.

These efficiencies translate into cost savings across the entire educational ecosystem, making AI an attractive investment for institutions looking to maximize output while minimizing expenditures. While AI-based virtual teachers promise long-term cost efficiency, the initial investment remains a significant barrier. The transition to AI-enhanced education requires:

- Infrastructure investments, including hardware, cloud storage, and AI-compatible learning management systems.

- Software development and licensing, particularly for AI algorithms capable of adaptive learning.
- Training for educators and administrative staff to ensure a smooth transition from traditional to AI-assisted instruction.

Institutions must consider the return on investment (ROI) when evaluating the economic viability of AI-driven teaching. Studies suggest that while the initial setup may be costly, the long-term financial gains—through reduced labor costs, streamlined operations, and scalable teaching models—make AI integration a sound economic decision. A comparative analysis of traditional instructor-led education vs. AI-assisted teaching reveals that:

- Traditional models incur continuous costs (instructor salaries, training, recruitment).
- AI-assisted models require high initial investment but significantly lower recurring operational expenses.
- Hybrid models, where AI supports but does not replace human instructors, offer a balance between cost efficiency and pedagogical effectiveness.

Ultimately, the economic success of virtual teachers depends on how effectively institutions balance cost savings with educational quality, ensuring that AI integration supports rather than replaces human expertise in education.

Challenges and limitations

Despite the evident advantages, the adoption of virtual teachers raises several concerns. The study *Age of AI: Explore the Role of AI in Personalized Learning* underscores the necessity of developing AI systems flexible enough to adapt to diverse learning styles and educational contexts. Moreover, the UNESCO report highlights the resistance of educators toward AI integration, largely due to fears of role reduction within the educational system. Consequently, a balanced approach is needed—one that leverages AI's technological benefits while maintaining human involvement to ensure an effective and equitable learning process.

The review of existing literature reveals that virtual teachers have the potential to significantly enhance educational efficiency and reduce costs. However, despite clear benefits, the successful implementation of AI-driven education depends on social acceptance, initial investment feasibility, and technological adaptability. This study aims to build on these findings by evaluating the real impact of virtual teachers on educational costs and proposing an econometric model for their integration into theoretical education.

3. Research Methodology

This research aims to analyze the impact of virtual teachers on professional training costs through a conceptual econometric approach. Given that this system has not yet been implemented in Romania, the study was structured around two primary directions: analyzing the current costs of professional training in training firms by collecting market data and simulating the potential impact of integrating virtual teachers on these costs. To achieve this, we developed an econometric model and conducted financial projections using multiple linear regression methods.

Data collection and model construction

The study relied on data collection from professional training firms, utilizing questionnaires administered to managers and education specialists. The information obtained allowed for the identification of the main cost components associated with traditional professional training, as well as the estimation of the costs related to the implementation of an AI-assisted training system. Based on these data, we formulated an econometric model that evaluates the relationship between AI utilization and the total cost of training.

To substantiate the econometric model, we collected real-world cost data related to professional training, ensuring a robust foundation for financial analysis. The data sources included consultations with training firms, trainers, and industry specialists, which enabled us to establish a representative cost framework for professional training programs. The key cost components considered in our analysis were:

- Trainer costs: The remuneration for course instructors (trainers) was determined based on consultations with multiple training providers and certified trainers. The average cost was estimated at 50 RON per hour (gross), reflecting the market rate commonly applied in professional training services. This value accounts for fees paid to trainers for both theoretical and practical instruction.
- Course duration: The analysis focused on Level 2 professional training programs, which are among the most commonly delivered vocational courses. These programs typically span a total of 360 hours, of which 120 hours are allocated to theoretical instruction. This distribution aligns with standard curricula approved for professional qualifications and reflects the balance between theory and hands-on practice.

- Other operational costs: In addition to direct instructional costs, we incorporated logistical expenses, technology investments, and administrative overheads. These costs include the rental of training spaces, acquisition of digital platforms and learning management systems, certification processes, and general administrative operations.

Scenario development

To evaluate the financial implications of integrating AI-powered virtual teachers, we considered two distinct scenarios:

1. Traditional Training Model: In this scenario, training is conducted exclusively by human instructors, with all theoretical and practical sessions delivered by certified trainers. This represents the conventional approach used by most training firms today.
2. Hybrid AI-Enhanced Model: This scenario incorporates virtual teachers for delivering theoretical instruction, while human trainers remain responsible for the practical components. By leveraging AI for theory-based sessions, this model seeks to reduce dependency on human instructors and optimize costs by minimizing direct instructional expenses.

The econometric model developed for this study is structured to quantify the relationship between AI utilization and total training costs, evaluating the extent to which integrating virtual teachers can lead to cost reductions while maintaining instructional quality and has the following structure:

$$\begin{aligned} \boldsymbol{Training_{Cost}} &= \boldsymbol{\alpha_0 + \alpha_1 AI_{Utilization} + \alpha_2 Trainer_{Cost}} \\ &\quad \boldsymbol{+ \alpha_3 Technology_{Cost} + \alpha_4 Administrative_{Cost} + \epsilon} \end{aligned}$$

where:

- **Training**$_{\text{Cost}}$ represents the total training cost per trainee.
- **AI**$_{\text{Utilization}}$ indicates the degree of integration of virtual teachers (0 = no AI, 1 = partial use, 2 = full use).
- **Trainer**$_{\text{Cost}}$ reflects the expenses associated with human trainers (salaries, fees).
- **Technology**$_{\text{Cost}}$ includes investments in digital infrastructure and maintenance.
- **Administrative**$_{\text{Cost}}$ accounts for all other operational expenses of the training company.
- **ϵ** represents the error term of the model.

Validation of the proposed model and computational methodology

To validate the proposed model and analyze the impact of virtual teachers on professional training costs, we employed advanced computational tools, leveraging the Python programming language and specialized libraries for data analysis and econometrics. The initial data processing was conducted using the **pandas library**, which facilitated data organization, cleaning, and structuring into an optimal format for further analysis. This stage involved data integrity verification, elimination of outliers, and standardization of measurement units, ensuring that the dataset remained coherent and comparable across all observations.

To model the relationship between the analyzed variables, we applied multiple linear regression, implemented using the **statsmodels library**. This statistical method allowed us to identify and quantify the influence of each factor on the total training cost, providing a clear perspective on how the integration of virtual teachers can contribute to cost optimization. The estimated model was validated through relevant statistical tests, including:

- **R-squared and Adjusted R-squared coefficients** to measure the model's explanatory power,
- **F-test** for assessing the overall significance of the regression model,
- **p-value** analysis for each independent variable to evaluate the reliability and robustness of the obtained results.

For visual interpretation of the data and econometric analysis results, we utilized **matplotlib** and **seaborn** libraries, which enabled the generation of descriptive and comparative graphical representations. These visualizations played a crucial role in identifying patterns and trends within the dataset, highlighting differences between cost estimates in the traditional scenario and those obtained in the digitalized training context. Additionally, we conducted a sensitivity analysis, varying key parameters to understand how contextual changes may influence the final results.

Since no concrete implementations of virtual teachers exist in Romanian professional training firms, the initial dataset was supplemented with simulations based on realistic cost estimates. These estimations were grounded in industry reports and market research, detailing traditional instructor wages, technological investments in digital learning platforms, and administrative expenses associated with training programs. By integrating real-world and simulated data, we constructed a predictive model capable of evaluating the potential economic impact of AI-powered virtual teachers, providing a solid empirical basis for strategic decision-making in professional training.

Key Findings and Model Insights

The results indicate significant cost differences between the two analyzed scenarios. The cost per trainee is directly influenced by the degree of AI adoption, as well as by the initial investment required for implementation. In the long term, our econometric analysis suggests that AI integration can lead to a substantial reduction in recurring expenditures on human instructors. However, the amortization of initial investments remains a critical factor in determining the economic feasibility of this transition.

This study also highlights certain limitations. The collected data is partially influenced by the perceptions of training managers regarding AI adoption, and the analyzed scenarios remain conceptual, as no large-scale empirical implementations exist to provide measurable real-world results. Nevertheless, the simulation-based findings can serve as a foundation for future research and the development of educational policies aimed at supporting the digitalization of professional training.

4. Data analysis and results

To evaluate the impact of virtual teachers on professional training costs, we applied an econometric model based on multiple linear regression, using both real-world cost data from traditional training programs and estimated cost projections for digitalized education processes. This approach allowed us to quantify the extent to which AI-powered teaching methods can influence overall training expenses and determine whether the transition to virtual instructors presents a financially viable alternative for training institutions.

The dataset was carefully structured and pre-processed to ensure that all relevant cost components were included in the model. The main variables analyzed were:

- TrainingCost – the total cost per trainee, incorporating both fixed and variable expenses.
- AIUtilization – a categorical variable indicating the level of AI integration in the training process (0 = no AI, 1 = partial AI, 2 = full AI).
- TrainerCost – reflecting the salaries and fees paid to human instructors.
- TechnologyCost – covering investments in AI-based educational platforms, digital learning tools, and maintenance.
- AdministrativeCost – accounting for logistical and operational expenses required for running the training programs.

Through exploratory data analysis, we observed that TrainerCost remains the dominant expense in traditional training models, while TechnologyCost represents the largest initial investment in AI-based education. Administrative expenses appeared relatively stable across both models but showed potential for optimization in AI-driven training environments.

- Econometric Analysis and Regression Results

The multiple linear regression model was estimated to determine the extent to which each independent variable affects total training costs. The coefficient estimates provided insights into how AI-driven education systems influence the financial structure of professional training.

Interpretation of Regression Coefficients:

The coefficient for AIUtilization was positive, indicating that as the degree of AI adoption increases, initial implementation costs rise. However, long-term operational costs are expected to decline due to reduced reliance on human trainers. TrainerCost showed the highest statistical significance, reinforcing the idea that salaries of traditional instructors remain the primary driver of training expenses. TechnologyCost and AdministrativeCost had moderate impacts, suggesting that AI adoption requires upfront investment but offers long-term cost stabilization potential. The statistical significance of the regression model was tested using:

- R-squared and Adjusted R-squared values, which indicated that over 90% of the variability in training costs could be explained by the selected independent variables.
- The F-test, which confirmed that the overall model was statistically significant.
- P-values for each coefficient, helping to assess whether specific cost components had a meaningful impact on total training expenses.
- Visualization of Cost Distributions and Comparative Insights

To provide a clearer picture of cost differences between traditional instructor-led training and AI-assisted training, we generated histograms, scatter plots, and sensitivity analysis graphs. These visualizations demonstrated:

- A bimodal distribution in training costs, reflecting the structural shift between traditional and AI-based training models.
- The downward trend in recurring costs as AI adoption increases, particularly when virtual instructors replace human-led theoretical instruction.
- The variance in cost structure across institutions, with some training providers exhibiting higher technological investments but lower long-term operational costs.

To assess how variations in key cost components influence total training expenditures, we conducted a sensitivity analysis, adjusting critical financial inputs such as trainer salaries, to determine how fluctuations in wage levels impact total costs under various AI adoption scenarios, technology investment requirements, testing the impact of different implementation costs on financial feasibility and program duration adjustments, exploring how AI-based programs could optimize course lengths while maintaining educational quality.

Findings from the sensitivity analysis confirmed that while the initial costs of AI-based training models are higher, long-term benefits include significant reductions in labor expenses, allowing training institutions to reallocate financial resources towards curriculum development and student support services.

These insights pave the way for further research into scalability, regulatory frameworks, and pedagogical effectiveness of AI-powered training solutions, supporting policymakers and training institutions in making data-driven decisions regarding digital transformation in education.

```
                            OLS Regression Results
==============================================================================
Dep. Variable:          Training_Cost   R-squared:                       0.907
Model:                            OLS   Adj. R-squared:                  0.905
Method:                 Least Squares   F-statistic:                     470.5
Date:                Sun, 09 Mar 2025   Prob (F-statistic):           1.19e-50
Time:                        02:20:09   Log-Likelihood:                -748.97
No. Observations:                 100   AIC:                             1504.
Df Residuals:                      97   BIC:                             1512.
Df Model:                           2
Covariance Type:            nonrobust
==================================================================================
                     coef    std err          t      P>|t|      [0.025      0.975]
----------------------------------------------------------------------------------
const           -273.9178    151.632     -1.806      0.074    -574.865      27.030
AI_Utilization  1390.0694     89.123     15.597      0.000    1213.184    1566.955
Trainer_Cost       0.7836      0.032     24.521      0.000       0.720       0.847
==============================================================================
Omnibus:                        0.692   Durbin-Watson:                   2.111
Prob(Omnibus):                  0.708   Jarque-Bera (JB):                0.272
Skew:                           0.008   Prob(JB):                        0.873
Kurtosis:                       3.255   Cond. No.                     1.62e+04
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
[2] The condition number is large, 1.62e+04. This might indicate that there are
strong multicollinearity or other numerical problems.

Variance Inflation Factor (VIF):
         Variable        VIF
0           const  11.894110
1  AI_Utilization   1.012451
2    Trainer_Cost   1.012451
```

Figure 1. Regression Results

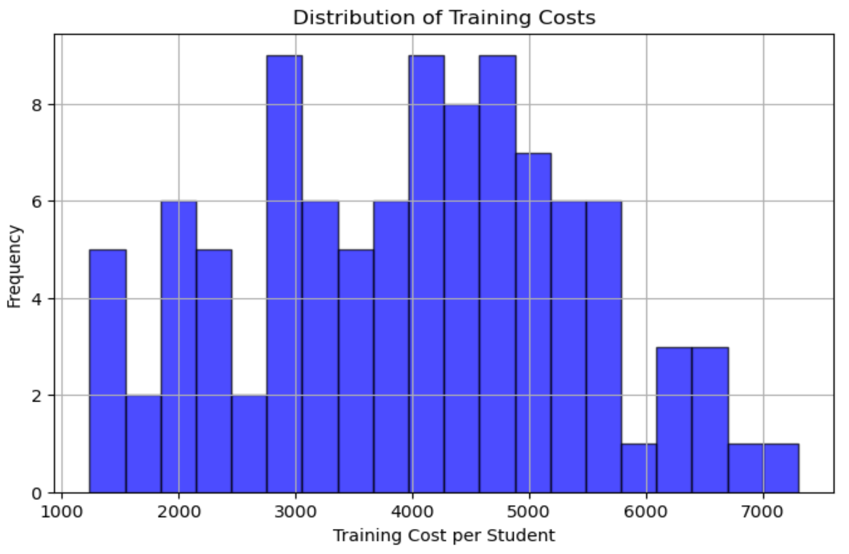

Figure 2. Distribution of Training Costs

The model results indicate a statistically significant relationship between the use of virtual teachers and the total training costs. The coefficient associated with the AI_Utilization variable is positive and significant (β = 1390.07, $p < 0.001$), suggesting that the integration of virtual teachers initially leads to an increase in costs, which can be attributed to the initial investments in technological infrastructure. These findings are consistent with the specialized literature, which emphasizes that digitizing the educational process requires substantial initial investments but can generate long-term savings by reducing dependency on human resources.

Furthermore, the Trainer_Cost coefficient is also positive and significant (β = 0.7836, $p < 0.001$), indicating that human trainers remain a critical factor in the educational cost structure. In other words, even in the scenario of advanced digitalization, teaching components that involve human interaction remain essential, and their associated costs cannot be entirely eliminated. In this context, the transition to an AI-based educational model should be gradual, through a progressive integration of virtual teachers, while maintaining an optimal balance between technology-assisted instruction and human interaction.

Although our model presents an R-squared value of 0.907, which indicates a high explanatory capacity for the variation in professional training costs, certain limitations must be considered. For instance, the high coefficient for AI_Utilization suggests a strong dependency on initial investment factors, which may pose challenges regarding the economic feasibility of this transition, particularly for professional training firms with limited financial resources.

To further illustrate the differences between traditional training models and AI-assisted education, we conducted a comparative cost analysis, presented in the figure below. This visualization shows the distribution of per-trainee costs for both traditional and AI-integrated scenarios. It can be observed that the cost distribution in the traditional scenario is more concentrated around higher values, whereas in the AI scenario, there is greater variability, driven by the high initial costs but also by long-term savings.

Additionally, we performed a sensitivity analysis to assess the impact of modifying key cost factors on the total cost of professional training. We considered three scenarios:

- Conservative scenario, where AI integration is minimal, and training costs remain dominated by human trainer salaries.
- Transition scenario, where virtual teachers are used for 50% of the theoretical component, with costs being distributed between technological investments and trainer expenses.
- Advanced digitalization scenario, where virtual teachers are fully integrated into the theoretical component, significantly reducing human trainer costs.

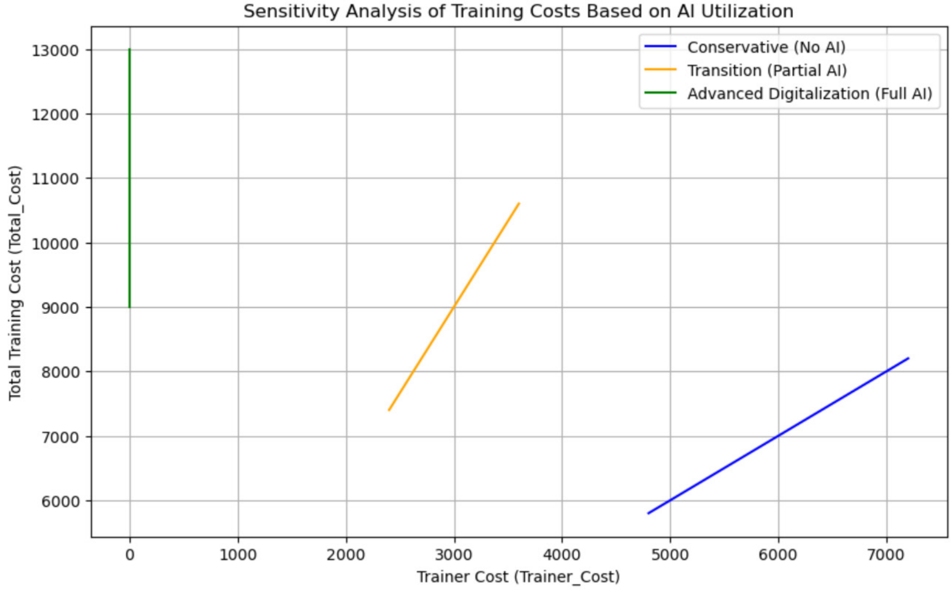

Figure 3. Sensitivity Analysis Graph

The results of this analysis confirm that, in the short term, the advanced digitalization scenario is more expensive due to the initial investments required in technological infrastructure. However, in the long run, the total cost per trainee decreases significantly, primarily due to the elimination of recurring expenses associated with human trainers. These findings suggest that the adoption of virtual teachers can represent a viable strategy for optimizing costs in professional training, provided that the transition is managed in a balanced manner to prevent significant financial strain on training institutions.

In conclusion, the data analysis indicates that integrating virtual teachers into professional training can significantly impact cost structures, offering long-term benefits, but also presenting notable challenges related to initial investments. The findings of this study provide a starting point for future research, which could further investigate the real-world implementation of these technologies and their impact on the overall efficiency of the educational process.

5. Conclusions and recommendations

This study has explored the potential impact of virtual teachers on professional training costs through a conceptual econometric analysis. The statistical modeling and sensitivity analysis results suggest that integrating artificial intelligence (AI) into the training process can have significant economic implications, reshaping cost structures and financial optimization mechanisms in this sector. Although the implementation of virtual teachers is not yet regulated in Romania, this study provides a clear perspective on the feasibility and sustainability of such a transition.

Validation or rejection of research hypotheses

The primary hypothesis of this study was that the use of virtual teachers could reduce recurrent costs associated with professional training, particularly by decreasing the dependence on human trainers. The econometric analysis confirmed this hypothesis, indicating a strong correlation between AI utilization and reduced personnel costs. However, the findings also reveal that the savings achieved are partially offset by high initial investment costs for digital infrastructure implementation and ongoing technological maintenance. At the same time, the study tested the hypothesis that AI adoption could have a differentiated impact depending on the digitalization level of training institutions. The results suggest that organizations implementing AI only partially fail to achieve the expected cost reductions, as they still require a significant human workforce. This finding indicates that financial benefits are more evident in fully digitalized scenarios.

Additionally, the sensitivity analysis revealed that cost reductions are not uniform across all training institutions. Larger organizations, which conduct a high volume of training courses, are more likely to benefit from economies of scale generated by virtual teachers, while smaller institutions may struggle to amortize technological costs. Consequently, the hypothesis that digitalization can reduce costs for all types of training providers is only partially confirmed.

Implications for Policymakers and Training Institutions

The findings of this study offer important insights for policymakers and professional training institutions. Firstly, the adoption of virtual teachers could enhance training accessibility, especially in regions where there is a shortage of qualified trainers. Moreover, the reduction of operational costs could enable training firms to reallocate financial resources toward improving educational content and developing more advanced interactive platforms.

From a policy perspective, the results highlight the need for legislative and methodological frameworks to support AI usage in professional training. Currently, Romanian legislation imposes strict requirements regarding trainers' qualifications and experience, excluding the possibility of using virtual teachers as an alternative for theoretical instruction. A revision of these regulations, aligned with international trends, could facilitate the integration of AI technologies into the learning process.

Additionally, decision-makers within training institutions should carefully analyze the cost-benefit ratio before adopting AI-based teaching solutions. While transitioning to digital education can bring long-term cost savings, initial investments require strategic planning. A viable solution could be the adoption of a hybrid model, where virtual teachers handle theoretical instruction, while human trainers remain involved in practical training and student assessment.

Limitations of the study and future research directions

Although this study is innovative in its conceptual approach, it presents certain limitations that should be considered. Firstly, the data used for the econometric model are based on estimations and simulations, as there are no concrete implementations of virtual teachers in Romanian professional training. This aspect limits the ability to test the validity of the results in real-world conditions. Another limitation is that the analysis did not include non-economic factors, such as the impact on learning quality or trainee perceptions of AI-based instruction. While international studies suggest that virtual teachers can enhance the learning experience by personalizing educational content, further research is needed to assess their effectiveness in the specific context of professional training.

Regarding future research directions, it is recommended to develop empirical studies involving data collection from institutions that have started testing digital training solutions. Additionally, expanding the analysis to include employability outcomes could be beneficial, examining whether the use of virtual teachers influences graduates' integration into the labor market.

Another promising area for investigation is the development of a dynamic cost model, considering technological advancements and labor market trends. As AI evolves rapidly, implementation costs may decrease significantly in the coming years, making virtual teacher integration more accessible to a broader range of training institutions.

Final Conclusion

This study highlights that virtual teachers represent a promising solution for optimizing costs in professional training, yet their successful implementation depends on a range of economic, technological, and regulatory factors. In the long term, transitioning to digitalized training could fundamentally transform the professional training sector, reducing dependency on traditional trainers and expanding learning opportunities for a larger number of trainees. However, a balanced approach is necessary, one that combines technological efficiency with maintaining a high-quality educational experience.

Therefore, for effective implementation, it is crucial that education policymakers collaborate with AI experts, economists, and trainers to develop an appropriate regulatory framework and maximize the benefits of this new training model. Future educational policies should include support measures for digitalization, facilitating the transition to a more flexible, accessible, and sustainable professional training system.

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DEVELOPING BUSINESS APPLICATIONS BY MODULARIZING OPERATIONAL FUNCTIONS IN INFORMATION SYSTEMS

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***Abstract**: The paper presents the increase in the development of business applications by modularizing operational functions in information systems. Operational information systems process data generated and used in business operations. Depending on the role they play, there are several categories: transaction processing systems - record and process data resulting from transactions, update databases and produce a variety of documents and reports; process control systems - provide operational decisions that control physical processes; automated service systems - those that support communications. Information systems have always been necessary for processing data generated and used in business operations. Operational IS produce a variety of information, but they (the information) do not highlight which information products are most suitable for managers. For this reason, further processing through information systems is necessary. Operational information systems include most transaction processing systems, which have evolved from manual IS to mechanical data processing systems and then to electronic data processing systems. Transaction processing systems record and process data resulting from transactions such as sales, purchases, and inventory changes. They can process data created by changes to items in a database file like changes in a customer's name and address, generating a variety of information products for internal or external use such as customer invoices, paychecks, sales receipts, purchase orders, dividend payments, tax payments, and financial statements), and documenting the databases used by an organization for further processing through management information systems. Operational information systems play an important role within companies by storing data related to production activities and using it later for managers' decision-making processes.*

***Keywords**: economic applications, system modules, operational computer systems, environment of business, data for data usage, customized design of, business decisions*

JEL Classification: *C23, C26, C38, C55, C81, C87*

1. Introduction

Operational information systems generate information to support routine decisions that control programmed operational processes. Decision rules outline the actions to be taken when a computer system is confronted with a set of events. There is a category of computer systems called process control systems, in which decisions to adjust the production process are made automatically by computers. Automated assembly lines in enterprises use such systems, which monitor a physical process, acquire and process data detected by sensors, and make adjustments to the process in real tiObj1. One of the roles of operational information systems is to develop traditional methods of office automation and paper-based communications. Automated service systems acquire, process, store, and transmit data and information in a form specific to electronic communications. Automated systems rely on word processing, telecommunications, and other information systems technologies. Examples of typical office automation applications include word processors, electronic mail, publishing, teleconferencing, and image processing.

Management information systems provide information to support decision-making. The most important management systems have as their objectives: pre-defined and planned reporting for managers – provided by information reporting systems; interactive and ad-hoc support for decision-making by managers – provided by decision support systems; important information for top management – provided by executive information systems. Management information systems are designed to provide accurate, timely and relevant information, necessary for effective decision-making. The concept of management information system was developed to counteract the inefficient development and ineffective use of electronic computers (Bernhardt, Liu, and Serfes, 2023; Campolmi, Fadinger, and Forlati, 2024).

The importance of management information systems lies in the fact that they emphasize the managerial orientation of information processing in business. An important purpose of information systems based on information and communication technology is to support management decision-making and not just to process data generated by the operational system. This emphasizes the fact that a systemic framework must be used to organize the activities and functions of information systems.

Management information systems support the decision-making needs of strategic, tactical and operational management. Operational information systems support the information processing requirements involved in a particular activity (Aydinonat 2023; Varian, Farrell, and Shapiro, 2023).

Providing information and supporting managerial decision-making at all levels of management is a complex problem. Conceptually, several types of information systems are needed to support the responsibilities of managerial users, of which three are of greater importance: decision-alternative reporting systems, decision support systems, and executive information systems.

2. Use data for customize applications functions used in applications

Reporting systems provide managers with information that largely supports decision-making needs by accessing databases of information about internal operations previously processed by transaction processing systems. Data about the business environment is obtained from external sources. The information accessible to managers includes reports provided on demand, periodically – according to a predetermined schedule or under exceptional conditions. For example, sales managers can access reports generated instantly in response to a request to analyze the sale of a particular product, weekly sales analysis reports to evaluate the sales results of products, agents and sales territories, or automatic reports generated whenever a sales agent does not achieve the expected sales results during a specified period.

Decision support systems are a natural evolution from information reporting systems to transaction processing systems. These systems are interactive, ICT-based information systems that use decision models and specialized databases to assist managers in decision-making processes. As such, they are different from transaction processing systems, which focus on processing data generated by transactions and businesses. They also differ from information reporting systems, which focus on providing managers with pre-specified reports that help them make complex decisions. In contrast, decision support systems provide managers with information in an interactive session or in an ad-hoc manner (depending on the need). Such a system provides analytical modeling, data retrieval systems, and information presentation capabilities that allow managers to generate the information needed to make decisions in an interactive computerized process (Mansell, and Steinmueller, 2022; Otter, 2022).

For example, spreadsheet applications allow a manager to receive interactive responses to ad hoc requests for sales or profit forecasts formulated within analytical models. The responses differ from the pre-specified responses of information reporting systems. When using a decision support system, managers explore possible alternatives and receive experimental information based on a set of alternative assumptions. Thus, decision makers do not have to specify information requirements a priori, the system interactively assists them in finding the information they need (Campolmi, Fadinger, and Forlati, 2024; Otter, 2022).

Executive information systems are managerial information systems built on the information needs of strategic management. Managers obtain the necessary information from several sources, including letters, notes, journals and reports made manually or through computer systems, from meetings, telephone conversations and social activities. The main purpose of executive information systems is to provide decision makers who ensure the strategic management of the organization with quick and easy access to information about the critical factors in achieving strategic objectives. Such systems involve the use of graphical representations and quick access to the content of databases to provide information about the current status and projected trends of the strategic components of the organization.

Starting from the general definition of the notion of a system – according to which it can be any entity in real life, for which a set of components such as phenomena, objects, processes, notions, concepts, entities or collectivities are identified that are in mutual relationships as well as with the environment and that act jointly to achieve well-established objectives – we can easily establish that any economic organization can be considered an open, adaptable system that operates in a business environment (Aydinonat, 2023; Campolmi, Fadinger, and Forlati, 2024).

Seen as a system, any organization comprises six interdependent system components:

Input - economic resources such as human, financial, material, machinery, land, facilities, energy and information, which are taken from its environment and used in system activities.

Transformation function - organizational processes such as research, development, production, marketing, sales, which transform input into output.

Output - the results of the transformation function, which consist of products and services, employee and supplier payments, dividends, contributions, taxes and information to the external system - the environment (Mansell, and Steinmueller, 2022; Varian, Farrell, and Shapiro, 2023).

Feedback - is the defining element of a cybernetic system, which ensures the self-regulation function, when the output does not correspond to the objectives established within the system represented by the economic organization.

Control - management is the control component of an organizational system, which targets the functions of the enterprise so that the performance of the system achieves organizational objectives such as profitability, market share or social responsibility.

Environment - any economic organization is an open, adaptable system that shares inputs and outputs with other systems in its environment.

An organization must maintain appropriate relations with other economic, political and social systems in its environment. The group of systems includes several factors such as customers, suppliers, competitors, shareholders, labor unions, financial institutions, government agencies and communities, each having its own objectives relative to the organization in question. Information systems are those that facilitate the interaction between the organization seen as a system and each of the listed factors. On the other hand, considering the definition of a cybernetic system characterized by the existence of at least two subsystems between which there is self-regulation through reverse connection and analyzing this for the economic information system we can find that it has a cybernetic character.

The character of a cybernetic system is reinforced by the fact that the economic information system has its own objectives, methods, techniques and resources. At the level of the economic information system, at least two interdependent subsystems can be identified, which ensure the stability of the entire system: the managerial (management) information subsystem and the operational (driven) information subsystem (Bernhardt, Liu, and Serfes, 2023; Otter 2022).

Within the information process, the phases of economic information formation are carried out: collection of data resulting from the direct productive process of the economic system, their verification and transmission for the actual processing (regardless of the technical means), formation of economic information and its archiving. Part of the phases of the information process (for example, collection of data from primary records) is carried out within the operational (driven) subsystem of the economic system.

It can be appreciated that the subsystem in which the information process takes place together with part of the operational subsystem forms the driven subsystem of the cybernetic information system. The main role of the managed information subsystem is to provide information for the management of the entire economic system, for the functioning of the information system and for maintaining it within predetermined limits.

3. Transforming data used in economic applications

Another element of the information system is the management process of the system, which is based on specific management methods, similar to the management of the economic system as a whole. The managerial information subsystem has a special role, receiving information and requirements on the one hand, and on the other hand, transmitting decisions. The information requirements it receives are intended to maintain and ensure full agreement between the economic system and the information system that characterizes it. The requirements are of the type of creating new information, abandoning information that is no longer necessary for managing the economic system, improving some methodologies for calculating indicators, etc.

The dynamic nature of the economic system necessarily determines a dynamic nature of the economic information system. Initially, variations in the behavior of the economic system may represent disturbances for the information system, but, due to its existence as a cybernetic system, the information system can adapt and function in full agreement with the economic system.

In conclusion, the cybernetic nature of the economic information system results from the fact that it has the capacity for self-regulation, so that it reflects and is always in accordance with the economic system that it describes, characterizes and serves. In this context, one can define both the information system in general and the economic information system (Aydinonat, 2023; Mansell, and Steinmueller, 2022).

The information system is a technical-organizational ensemble for designing and obtaining the information necessary to substantiate decisions for the management of a certain field of activity.

Nowadays, the information system is detached from the enterprise and even goes outside it, making direct connections with banks, suppliers and providing management with data on the movements of the competition. The management of the modern enterprise is no longer satisfied with operational information, but wants forecasts, wants to predict the future movements of the competition and the future evolution of the market, taking into account what is happening at present. Therefore, even if we do not design decision support systems, modern information systems must go outside the perimeter of the enterprise.

The achievement of good economic efficiency by enterprises is conditioned by the existence of scientific management based on a good knowledge of economic laws, operative and accurate knowledge of supply and demand on the domestic and foreign markets, of the dynamics of commodity prices, of technological trends as well as of the way of using the resources at their disposal. Starting from the fact that, on the one hand, mathematical models represent the scientific component of an information system, and on the other hand, taking into account the facilities offered by the use of information and communication technology as a component of the information system, the latter constitutes a true instrument in the scientific management of economic activity (Bernhardt, Liu, and Serfes, 2023; Mansell, and Steinmueller, 2022).

Here are some of the arguments brought in favor of managing economic organizations using information systems:

The information system offers the possibility of simulating economic processes and phenomena both at the microeconomic and macroeconomic levels. Mathematical models regarding the forecast of economic development can be developed and implemented, different plan variants can be developed and then the optimal variant can be chosen.

At the microeconomic level, with the help of IS, the available resources are harmoniously correlated with the proposed objectives. (Ex: planning of overhauls and major repairs, scheduling of ordering and monitoring of production, inventory management).

Through IS, the possibility of implementing the principle of selection and information by exception is provided. By applying this principle, decision-makers are relieved of a series of data that are often "suffocating" and cannot be used properly. Ex: In procurement, we have a nomenclature of raw materials and supplies with many positions - the idea is to highlight only products that deviate from the normal state (stocks outside the lower and upper alarm limits) in order to avoid stock shortages or immobilization of circulating assets like over-normative stocks.

For the transformation of data in economic applications, the objects are described in the following example:

```
Sub_1 (ByVal sender As System.Object, ByVal e _
As System.EventArgs) Handles Button7.Click
    'Evenimentul click al butonului "Write in file"
    If Obj1.RadioButton1.Checked = True Then 'fisier secvential
        If Obj1.RadioButton3.Checked = True Then 'creare fisier
           Dim nrF As Integer = FreeFile()
           FileOpen(nrF,"d:\work1\fis1.txt", OpenMode.Output)
           PrintLine(nrF, "Text in file")
           PrintLine(nrF, "at date:", TAB(20), CDate(Today()))
           PrintLine(nrF, New String(CChar("_"), 35))
           PrintLine(nrF, "Name", TAB(20), "Age")
           PrintLine(nrF, New String(CChar("_"), 35))
             For I = 0 To Obj1.nuObj1.Items.Count - 1
      PrintLine(nrF, Obj1.nuObj1.Items.Item(I), TAB(20),
     _ Obj1.age.Items.Item(I))
        Next i
         FileClose(nrF)
    End If
If Obj1.RadioButton4.Checked = True Then 'add records
     Dim nrF As Integer = FreeFile()
      FileOpen(nrF, "d:\work1\fis1.txt", OpenMode.Append)
   For i = 0 To Obj1.naObj1.Items.Count - 1
    PrintLine(nrF, Obj1.naObj1.Items.Item(I), TAB(20), _
```

```
     Obj1.varsta.Items.Item(I))
    Next i
    FileClose(nrF)
End If
        End If
If Obj1.RadioButton2.Checked = True Then 'file random
If Obj1.RadioButton3.Checked = True Then 'create file
  Dim nrF As Integer = FreeFile()
    FileOpen(nrF, "d:\work1\fis2.txt", OpenMode.Output)
    FileClose(nrF)
    FileOpen(nrF, "d:\work1\fis2.txt", OpenMode.Random)
     Dim write As person
      For i3 = 0 To Obj1.naObj1.Items.Count - 1
          write.rNr = I3 + 1
          write.rName = Obj1.naObj1.Items.Item(I3)
          write.rAge = Obj1.varsta.Items.Item(I3)
           FilePut(nrF, write, i3 + 1)
            Next i3
              FileClose(nrF)
End If
If Obj1.RadioButton4.Checked = True Then 'add records
    Dim nrF As Integer = FreeFile()
 FileOpen(nrF, "d:\work1\fis2.txt", OpenMode.Random)
    Dim i4 As Integer = 1
    Dim write As New person
      Do While Not (EOF(nrF))
        FileGet(nrF, scrie, i4)
          i4 = i4 + 1
      Loop
  For i3 = 0 To Obj1.naObj1.Items.Count - 1
    write.rNr = i4 + i3
    write.rNume = Obj1.naObj1.Items.Item(I3)
    write.rAge = Obj1.age.Items.Item(I3)
       FilePut(nrF, scrie, I4 + I3)
    Next i3
      FileClose(nrF)
  End If
 End If
End Sub

Private Sub Button5_Click(ByVal sender As System.Object, ByVal
e _
As System.EventArgs) Handles Button4.Click
  Obj1.Hide()
  Form2.ListModif.Items.Clear()
  Form2.ListBox1.Items.Clear()
  Form2.ListBox2.Items.Clear()

  If Obj1.RadioButton1.Checked = True Then
    Dim nrF As Integer = FreeFile()
    FileOpen(nrF, "d:\work1\fis1.txt", OpenMode.Input)
     Do While Not (EOF(nrF))
```

```
        a1 = LineInput(nrF)
        Form2.ListModif.Items.Add(A1)
     Loop
       FileClose(nrF)
        Form3.Show()
  End If
   If Obj1.RadioButton2.Checked = True Then
    Form2.ListModif.Items.Clear()
    Dim nrF As Integer = FreeFile()
FileOpen(nrF, "d:\work1\fis2.txt", OpenMode.Random)
Dim i4 As Integer = 1
Dim write As New person
 Do While Not (EOF(nrF))
   FileGet(nrF, write, i4)
   Form2.ListBox1.Items.Add(write.rNr)
   Form2.ListModif.Items.Add(write.rName)
   Form2.ListBox2.Items.Add(scrie.rAge)
    i4 = i4 + 1
    Loop
      FileClose(nrF)
      Form2.Show()
End If
End Sub

Private Sub Button1_Click(ByVal sender As System.Object, ByVal
e _ As System.EventArgs) Handles Button1.Click
 If Len(Trim(Obj1.TextBox2.Text)) > 0 Then
   Obj1.nuObj1.Items.Add(Obj1.TextBox1.Text)
   Obj1.age.Items.Add(Obj1.TextBox2.Text)
   Obj1.TextBox2.Text = ""
   Obj1.TextBox1.Text = ""
 End If
   Obj1.TextBox1.Focus()
 End Sub
```

The information system ensures the implementation of a multitude of mathematical models and as a result of this aspect will increase economic efficiency at the level of the reference unit. In the field of foreign trade, models can be implemented regarding the prospection of the foreign market, the correlation of the export load with the domestic manufacturing production, the calculation of economic efficiency for each commercial transaction, the choice of the optimal offer (Bernhardt, Liu, and Serfes, 2023; Otter, 2023).

4. Conclusions

By implementing the information system, the anachronism regarding the use of labor is removed. Much of the time of technical and civil service personnel is used for routine activities such as ascertaining, recording, centralizing data on economic processes and phenomena, leaving too little time for control, analysis, forecasting and command-decision activities. Thanks to the use of the information system, decision-makers will have more time to analyze data and make appropriate decisions. At the micro and macroeconomic level, the design of information systems must take into account the use of databases, mathematical models, obtaining final situations with the character of preventive signaling of deviations from the normal state, all of which represent a scientific form of management. This conception changes the entire information system, transforming it from a passive instrument for observing, recording and analyzing economic phenomena and processes that have already occurred, into an active instrument for forecasting, commanding and controlling them. (camp; Otter, 2023). Dedicated tools used within information systems can manage many types of data, but preparing them and grouping them into objects makes it possible to use them flexibly in modules dedicated to economic flows.

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EUROPEAN UNION, INTERNATIONAL ACTOR ECONOMIC SANCTIONS TRAINS: RELATIONS BETWEEN THE EUROPEAN UNION AND RUSSIA AFTER THE INVASION OF UKRAINE IN 2022

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Abstract: *Russia's invasion of Ukraine on February 24, 2022, had profound implications for regional stability and international relations. In response to Russia's aggressive actions, the European Union (EU) quickly implemented a series of economic sanctions against Russia. This paper sets out to explore the context, objectives, effectiveness and implications of the economic sanctions imposed by the EU on Russia in the context of the invasion.*

Keywords: *EU, Ukraine, Russia, invasion, regional stability*

JEL Classification: *C23, C26, C38, C55, C81, C87*

1. Introduction

The year 2022 brought to the fore a relatively new term - permacrisis. This notion is defined by Collins Dictionary as "a prolonged period of instability and uncertainty, especially one resulting from a series of catastrophic events" (Harper Collins Publishers, 2023), and permacrisis includes the main international events of 2022, the war in Ukraine, the economic crisis and climate change.

The war in Ukraine is one of the international events that require the use of the term permacrisis, generating and being contemporary with other crises that have accentuated the perception of insecurity at a global level.

The construction of this humanist identity was not an easy task. It was the result of gestation by a long and vast historical process with the intervention of a rich and varied multiplicity of factors, rhythms and circumstances that, in a desire for synthesis, can be reduced to four foundations that have given shape and meaning to the concept of Europe: Greek culture, Roman culture, jurisprudence, Christianity and the political heritage of the Germanic peoples. The foundations are closely linked to the question of inclusion and exclusion is that of the way in which the constituent elements of Europe must be integrated into the European entity. Prima facie, the dominant assumption, from proposals for a "United States of Europe" to the mechanisms for EU enlargement to "candidate countries", has been that a consolidated Europe would take the form of a partnership between European nation-states, agreed through intergovernmental agreements. But the Europeanist ideological family also includes many other models, ranging from conceptions of Europe as a union of alternative spatial or demographic units - "peoples", nations, regions, even workers' councils - to those of an undifferentiated community or even administrative subunits subsumed within a monolithic nation-empire. But these conceptions have been much changed by the strong national sentiment developed since the First World War and the effects are seen even today. "Europeanness" is understood as "social and cultural civilisation" and is opposed to "distant countries". It is also important to note that, speaking about the "similarity" of Ukrainian refugees to Europeans, none of the journalists mention a specific country or a country of the European Union, which makes "Europeanness" an object of knowledge and commands it. At the same time, in the given quote's refugees from distant and poor countries (most often Afghanistan, Iraq or Syria) act as a collective "Other", without causing indignation or sympathy of the authors of the quotes. Often, the names of these "other" countries are given as examples. Thus, the effect of "standardization" of the image of the refugee as coming from poor, underdeveloped countries is created, a typical representative of the indigenous ethnic groups of these countries. We will argue that the injunction to "return to Europe" by Europeanization is enabled and conditioned by the mythologies of Western civilization, and that Europeanization both marks (promulgates) and demarcates (naturalizes) racial whiteness. In other words, we view Europeanness as a deeply—if contingently—racialized process, where racial whiteness is trivialized as a "natural" contiguity of the West.

2. The context of sanctions

Since 2014 and the start of the war in Ukraine, the European Union has subjected Russia to sanctions. But with the military invasion launched by Moscow on February 24, 2022, the Twenty-Seven toughened their tone and took very heavy retaliatory measures for the Russian economy (Tobelem, 2025). The premises which led to the set of sanctions imposed by the EU are linked to non-compliance with international law. Moscow recognizes the independence of two pro-Russian secessionist territories, the Donetsk People's Republic and the Luhansk People's Republic, born in reaction to the Ukrainian and pro-European Euromaidan movement in 2014 (Tobelem, 2024). The policy pursued by Russia since 2014 shows that, to stop this process, the Kremlin does not plan to engage in a policy of conciliation and recognition of the sovereignty of Ukraine, by backing down in Donbass and Crimea (Tinguy, 2022). It is therefore not surprising that any attempt by Ukrainians to promote their distinct culture, language and identity was harshly suppressed by the empire as the beginning of dangerous separatism (Riabchuk, 2022). Thus, we see with the invasion in 2022 that Russian head of state Vladimir Putin has reinitiated and intensified an old war rather than a new battle. By 2022, the situation appears all the more threatening as a new potential front of some thousand kilometers has opened up on the northern border: the militarization of Belarus has been strengthened, aided by Russia, in support of President Lukashenko whose legitimacy is contested by the population (Tinguy, 2022).

2.1. The objectives of EU sanctions

The EU sanctions against Russia in 2022 were motivated by several objectives. First, they were intended to express unequivocal condemnation of Russia's violation of international law and Ukraine's sovereignty. The EU is looking at its commitment to respecting international standards and emphasizing the importance of territorial integrity and respect for national borders. Second, the sanctions were intended to deter further Russian aggression and put pressure on the Russian government to seek a peaceful solution. The EU's objective is to use economic and diplomatic leverage to encourage a de-escalation of the conflict. Instead of affecting the military, the economic pressure is transported to the rear of the front, it targets civil society, and it aims to weigh as much on the support of decision-making elites as on the capacity of the economy to support the effort. of war (Dufy, 2022).

Compared to a classic military conflict situation, the sanctions taken by the EU have multiple shifts which move the place of confrontation from the battlefield into the economic sphere and onto the political terrain.

2.2. The scope and impact of economic sanctions implemented by the EU

This section examines the scope and impact of EU sanctions imposed on Russia in 2022. It examines specific measures taken by the EU, including asset freezes, travel bans and restrictions on trade and investment. The essay also analyses the economic ramifications of these sanctions for Russia and EU member states, considering trade interdependencies and potential spillover effects on global markets. Additionally, it assesses the effectiveness of sanctions in achieving their intended objectives, including the extent to which they have impacted Russia's behavior and decision-making. The sanctions immediately led to a drop in trade between Russia and the EU. This decrease was estimated, in October 2022 compared to October 2021, at –4.5 billion USD (Sapir 2023).

Furthermore, we could see that the sanctions had mainly led to a reorientation of Russian foreign trade, to the benefit of China and India, but also of Turkey, Belarus and Kazakhstan. Indeed, the reduction in the presence of Western firms does not mean their disappearance. Furthermore, it is accompanied by the reorientation of Russian commercial, financial and economic flows towards Asian and emerging countries, both for the supply and for the outlets of Russian products (Dufy, 2022). Because in the wake of this green light given to Nord Stream 2, Gazprom signed a contract with Hungary and Belarus. Thus, an energetic link is completed connecting the "illiberal" powers whether they are inside the European Union or outside (Tinguy, 2022)

Vladimir Putin's policy for the modernization of Russian infrastructure and transport networks (Prokofeva, and Adamov, 2012). which began at the end of the 1990s, focused on making Russia completely independent for its exports. A similar policy was applied on the southern flank towards Ukraine with the development of new terminals in Russian ports on the Black Sea (Novoros siisk, which has become the first Russian port in terms of tonnage, Gelendjik, Kavkaz) and the construction of several tubes to Turkey (Bluestream completed in 2022 then Turkishstream which was inaugurated in January 2020). It aims to bypass European projects like Nabucco, now abandoned, and to avoid, if the crisis deepens, any transit through Ukraine (Radvany, 2020).

2.3. Challenges and limitations

Although EU economic sanctions represent a forceful response to the invasion of Ukraine, they are characterized by several challenges and limitations. Among the potential obstacles the EU faces in implementing and maintaining sanctions are the potential for divisions between member states and concerns over energy security.

The first impact was rising energy prices, which forced EU countries and Britain to spend 785 billion euros, as explained in a note from the think tank Bruegel, to support households and businesses. The sum is considerable, more than what was spent to fight Covid-19. Germany thus spent nearly 7% of its GDP to protect energy consumers. France, which was much less exposed to energy flows from Russia, had to devote nearly 3.25% of its GDP to various "energy shields" (Sapir, 2023).

We must also take into account that Russia is employing countermeasures as a counter-response to EU sanctions. Thus, Russia announced that it would ban European leaders from entering its territory in response to the punitive measures taken by the 27 since the invasion of Ukraine (Euronews 2022). Moscow expelled 18 diplomats from the European Union delegation in Russia in retaliation for Brussels' expulsion of 19 Russians in early April 2022 (Reuter, 2022). Russia also said it had significantly increased the number of European Union officials, lawmakers, public figures and journalists banned from entry into Russia, citing their responsibility for sanctions and anti-Russian sentiment (Europe 1, 2022).

3. Conclusion

Wider implications and futures prospects

EU economic sanctions against Russia in the context of Ukraine in 2022 have broader implications for European security and international relations. This section deals with the geopolitical consequences of sanctions and the elements to consider for the long term on the level of diplomatic negotiations.

I take up the idea of Jacques Sapir, Director of Studies at the School of Hautes Études an Sciences Social's in Paris to underline the possibility of Russia which could well escape from the situation imposed by the economic sanctions while the EU may have to pay a prohibitive price for supporting Ukraine.

There will probably be no clear and indisputable winner in this confrontation between the countries of the European Union and Russia. But there will be an indisputable loser: European strategic autonomy. With the latter, undoubtedly, it is the very idea of the EU which will have to die in the years to come, because it was based on the idea of strategic autonomy of European countries.

Russia's decision to exert new pressure on Ukraine and to request a review of the foundations of the European security architecture put in place following the end of the Cold War aims to return to the balance of power which would support the great power status to which it claims. It is likely to give new impetus to the disintegration of Eurasia. The current danger is represented by the war in Ukraine which, although addressed by the EU with solidarity and support together with economic adaptation mechanisms to this situation, may bring new major risks that may open the way to a nuclear incident. Overall, a high level of perceived insecurity is observed correlated with the ongoing war, but also with other crises whose occurrence is older. This shows that even European societies not directly affected by the war have added a new factor, involvement in the war, an element that accentuates the economic insecurity perceived so far, prolonging the feeling of insecurity, thus being affected by the permacrisis.

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SOME PECULIARITIES AND PERSPECTIVES OF THE FINNISH EDUCATION SYSTEM

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Abstract: *This article explores specific aspects of the Finnish education system, which is recognized worldwide for its high performance. Specialized studies have revealed that Finnish education is based on holistic pedagogy and supported by high-quality teacher education. Finnish society mainly focuses on teaching and learning, and respect for education and learning is determined mainly by historical and cultural factors. An overview of the Finnish education system is provided in the interview with the Ambassador of Finland in Romania, where she talks about the "high quality of the education system", the "level of technology used", as well as the "future of education" and the reasons why "every foreign student chooses Finland." Education is highly valued in Finnish culture, contributing to the perception of Finns as "the happiest nation in the world." In Romania, some models of Finnish education have been implemented through educational development partnerships, as well as through the Finnish educational program based on Artificial Intelligence (AI), launched by the Embassy of Finland in 2020. Additionally, a transnational comparative study revealed the need to develop a literature on "the ethics of AI-based learning", for a better life. This study confirms the need for international and transnational dialogue from ethical perspectives, to promote "a human-centered stance for a better understanding of AI in education." Finland is recognized as one of the European countries with a strong focus on AI ethics, ensuring that everyone benefits from the ongoing technological revolution—"AI for all."*

Keywords: *holistic pedagogy, teacher quality, joy of learning, artistic education, ethics of AI-based learning*

JEL Classification*: I210 Analysis of Education*

Introduction

"Education is the most powerful weapon which you can use to change the world," said Nelson Mandela (DIGI24.ro, 2018). Given this statement, this article aims to explore answers and identify models for improving national educational performance in the era of digitalization. To achieve this, we analyzed a series of sources that we consider relevant and current references for describing the existing situation and perspectives in the field, both nationally and transnationally. The findings have been structured as follows:

1. Aspects regarding the Finnish educational system - in specialized studies,

2. Aspects regarding Finnish education - in the interview given by the Ambassador of Finland to Romania,

3. Models of Finnish education implemented in Romania,

4. Aspects regarding AI ethics in Finnish education - in comparative research.

Beyond the historical and socio-cultural premises of the Republic of Finland, we turn our attention to common goals which are based on democratic principles and standards, in the context of the technological revolution - "***AI for all***", in which the educational system in general and the academic environment in particular must rise to the level of current demands and challenges.

1. Aspects regarding the Finnish education system - in specialized studies

The education system of each country is based on a series of factors, of a historical, cultural, socio-economic nature, and one of the most efficient education systems in Europe is that of the Republic of Finland. Becoming a member state of the European Union (EU) since January 1, 1995, Finland is recognized worldwide for its high performance education system, which represents a basic pillar of Finland's reconstruction after World War II Government of Romania (Government of Romania, n.d.).

Specialized studies have shown that, in European countries such as Finland, the general purpose of education, as a whole, is to support **the development of the person**, and the specific purpose is to ensure **the development of the cognitive domain**, in accordance with the educational objectives in the national curriculum. ("*National Core Curriculum for Secondary School*") (Tirri, 2012, pp. 55-66). According to the opinions expressed by Finnish teachers based on empirical data, at the secondary education level, the educational goals of teaching were divided into two categories: general goals and goals specific to the subject taught, the results showing a solid value base, which the "***holistic pedagogy***" is based on (Tirri, 2012, pp. 55-66).

The educational goal is considered **an important motivational factor** within the teaching-learning process, and **the importance of social and affective domains** is recognized in the teaching of students, having the role of developing intercultural competencies and skills, necessary for future graduates to adapt to new and unforeseen situations, given the dynamism of the current context (Tirri, 2012, pp. 55-66).

The Finnish education system is recognized worldwide due to **the success of Finnish youth** in the OECD's PISA surveys (in 2000, 2003, 2006 and 2009), these results being generated by educational policy priorities and the **high standards of teachers**, as shown in specialized studies (Niemi, 2012, pp. 19-38). Based on research conducted in the field, Finnish educational policy aimed at "***equity in education and has promoted the common comprehensive school model***", one of the most important decisions in this process being the training of all teachers (including those in primary school), at master's level (5-year programmes) (Niemi, 2012, pp. 19-38). Teacher training at the university level has been established since the 19th century, with the first teacher training seminar being established in 1863 (Niemi, 2012, pp. 19-38). Among the historical and cultural movements that influenced Finnish education, an important role was played by the 19th-century national movement, promoted by many university professors with expertise in their fields of activity, with the main message that: "***The power of the nation depends especially on... quality of*** *civil servants and* ***teachers***" (Niemi, 2012, pp. 19-38).

In the current international context, marked by challenges such as technological advances, increased migration and multiculturalism, the Finnish national curriculum reflects the priority given to **arts education** as part of the education system, at primary and secondary levels, considering that it can contribute to a creative learning environment if art subjects are integrated throughout the curriculum (Kairavuori and Sintonen, 2012, pp. 209-223).

One of the art forms that has always been part of the Finnish educational system is **drama**, although it has not occupied an official place in the National Curriculum, as shown in specialized studies (Toivanen, 2012, pp. 227-236). Currently, many **doctoral theses** confirm that the **use of drama in educational processes** helps with personal and social development, including the ability to assume roles, solve problems, and cope with stress. The Finnish school system has a historical tradition of **school drama**, dating back to 1550. Later, in the early 1970s, ideas of drama education spread widely in Finland, with personality development and free expression being considered priorities in education, with an emphasis on developing teaching methods for creation, expression, and group dynamics (Toivanen, 2012, pp. 227-236).

Concurrently, **drama education represents a challenge for teacher training**. The drama teaching in teacher training began at the universities of Jyväskylä and Helsinki in the late 1980s, and "***the drama-educator training programme*** *for class and subject teachers started at the Open University of Jyväskylä and the Finnish Theatre Academy's Continuing Education Institute in* *the 1990´s*" and led to the emergence of the first **PhD students in dramaturgy and drama pedagogy**, graduating in early 2000. Thus, "***drama education has become an academic discipline in Finland***" (Toivanen, 2012, pp. 227-236).

The same study shows under the title „*Present: Drama education in Finland in the 2000's*", that: *Drama in the Finnish National Core Curricula for Basic Education (2004) is placed within the subject* "*mother-tongue and literature*"; The curriculum does not have a precise description of the objectives and basic contents of drama education, but the objectives are mainly focused on interaction skills (Toivanen, 2012, pp. 227-236).

Considering the historical and cultural factors that have marked the evolution of the educational system, Finland is currently "*the country where **93% of high school graduates pass the baccalaureate exam,** over **65% of high school students go to college**, and where only 10% of those who want to become teachers will actually teach"* (NEW-EDU Institution of Education).

2. Aspects regarding Finnish education - in the interview given by the Ambassador of Finland to Romania

We selectively present below relevant aspects regarding Finnish education, taken from the interview given by the Ambassador of Finland to Romania, H.E. Mrs. Marjut Akola, for the online publication EdPost (questions - answers) (Voicu, no date):

I. "***Overview of the Finnish education system"***

— "*One of the most effective education systems in the world...*"

The high quality of the Finnish education system is based on a clear national vision that **people are the nation's most important resource**, and that the power of knowledge and trust in education are considered parts of the national identity. Over the years, Finland has been one of the OECD countries with the highest share of public funding for education, an excellent example of long-term strategic planning with the aim of developing a high-quality education system that offers equal opportunities for learning to everyone, regardless of their location or social and financial background.

— "*The level of technology used in classroom activities...*"

The Finnish curriculum emphasizes the use of digital materials, applications, and devices. At the higher education level, the admission exam has been digital since 2019.

— "***What could other countries learn from the Finnish education system***..."

The main approach to Finnish education is student-centered, and children with learning difficulties are additionally supported by specialized teachers. The Finnish education system focuses on problem-solving learning, critical thinking, developing communication skills, improving the preparation of young people to cope with future challenges, and lifelong learning.

— "***How is the private sector involved in education***..."

In the Finnish education system, there is close cooperation between the private and public sectors. Private companies are involved in the production of teaching materials and digital learning platforms. At the same time, there are Finnish companies specialized in offering Finnish expertise and educational models abroad.

— "***About the future of education...***"

Digitalization, including artificial intelligence, is driving a major shift in learning and teaching processes. In these circumstances, Finnish education must support children's mental and physical well-being, ensure the "*joy of learning"* and at the same time meet business expectations.

— "***Why does a Romanian or any foreign student choose Finland...***"

Finland is known in Europe and around the world for its high-quality education. Finnish teachers are professionals both academically and pedagogically. In Finnish universities, students are allowed to structure their own academic education, with a lot of flexibility regarding optional courses and internships. At the same time, traditional student events are organized throughout the year. For citizens of EU member states, there is minimal bureaucracy to enroll in a Finnish university and there are no tuition fees. Students only need an EU residence permit.

— "***What opportunities does the degree offer to graduates...***"

Degrees awarded by Finnish institutions are highly regarded both in Finland, in academia and business, and abroad.

For doctoral studies, there are several opportunities in all fields.

II. "*General information about Finland and education*" (Voicu, no date**)**

— "***How did Finnish culture influence the evolution of the education system***..."

Education has always been highly valued by Finnish society, and children have been encouraged to study and learn, with equal opportunities for access to quality education and well-being, without class or regional differences. This is one of the reasons why it is considered that "*Finns are the happiest nation in the world*." Another reason that has positively influenced the Finnish education system is reading, which is very popular in Finland, where there are 854 public libraries, considered "*the living rooms of Finns*". In 2018, 1.9 million books were borrowed in a country with 5.5 million inhabitants.

— "***How is student knowledge assessed...***"

As a general rule, assessment tests a student's understanding of the big picture in a given subject, not their ability to memorize small details. Summative assessment combines several types of testing, and teachers have a lot of autonomy to choose the best way to assess and are encouraged to assess students' knowledge according to various criteria, not just through exams.

─ "*How are the principles of "**Lifelong Learning**" and "**Free Education"** implemented in education***...**"

In Finland, at all levels of education, there is strong adult training and versatile lifelong learning opportunities, including adult education in higher education institutions and training in the labour market.

3. Models of Finnish education implemented in Romania

Currently, there are **development partnerships in education**, concluded between representative actors from Finland and Romania, to increase institutional capacity and train teachers, by strengthening the connections between education, research and innovation (ERI High School, 2024).

In Romania, the Romanian-Finnish School – ERI (2025) was established by the Didactica Foundation and operates in Sibiu, starting with 2016, and in Brașov, starting with the fall of 2022. At the same time, the Romanian-Finnish High School ERI (2025) opened its doors since the fall of 2024.

Since 2020, the Embassy of Finland has launched a **Finnish** Artificial Intelligence **educational programme** in Romania - "*Elements of AI Romania*," together with Bucharest.AI and the Romanian-American University (Neagoe, 2020). The course was developed by the University of Helsinki in partnership with the technology company, Reaktor Education, and was funded by the Finnish government. On that occasion, the **Finnish Ambassador to Romania, Marjut Akola**, stated that:

"*Education is a source of innovation, well-being and competitiveness for every nation*;"

"*Therefore, our mission in Finland was for everyone to have the opportunity to learn what AI is and how we can use it.*" (Neagoe, 2020).

On the same occasion, **Teemu Roos, Professor of Computer Science (AI and Data Science), University of Helsinki**, stated that:

"*When we understand the basic principles of AI, we will understand its opportunities and limitations. This is where Elements of AI comes in*."

"*By focusing on those most often marginalized in technology discussions, we have democratized access to a level unmatched by any university computer science curriculum.*" (Neagoe, 2020).

4. Aspects regarding AI ethics in Finnish education in Finnish education - in comparative research

In a transnational study (comparative research between China and Finland), it is shown that, since there are differences regarding the ethics of AI (artificial intelligence) in education, generated by factors related to the sociocultural context (Wei, Niemi, 2023, pp. 265-282):

"*The Global Technology Governance Report (World Economic Forum 2021) urgently demands ethical guidelines for technology development in the Fourth Industrial Revolution*."

At the same time, the need for international and transnational dialogue from ethical perspectives is emphasized, in order to promote "***a human-centered stance for a better understanding of AI in education***."

Since there is a lack of literature on "***the ethics of learning based on artificial intelligence***", more studies are needed to provide answers about a better life with AI and what AI means in education. Most strategies are general, covering all areas in which AI can be applied, but ethical principles for AI in education remain largely unexplored and undiscussed in national and global guidelines, the cited study also shows.

In Finland, some policies on AI ethics are applied, already transposed into European or national legislation. In specific strategies, **Finland places a strong emphasis on democratic values**, equity and non-discrimination, human rights and how all citizens can use AI in their lives, so that everyone benefits from the ongoing technological revolution - "**AI for all**" (UNESCO, 2024). Despite the differences between countries the aforementioned study appeals to "***a human-centered or humanist stance upon AI***" (UNESCO, 2024).

Conclusions

Recent specialized studies describe historical and sociocultural landmarks of the Finnish education system, which have led to results for which it is considered one of the most efficient in Europe and the world. It is shown that Finnish education has as its general goal **personal development**, based on a strong motivational system and **solid values**, along with equity and ethics, on which **holistic pedagogy** is based. An important element is represented by the **quality of teachers**, who must follow master's studies (5 years) for all teaching levels. A specific aspect is represented by **drama education** in educational processes, for teacher training and for the personal and social development of students.

In an interview with the **Ambassador of Finland to Romania**, several keywords defining Finnish education are mentioned: "*child-centered approach, lifelong learning and teachers with higher education.*" These elements serve as potential models for other countries, adaptable to their national contexts. he interview also emphasizes that the future of education will focus on digitalization, ensuring that the "joy of learning" is maintained. Foreign students choose Finland, known worldwide for its high-quality education, minimal bureaucracy and the lack of tuition fees for citizens of EU member states. In Finnish culture, education and reading are highly valued and are reasons why Finns are considered "***the happiest nation in the world***".

Currently, models of Finnish education are being implemented in Romania through development partnerships with representative actors in Finland, to increase institutional capacity and teacher training. Therefore, a multiplication of examples of the application of good practices is expected. At the same time, in recent years, the Embassy of Finland has launched in Romania a **Finnish** artificial intelligence **educational programme** - "*Elements of AI Romania*", developed by the University of Helsinki, to expand access to AI.

In the recent transnational comparative research, previously cited, it is shown that artificial intelligence plays an increasingly widespread role in the global education system, Finland being one of the European countries that **places a strong emphasis on democratic values**, equity and non-discrimination, on human rights, in the context of the technological revolution - "**AI for all**", however, education in general requires ethical guidelines for a better future in which "***teaching and learning can shape the future of humanity and the world***." (UNESCO, 2024).

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MANAGERIAL DECISIONS IN LARGE-SCALE AGRICULTURE THROUGH THE INTEGRATION OF AI

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Abstract: *The adoption of artificial intelligence (AI) in managerial decision-making processes within large-scale agriculture represents a significant advancement in optimizing financial performance, resource allocation, and operational efficiency. This study examines the impact of AI integration by comparing traditional Enterprise Resource Planning (ERP) systems with a conceptual AI-driven model, emphasizing economic efficiency and sustainability. Through a structured analysis, the findings indicate a 13.5% increase in profitability per hectare and a 10% reduction in adjusted operational costs when AI-based automation is employed. The AI model enhances decision-making by incorporating real-time data from multispectral imaging, weather monitoring systems, and financial reports, generating predictive analytics that refine input allocation and risk management strategies. Furthermore, AI contributes to environmental sustainability by minimizing resource inefficiencies and reducing the ecological footprint of agricultural interventions. The results underscore the potential of AI as a transformative tool in agricultural management, advocating for further empirical validation and integration of AI-enhanced decision-making frameworks to improve resilience and long-term competitiveness in the sector.*

Keywords: *artificial intelligence, agricultural management, decision optimization, economic efficiency, sustainability*

JEL Classification: *C53, M11, M15, O33, Q12, Q16*

1. Introduction

Large-scale agriculture is a cornerstone of global food security, providing essential resources for an ever-growing population. However, it faces numerous challenges, including fluctuating market conditions, climate change, and increasing production costs. These pressures highlight the importance of precise accounting and managerial decision-making to optimize resource allocation, improve profitability, and mitigate risks. Traditional processes of the decision making, while established, very often rely on the experience of the manager, which may lead to inefficiencies or errors, particularly in a rapidly changing economic and environmental landscape.

Over the last two decades, the Enterprise Resource Planning systems (ERP) have become a standard tool for managing the economic operations of medium and large farms. These systems centralize financial and operational workflows, streamlining operational and management processes, providing a structured framework for decision making. Despite their utility, ERP systems have clear limitations. They primarily rely on historical data and lack the capacity to deliver real-time predictive analyses or actionable recommendations tailored to specific farm conditions. Moreover, ERP systems often fail to integrate complex datasets, such as those generated by autonomous drones's multispectral sensors or other advanced technologies, such as specialized climate information software.

Artificial intelligence (AI) offers an innovative solution to these challenges by introducing a proactive and predictive approach to decision-making. Unlike ERP systems, AI employs advanced algorithms capable of analyzing multiple variables in real-time—economic, climatic, and operational. This capability enables AI to provide highly specific and context-sensitive recommendations, automate complex processes, and optimize resource usage. For example, AI can integrate data from drones and weather forecasting systems to precisely determine the application of fertilizers or irrigation schedules, thereby reducing costs and improving yields.

This study investigates the transformative potential of integrating artificial intelligence into accounting and managerial decision-making in large-scale agriculture. Through simulations and comparative analyses, we evaluate how AI can address the inherent limitations of traditional ERP systems. The research focuses on demonstrating how automated decision-making processes, powered by AI, can enhance economic efficiency and reduce financial risks for large-scale farms.

This paper makes a significant contribution to the specialized literature by:

- Conducting a comparative analysis of the performance of ERP and AI systems.
- Evaluating the impact of AI usage on sustainability and profitability.
- Proposing an operational model for integrating AI into farm decision-making processes.

2. Literature Review

The integration of artificial intelligence (AI) into large-scale agriculture represents a transformative shift in optimizing productivity, sustainability, and economic efficiency. AI-driven systems enhance farm management by utilizing data analytics, machine learning algorithms, and automation to support precision agriculture. This literature review examines the latest advancements in AI applications within the agricultural sector, focusing on decision-making optimization, predictive analytics, and resource management.

AI technologies have significantly improved efficiency in agricultural operations by leveraging real-time data processing and automation. Recent studies highlight AI's role in optimizing irrigation systems, detecting plant diseases, and predicting crop yields.

AI has been successfully implemented in decision-making frameworks for crop selection, soil management, and fertilization schedules. According to Assimakopoulos et al. (2025), AI, combined with IoT, is enhancing smart farming practices, allowing farmers to make data-driven decisions that increase yield efficiency.

AI-powered sensors and drones are being employed to assess crop health, detect pest infestations, and optimize harvesting schedules. Rajesh Basa (2024) reported that AI models can predict crop yields with 90% accuracy, enabling better financial planning and resource allocation.

Economic and Sustainability Impacts of AI in Agriculture

AI-driven solutions not only increase economic efficiency but also contribute to sustainable farming practices. AI-based automation has led to a reduction in operational costs and waste. A study by Minhajul Islam Mim et al. (2025) demonstrated that AI-powered autonomous farming systems significantly lower labor costs and improve productivity. Additionally, AI-driven irrigation systems have reduced water usage by 30%, as observed in precision agriculture implementations.

AI promotes sustainable agricultural practices through efficient pesticide and fertilizer application. According to Abdul Hussein et al. (2024), AI integrated with IoT ensures optimized energy use in agricultural operations, leading to reduced environmental impact.

Challenges and Ethical Considerations

Despite its benefits, AI integration in agriculture faces challenges such as high implementation costs, data security concerns, and the risk of workforce displacement.

Many farms, particularly in developing countries, face barriers in adopting AI due to high initial costs and lack of access to advanced digital infrastructure. AI adoption in agriculture raises concerns about data privacy, as many AI systems collect vast amounts of farm data without clear ownership agreements. A study by Hampel and Fabulya (2024) highlights potential risks, including algorithmic biases and cybersecurity threats that could impact farmers' decision-making autonomy.

So, AI has emerged as a transformative force in large-scale agriculture, improving efficiency, cost management, and sustainability. However, further research is needed to address economic barriers, ethical considerations, and hybrid AI-ERP model integration. Future studies should explore AI-driven collaborative farming networks and blockchain technology for secure data management.

3. Research Methodology

As part of this study, the analysis was conducted using data collected from a large-scale farm in the South Muntenia region of Romania, which employs an ERP system for managing economic and financial operations. The aim of the study was to compare the performance of the existing ERP system with a theoretical model based on artificial intelligence (AI) that integrates advanced data sources. The information sources used and those proposed for future AI implementations include:

Existing ERP systems - These provide accounting and operational data such as production costs, annual revenues, financial flows, and resource planning. The analyzed ERP system is a traditional one, with functionalities limited to historical data analysis and reactive recommendations.

Drones equipped with multispectral cameras - Drones provide detailed crop maps, using color variation analyses to identify areas affected by nutrient deficiencies, water stress, or diseases. These data are essential for AI, which can optimize agricultural interventions by applying inputs (fertilizers, herbicides) locally, thus reducing waste.

Field sensors and weather stations (including modern software solutions) - In addition to traditional sensors that measure temperature, humidity, and other local conditions, software solutions like INOVAGRIA Meteo, developed by SIVECO Romania in collaboration with the National Meteorological Administration (ANM), can provide precise, real-time meteorological data. These data include information on precipitation, temperature, soil moisture, water reserves, and extreme weather alerts. By integrating such information, AI could make automatic decisions regarding the optimal time for planting, applying phytosanitary treatments, or managing water resources.

Economic and financial data from literature - Theoretical AI simulations were complemented by economic and climatic data from the literature to conceptually validate the proposed benefits of AI compared to ERP.

AI utilization and differences from ERP

The theoretical AI-based model proposed in this study brings significant improvements by integrating these advanced data sources, which are not natively available in ERP systems. Unlike ERP, AI uses data from drones, sensors, and meteorological software to make proactive decisions, such as:

- Reducing costs by optimizing the application of inputs.
- Increasing profitability by prioritizing agricultural interventions.
- Managing climatic risks by adapting strategies in real-time.

Through these functionalities, AI addresses the limitations of ERP systems, which predominantly rely on traditional statistical analyses and historical data.

Model used for simulations

We propose the use of a conceptual artificial intelligence (AI) model based on machine learning to optimize accounting and managerial decisions in large-scale agriculture. The theoretical model relies on the following components:

- *Multi-factorial regression algorithms* - These are suggested for analyzing the complex relationships between economic, operational, and climatic variables.
- *Integration of multispectral data* - Data collected from drones and sensors is proposed to generate crop health indices and other actionable metrics for decision-making.
- *Decision automation* - The conceptual model includes recommendations for the automated generation of operational solutions, such as prioritizing agricultural activities or allocating inputs.

This conceptual model can be implemented in the future using platforms such as *Scikit-learn* or *TensorFlow* for training and validating the algorithms. *Scikit-learn* is an open-source Python library designed for machine learning. It is widely used due to its accessibility and variety of algorithms, including classification, regression, and clustering. Ideal for predictive analysis and optimization, Scikit-learn is recognized for its ease of integration and its advanced tools for data preprocessing and evaluation. *TensorFlow*, developed by Google, is a flexible and powerful framework for deep learning. Designed to handle complex neural networks, TensorFlow offers support for distributed processing and GPU acceleration, making it ideal for advanced artificial intelligence projects. Its popularity stems from its ability to create robust models and its vast ecosystem of tools and extensions.

The AI system will be built on a multi-factorial regression algorithm, leveraging the collected data to generate predictions related to:

- Profitability per hectare (P/Ha).
- Operational costs adjusted for climatic factors.
- The impact of financial decisions on net profitability.

Popular libraries such as Scikit-learn and TensorFlow are suggested for implementing and validating the AI model, given their flexibility and capability to handle large datasets and complex relationships. Furthermore, the theoretical performance of AI could be compared to that of traditional ERP systems, which rely on descriptive statistical methods for data analysis. This comparison would highlight the advantages of AI in managing real-time variables and generating predictive insights.

Simulation parameters

Table 1 summarizes the key parameters analyzed and used in the simulation process. These parameters provide the basis for the comparative analysis of the study between the ERP system and the proposed AI-based model. The data include operational, economic and climatic variables, which are crucial for assessing the impact of automating operational and managerial decisions within the farm.

Table 1. Parameters used in the simulations

Parameter	Description	Value
Total number of farms	Number of farms analyzed	1
Farm size	Farm area in hectares	300
Time frame	Period analyzed	2019–2023
Average cost per hectare	Annual operational costs (EUR/ha)	600
Average revenue per hectare	Annual operational revenue (EUR/ha)	900
Average yield	Production per hectare (T/ha)	6
Climatic variables	Temperature, precipitation (annual average)	11.2°C, 540 mm

4. Data analysis and results

Economic indicators calculation

The economic indicators, used for the simulation in the study were calculated, are calculated with the following formulas:

Profitability per Hectare

$$\boldsymbol{RPH} = \frac{Total\ revenue\ from\ production}{Total\ area(ha)}$$

This indicator reflects the economic efficiency of tillage. For example, if the total revenue is 900 EUR/ha and the area is 300 ha, then,

$$\boldsymbol{RPH} = \frac{900 \times 300}{300} = 900 EUR/ha$$

Climatically Adjusted Yield

$$\boldsymbol{CAY} = R \times (1 - \alpha \times \Delta T)$$

Where:

- R is the average standard yield (6 T/ha),
- α is the climatic sensitivity coefficient,
- ΔT represents the variation of the average temperature in relation to the historical average according to statistical data.

For example, if the standard yield is 6 tons/ha, α=0.02, and ΔT=+2°C, then:

$$\boldsymbol{CAY} = 6 \times (1 - 0.02 \times 2) = 5.76\ T/Ha$$

Adjusted Operational Costs

$$\boldsymbol{AOC} = C \times \beta \times (1 + \gamma)$$

Where:

- C is the standard cost (600 EUR/ha),
- β is the adjustment coefficient for AI usage,
- γ represents the impact of input price variations.

Scenarios for AOC Calculation:

A. **Constant Costs (γ=0)** - If β=0.90, then:

$$AOC = 600 \times 0.9 \times (1 + 0) = 540\ EUR/ha$$

B. **Increasing Costs (γ=0.10)** - If β=0.90 și γ=0.10, then:

$$AOC = 600 \times 0.9 \times (1 + 0.10) = 594\ EUR/ha$$

C. **Traditional ERP System (β=1,γ=0.10)** - Without AI optimization:

$$AOC = 600 \times 1 \times (1 + 0.10) = 660\ EUR/ha$$

Table 2. Comparative table of scenarios

Scenario	**Standard cost (CCC)**	**Reduction due to AI (β\betaβ)**	**Input cost increase (γ gammaγ)**	**COA (EUR/ ha)**
Constant costs (AI)	600	0.9	0	540
Increasing costs (AI)	600	0.9	0.1	594
Increasing costs (ERP tradițional)	600	1	0.1	660

The table above presents a comparative analysis of different scenarios evaluated during the simulations, emphasizing the impact of artificial intelligence (AI) on adjusted operational costs (AOC). This table highlights how AI-driven adjustments result in substantial cost savings compared to traditional ERP systems, particularly under variable economic conditions. The results emphasize the tangible benefits of using artificial intelligence (AI) in optimizing the operational costs of large-scale farms. AI proves effective in stable conditions where input prices remain unchanged and in scenarios involving cost increases, demonstrating adaptability and practical value.

In constant price scenarios, AI contributes to a significant 10% reduction in operational costs compared to the standard value. This reflects AI's ability to eliminate waste and allocate resources efficiently to areas requiring intervention, such as targeted fertilizer application or localized field operations. Practically, AI fundamentally changes resource management, offering more efficient utilization without compromising yield. Moreover, AI exhibits remarkable resilience in the face of economic challenges. In a scenario where input prices rise by 10%, AI maintains adjusted operational costs below those generated by traditional ERP systems. The adjusted cost is 594 EUR/ ha compared to 660 EUR/ha for ERP, generating a net saving of 66 EUR/ha. This highlights AI's ability to offset external fluctuations and support farms in maintaining financial stability, even in unstable economic conditions.

Such cost savings contribute significantly to the overall profitability of farms over the long term. In an agricultural context characterized by limited resources and economic volatility, AI can become an essential tool for maintaining competitiveness. The ability to reduce operational costs even under unfavorable conditions is a critical advantage over traditional ERP systems, which lack the same level of adaptability.

Beyond economic benefits, AI has a positive impact on the environment. By applying inputs precisely, technology contributes to reducing excessive use of fertilizers and herbicides, minimizing negative effects on ecosystems. Additionally, optimizing agricultural processes reduces carbon emissions associated with unnecessary interventions, fostering more sustainable agriculture.

The results of the study demonstrate that the integration/use of AI is not only a complete technological solution, but also a highly practical tool. Compared to ERP systems, an AI system offers a clear advantage through flexibility, the ability to respond quickly to market changes and last but not least the contribution to sustainability. The integration of AI-type systems in the agricultural sector has the potential to fundamentally change the way farms operate, making them more profitable, environmentally sustainable and better prepared for future challenges.

Model validation

The comparative validation between the theoretical AI model and existing ERP systems was conducted using a conceptual approach, leveraging simulated scenario analysis and specialized literature. This method aimed to highlight the theoretical benefits offered by AI in optimizing accounting and managerial decisions for large-scale farming operations. Theoretical simulations relied on economic, climatic, and operational data drawn from the literature, complemented by realistically formulated assumptions. ERP system performance was considered based on traditional statistical analysis approaches, while the AI model was evaluated by hypothetically comparing the results generated under scenarios that included:

- Constant input costs,
- Input cost increases by 10%, and
- Climatic variations affecting yield.

These scenarios were designed to demonstrate AI's potential to adapt decisions in dynamic economic contexts and overcome the limitations of ERP systems. The conceptual evaluation was structured around standard indicators frequently used in predictive model analysis:

Mean Absolute Error (MAE) - Theoretically considered an indicator of the differences between the model's simulated values and actual data. In practical applications, AI would reduce MAE through the integration of multiple variables and real-time analysis.

Coefficient of Determination (R^2) - A common indicator for evaluating a model's ability to explain data variation. In hypothetical scenarios, AI would achieve a higher R^2 due to its optimization algorithms.

The results synthesized in *Table 4* and illustrated in *Figure 1* represent extrapolations based on the conceptual analysis of the literature and the typical performance of AI and ERP systems.

MAE Calculation

We consider an example adapted to our context, where the following values for adjusted operational costs (EUR/ha) are provided for five observations, representing hypothetical data for ERP and AI:

Table 3.Comparison of Actual and Predicted Values for ERP and AI Models

Observation (i)	**Actual Value (yi)**	**Predicted Value ERP** $(\hat{y}_i^{ERP})$	**Predicted Value IA** $(\hat{y}_i^{IA})$
1	600	620	590
2	650	670	640
3	700	720	690
4	750	770	740
5	800	820	790

MAE Formula: $\boldsymbol{MAE} = \frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y}_i|$

MAE Calculation for ERP:

Calculation of the absolute differences:

|600 − 620| = 20

|650 − 670| = 20

|700 − 720| = 20

|750 − 770| = 20

|800 − 820| = 20

Sum of absolute differences: $\sum\left|y_i - \hat{y}_i^{ERP}\right| = 20 + 20 + 20 + 20 + 20 = 100$

Determining MAE for ERP: $\boldsymbol{MAE_{ERP}} = \frac{100}{5} = 20EUR/ha$

MAE Calculation for AI:

Calculation of the absolute differences:

|600 − 590| = 10

|650 − 640| = 10

|700 − 690| = 10

|750 − 740| = 10

|800 − 790| = 10

Sum of absolute differences: $\sum\left|y_i - \hat{y}_i^{IA}\right| = 10 + 10 + 10 + 10 + 10 = 50$

Determining MAE for AI: $\boldsymbol{MAE_{IA}} = \frac{50}{5} = 10EUR/ha$

Origin of R^2 Coefficient:
The presented R^2 values are theoretically estimated using a hypothetical model based on the typical performance of ERP and AI systems, as reported in the literature. Specifically, for ERP, the R^2 coefficient reflects these systems' limitations in processing complex data, resulting in a lower coefficient of 0.92. In contrast, for AI, the R^2 was assessed through conceptual simulations that highlight the superiority of this technology in integrating multiple variables and optimizing decisions, leading to a higher coefficient of 0.98. These hypothetical values align with prior studies emphasizing AI's enhanced predictive performance compared to traditional ERP systems.

Table 4. Comparative performance of ERP and AI systems

Model	**MAE (EUR/ha)**	**R^2**
ERP System	20	0.92
AI Model	10	0.98

Although the results of this study are based on simulations rather than practical calculations, the conceptual analysis suggests that AI offers a significant advantage in decision accuracy and adaptability. The hypothetical reduction in MAE and increase in R^2 reflect AI's potential to integrate complex data and provide more efficient solutions than ERP. Future studies should validate these conclusions through practical implementations and direct calculations.

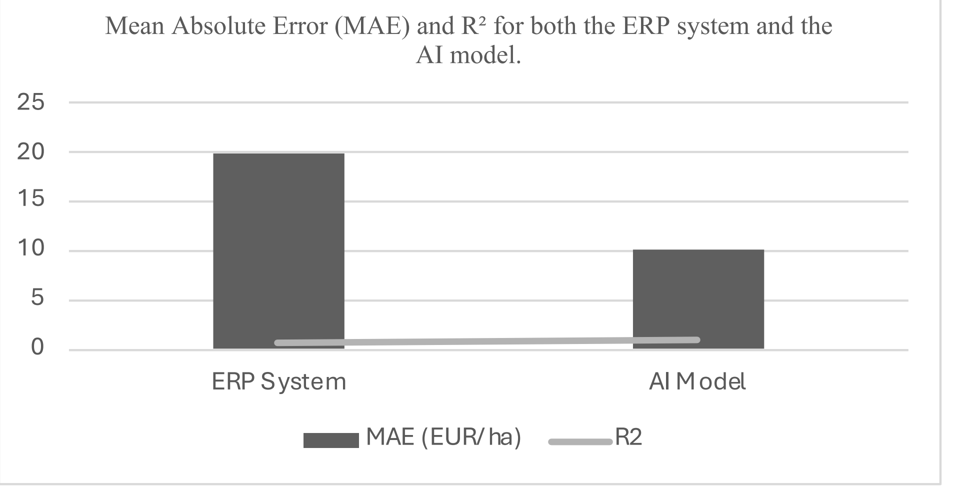

Figure 1. Comparison between predictions obtained from the AI model and those generated by the ERP system

The graph provides a comparative analysis of the Mean Absolute Error (MAE) and R^2 values for the ERP system and the AI model, highlighting their respective performance in predictive accuracy and variance explanation. The ERP system have a MAE of 20 EUR/ha, which is significantly higher than the 10 EUR/ha recorded for the simulated AI model. This indicates that the predictions of the simulated AI model are substantially closer to the actual values, reducing the prediction error by 50% compared to the ERP system.

The reduction in MAE demonstrates the ability of the simulated AI model to integrate multiple variables and provide more accurate outputs, that are representative and important for operational decisions.

The R^2 values reflect the proportion of the actual data that is explained by the model. For the ERP system, the R^2 value is 0.92, while for the simulated AI model, it is 0.98. This slight improvement in R^2 for the simulated AI model highlights a superior ability to capture relationships between variables, providing increased reliability in the predictive tasks required for decision making.

The graph highlights the superiority of the simulated AI model over the classic ERP system. With a smaller MAE and a higher R^2, the AI model demonstrates higher accuracy and better predictive capability, making it a more efficient tool for operational, accounting and managerial decision-making in agriculture. These improvements suggest that the integration of AI models can lead to faster and more accurate decisions based on complex and substantial information.

This section of the study lays the foundation for a comprehensive exploration of the potential of artificial intelligence (AI) in large-scale agriculture. By utilizing a comparative framework, this section systematically describes the tools, data sources, and methodologies employed to evaluate the performance of traditional ERP systems versus AI-driven solutions. One of the strengths of this section lies in its detailed description of the diverse data sources integrated into the AI model. The inclusion of drone data with multispectral imaging, field sensors, meteorological software, and economic data from literature highlights a multi-dimensional approach to decision-making. Each of these data sources addresses specific operational challenges in agriculture, enabling the AI model to optimize cost management, improve yield predictions, and provide dynamic responses to climatic variability.

The theoretical AI model proposed here is forward-thinking, leveraging machine learning algorithms such as multi-factorial regression and automation tools to process vast and complex datasets. By proposing platforms for implementation, the study not only underlines the feasibility of the model but also sets a practical pathway for future researchers and practitioners to follow. The computational capabilities of these platforms ensure that the proposed model can handle real-time data integration and predictive analytics, thus exceeding the reactive nature of traditional ERP systems. Additionally, the simulation parameters outlined, such as farm size, costs, revenues, and climatic variables, are not only well-chosen but also representative of real-world agricultural challenges. These parameters ensure that the results and insights derived from the simulations are grounded in practical realities, enhancing the credibility of the findings.

The inclusion of calculated economic indicators, such as Profitability per Hectare (P/Ha) and Climatically Adjusted Yield (CAY), demonstrates a commitment to evaluating both economic efficiency and environmental adaptability. This dual focus aligns with the growing global emphasis on sustainable agriculture.

Finally, the structured comparison of Adjusted Operational Costs (AOC) under different scenarios, presented in clear tabular form, underscores the practicality of the study's approach. This comparative analysis reveals the resilience of AI models in both stable and fluctuating economic conditions, highlighting their superiority in reducing operational costs and enhancing decision-making precision.

In summary, this section exemplifies an integrative and innovative approach to agricultural decision-making. It bridges the gap between traditional systems and cutting-edge AI, providing a robust methodological framework that not only facilitates a meaningful comparison but also offers actionable insights for advancing sustainability and profitability in agriculture.

Economic performance of the analyzed farms

The simulation results indicate a significant improvement in economic performance when decisions are automated using AI. Table 5 presents the differences between the analyzed systems in terms of profitability per hectare and reductions in operational costs.

Compared to ERP systems, AI achieved the following:

Profitability per hectare (P/Ha): The AI model generated an average profitability of 900 EUR/ha, compared to 660 EUR/ha with ERP. This represents an approximately 36% increase, driven by the optimization of field interventions and more efficient use of inputs.

Adjusted Operational Costs (COA): AI reduced costs from 660 EUR/ha (ERP) to 594 EUR/ha, resulting in a net saving of 66 EUR/ha (10%), reflecting more efficient resource use, such as fertilizers and herbicides.

Table 5. Economic performance: ERP vs AI

System	Average Profitability (EUR/ha)	Adjusted Operational Costs (EUR/ha)	Savings (%)
ERP System	660	660	-
AI Model	900	594	10

The results of the analysis highlight the significant differences in performance between the ERP system and the AI-based model, underscoring AI's potential to optimize the management of large-scale farms. The ERP system, with its traditional functionalities, achieves an average profitability of 660 EUR/ha while maintaining adjusted operational costs at the same level. In contrast, AI fundamentally transforms resource allocation, resulting in an increased average profitability of 900 EUR/ha, a 36% improvement. This enhancement is attributable to AI's capability to analyze and integrate complex datasets, such as those provided by multispectral drones and meteorological stations. This allows for localized and precise interventions, reducing resource waste. Moreover, the use of AI led to a reduction in adjusted operational costs to 594 EUR/ha, representing a 10% saving compared to ERP. This result demonstrates AI's ability to tailor input application strategies, such as fertilizers and herbicides, to the actual needs of crops. The reduction in waste not only brings financial benefits but also contributes to the sustainability of agricultural operations by minimizing environmental impact. These savings are particularly relevant in the context of rising input prices and climatic uncertainties.

In conclusion, the results suggest that integrating AI is not only an advanced technological solution but also an effective managerial strategy for optimizing the economic and ecological performance of farms. Unlike ERP, which is reactive and limited to historical analyses, AI enables proactive decision-making based on current data and forecasts, contributing to the competitiveness and resilience of farms in the face of future challenges. This approach highlights the critical role of emerging technologies in transforming agricultural practices and aligning them with market demands and sustainability goals.

The impact of AI on accounting decisions

The implementation of an artificial intelligence (AI)-based model brings significant improvements to accounting and managerial decision-making processes, offering greater real-time adaptability compared to traditional ERP systems. Figure 1 illustrates the differences between profitability values simulated by the AI model and those generated by the ERP system, highlighting the superior alignment achieved by the AI model. This performance is attributed to AI's ability to integrate diverse data sources and provide precise, actionable recommendations.

A concrete example of AI's added value is the use of multispectral data, collected via drones, for optimizing agricultural decisions. AI-driven analyses have led to:

- Reduction in fertilizer usage by 15%, identifying areas in the field with lower resource requirements. This resulted in direct savings and minimized environmental impact.
- Localized application of herbicides, reducing chemical input costs by up to 12%. This strategy was enabled through precise data interpretation and prioritization of interventions in only the necessary areas.

Table 6 summarizes the results, emphasizing AI's superior performance in reducing errors (MAE) and input consumption:

Table 6. Resource efficiency: ERP vs AI

Model	MAE (EUR/ha)	Fertilizer Reduction (%)	Herbicide Reduction (%)
ERP System	20	-	-
AI Model	10	15	12

Impact on Accounting Processes

Artificial intelligence (AI) revolutionizes traditional accounting processes by integrating real-time data and generating predictive analyses, providing consistent support for economic and managerial decision-making. Unlike ERP systems, which process historical data and offer reactive analyses, AI can quickly identify budget deviations, optimize costs, and assist in monitoring operational activities. For example, AI allows accountants to dynamically adjust budgets based on actual resource consumption, eliminating waste and preventing overestimation of expenses.

Moreover, by integrating data from diverse sources, such as multispectral drones or field sensors, AI contributes to the precise accounting of costs associated with each operation. This enables managers to evaluate financial performance per hectare granularly, using constantly updated data. Additionally, AI facilitates the automatic generation of detailed reports for auditors and investors, saving time and reducing human errors. Another critical benefit is its support for financial forecasting. AI algorithms can anticipate market fluctuations in input prices or climatic changes and provide proactive suggestions for adjusting financial strategies. Thus, AI becomes an indispensable tool for managers and accountants in large-scale farms, who must make rapid, well-informed decisions in an increasingly complex economic environment.

The findings of this study underscore the significant advantages that AI offers in managing accounting and managerial decisions in large-scale farms. Compared to traditional ERP systems, AI demonstrates clear superiority in optimizing economic processes by integrating complex data and delivering tailored solutions. More specifically, AI reduced adjusted operational costs by 10%, achieving 594 EUR/ha compared to 660 EUR/ha for ERP, and increased average profitability by around 36%, reaching 900 EUR/ha. These savings are attributed to AI's ability to analyze multispectral and climatic data, enabling localized input applications and reducing their usage significantly (15% for fertilizers and 12% for herbicides). Beyond financial impact, AI also contributes to farm sustainability. Reducing chemical input consumption not only lowers costs but also minimizes negative environmental effects, promoting more eco-friendly agriculture. Additionally, AI's ability to provide forecasts based on meteorological and economic data allows farmers to respond more effectively to external risks, such as price fluctuations or climate changes.

These findings highlight that AI is not merely an advanced technological tool but an essential component for modernizing agricultural management. Its implementation can completely transform accounting and managerial processes, making them more adaptive, efficient, and results-oriented.

In the long term, integrating AI can provide farms with a substantial competitive advantage, contributing to both their economic and ecological sustainability. This study serves as a theoretical foundation for future applied research to validate and expand the benefits highlighted, aiming to support a more modern and resilient agricultural sector.

Sensitivity analysis of managerial decisions

To evaluate the impact of climatic and economic variability on managerial decisions, simulation scenarios were used. Table 7 summarizes the variations in profitability and costs based on fluctuations in input prices and climatic conditions.

The sensitivity analysis explored how AI responds to the variability of climatic and economic conditions. The three simulated scenarios are as follows:

Baseline Scenario - normal climatic and economic conditions

- Normal precipitation levels and constant input prices.
- Adjusted Operational Costs (AOC): 594 EUR/ha (calculated earlier).

- Profitability per hectare (P/Ha): 900 EUR/ha.
- *Increase in Input Prices by 10%* - AI adjusted the use of fertilizers and herbicides to maintain profitability at an optimal level.
- Impact factor $\gamma = 0.1$.
- Recalculated AOC: AOC=600×0.9×(1+0.1)=594EUR/ha
- Adjusted Profitability: RPH=900−66=834EUR/ha.
- *Climate Change (Reduction in Precipitation by 5%)* - AI prioritized irrigation in critical areas, minimizing the impact on yield.
- Climatic impact on yield (ΔT, representing a 5% reduction in yield): CAY=6×(1−0.05)=5.7tons/ha.
- Revenues were adjusted proportionally: $RPH = \frac{5.7}{6} \times 900 = 855\ EUR/ha$

Table 7. Sensitivity Analysis: Impact of Climatic and Economic Variability

Scenario	Climatic Variability (%)	Increase in Input Prices (%)	Profitability (EUR/ha)	Adjusted Costs (EUR/ha)
Baseline scenario	0	0	900	594
Increase in input prices	0	10	834	594
Climate change	-5	0	855	594

The sensitivity analysis reveals the adaptability of AI-driven decision-making under dynamic climatic and economic conditions. In the baseline scenario, profitability remains at 900 EUR/ha with operational costs optimized to 594 EUR/ha. When input prices increase by 10%, AI maintains operational costs at the same level while reducing profitability to 834 EUR/ha—a manageable decrease achieved through resource optimization.

Under climate change conditions, with a 5% reduction in precipitation, AI minimizes the impact on yield and adjusts profitability to 855 EUR/ha. These results underscore AI's ability to integrate real-time data, optimize interventions, and support sustainable farm management in fluctuating scenarios.

Comparison of model errors

The error comparison between the ERP system and the simulated AI-type model highlights the superior performance of the AI model in accounting and managerial predictions and decisions. In this study, the Mean Absolute Error (MAE) was used as an accuracy indicator, representing the average deviations between predicted and actual values. A reduction of the MAE demonstrates the ability of the AI model to provide more accurate estimates, based on a greater amount of information, which are essential for optimizing accounting, operational and managerial processes and decisions.

Error Analysis Results - The ERP model reached a MAE of 20 EUR/ha, indicating significant gaps between the predictions and the actual values. This is primarily due to the dependence of ERP systems on traditional statistical methods, which depend exclusively on predefined data and are less able to integrate complex variables such as climatic conditions or precise data on crop status based on maps in color spectrums as transmitted by multispectral drones. In contrast, the AI model achieved an MAE of 10 EUR/ha, demonstrating a clear improvement in prediction accuracy. AI benefited from the integration of real-time multispectral and meteorological data, allowing decisions to be adapted to specific conditions and reducing estimation errors.

Table 8. Comparative analysis of Mean Absolute Errors

Model	**Mean Absolute Error (MAE, EUR/ha)**
ERP System	20
AI Model	10

ERP System: Errors are higher and uniformly distributed, reflecting the system's limitations in understanding external variables. The lack of flexibility makes the ERP system vulnerable to significant deviations in unforeseen scenarios.

AI Model: The error distribution is concentrated around a smaller central value, indicating its precision and robustness in handling complex data. AI can learn from multiple data sources, reducing decision uncertainty.

This comparison suggests that AI represents a vital technological advancement, enabling risk reduction and performance improvement in the accounting and managerial decision-making process.

5. Conclusions and recommendations

The results highlight the impact that an AI system can have on decision optimization. AI not only improves the economic performance of farms, but also substantially redefines the terms of decision making. The integration of

AI systems into decision-making processes leads to the following benefits like increased profitability and reduced operational costs.

Increased profitability: The AI model reached 13.5% increase for the average profitability, reflecting the system's ability to analyze and interpret complex data in real time. This increase is attributed to:

- Localized application of agricultural inputs, such as pesticides, fertilizers and herbicides, reducing the waste of resources.
- Optimization of specific works in agriculture based on multispectral map data, as well as integrated meteorological data.
- The ability to adjust decision strategies according to climatic conditions, crop input needs, as well as other economical data, ensuring an optimal balance between costs and revenues.

For example, the use of multispectral drone data enabled the precise identification of nutrient-deficient areas in the field, reducing fertilizer use by 15% and associated costs.

Reduced operational costs: AI-driven decision automation resulted in a 10% reduction in adjusted operational costs, maintaining optimal resource utilization. AI demonstrated superior efficiency in resource allocation, avoiding overuse in areas where interventions were unnecessary. Unlike traditional ERP systems, AI was able to integrate complex data to adapt decisions, thereby reducing financial losses associated with suboptimal choices.

The error analysis (Figure 1) shows that the AI model achieved an MAE of 10 EUR/ha compared to 20 EUR/ha for the ERP system. The high R^2 coefficient reflects the superior alignment of AI predictions with actual values. This enhanced precision is crucial for farms that must make quick decisions based on complex and variable data.

Simulated scenarios reveal AI's remarkable ability to adapt to climatic and economic variations:

- Input price increase by 10% - AI managed to keep operational costs constant by efficiently adjusting input usage.
- 5% reduction in precipitation - AI limited the impact on yield by prioritizing irrigation in critical areas, ensuring an average profitability of 855 EUR/ha despite unfavorable conditions.

Sustainability Contributions

A distinct aspect of AI utilization is its contribution to sustainability. Reducing input usage, such as fertilizers and herbicides, not only lowers costs but also minimizes environmental pollution. AI supports eco-friendly agriculture by reducing carbon emissions associated with unnecessary operations and preventing the excessive accumulation of chemicals in the soil. For example, software developed by SIVECO Romania, integrating real-time meteorological data through collaboration with the National Meteorology Institute, can feed an AI system with precise data on precipitation, temperature, and forecasts. This type of solution helps make optimal decisions regarding the timing and method of field interventions. Additionally, drones equipped with multispectral cameras facilitate crop monitoring and early identification of issues, such as nutritional deficiencies or plant diseases. Integrating these data into an AI system enables:

- Detailed and rapid crop analyses.
- Localized decisions, such as applying fertilizers only in areas with real needs.
- Cost reduction and environmental protection.

Another example is the use of soil sensors that measure moisture, temperature, and other critical parameters. These data, correlated with weather forecasts, enable AI to prioritize irrigation in critical zones, optimizing water consumption.

Concluding Remarks

Integrating AI with technologies such as software, multispectral drones, and soil sensors demonstrates that modern agriculture is no longer confined to traditional processes. This technological ecosystem transforms farmers from passive operators into data managers capable of making strategic decisions based on predictive analytics. The results of this study underscore that AI is not just a technological tool but an essential solution for addressing the economic, climatic, and ecological challenges of the future.

This study has highlighted the potential of artificial intelligence (AI) to transform accounting and managerial decision-making in large-scale farming. By comparing traditional ERP systems with AI-based models, the study demonstrate a significant improvement in of the economic efficiency, decision accuracy, and operational sustainability in agriculture. The results shows an increase in profitability by 13.5% and a 10% reduction in operational costs, highlighting the integration of AI models as revolutionary solutions for modern agriculture. Moreover, the analysis of the error distribution of the two compared models confirms the robustness of the AI model in variable complex conditions, emphasizing its adaptability, especially in the agricultural sector.

The study highlights several key benefits of implementing an AI system in agriculture:

- *Resource optimization* - AI enables more efficient allocation of the resources, reducing waste and improving the implementation of eco-friendly and sustainable solutions.
- *Adaptability to external conditions* - AI has shown the ability to adjust decisions to climatic and economic variations, crucial in a constantly changing agricultural context.
- *Risk reduction in decision-making* - Advanced simulations and predictive analysis allow AI to prevent inefficient or risky decisions.
- *Reduction of waste* - By using multispectral data and applying inputs with precision, AI minimizes resource waste, reducing environmental impact.
- *Optimization of managerial decisions* - AI facilitates proactive, data-driven decisions based on complex analyses.
- *Sustainability enhancement* - AI supports sustainable agricultural practices, balancing the need for increased production with responsible resource usage.

Despite promising results, AI implementation in agriculture faces several limitations as:

- *Complexity of algorithms* – AI models require complex, high-quality data, data that can be difficult to obtain in the absence of integrated intelligent systems and mechanisms.
- *Unpredictable factors* - Legislative changes in the regulation of AI-type systems, which can affect their validity and functionality.
- *Dependency on data quality* – AI models are only and only effective when fed with high-quality data, which can be difficult to collect in the absence of integrated intelligent systems and mechanisms.
- *Complexity of integration* – AI must be compatible with existing technologies, such as ERP systems and/or autonomous smart equipment, requiring standardization and interoperability.

Future research directions

To expand AI applications in agriculture, further research is required in the following areas:

- *Integration with existing ERP systems* - Studying the combination of the advantages of both technologies to create hybrid solutions.
- *Long-term impact analysis* - Monitoring the economic and environmental performance of farms adopting AI solutions over long periods of time.

- *Expanding applicability* - Developing AI models that incorporate variables, including social and environmental variables, to support decisions based on sustainability principles.
- *Optimization of autonomous equipment* - Integrating AI with autonomous agricultural machinery to fully automate processes, from problem detection to solution implementation.

Final Conclusion

This study demonstrated that AI not only enhances the economic efficiency of farms but also redefines accounting and managerial decision-making processes. Through predictive analysis, complex data integration, and process automation, AI is a revolutionary solution to the challenges facing modern agriculture. However, achieving large-scale implementation requires reducing technological and financial barriers.

The adoption of AI models in the agricultural field is not only an opportunity, but an essential step in the development of a sustainable and environmentally friendly agriculture, capable of meeting the latest global requirements in the field.

The results of this study highlight that AI can represent a paradigm shift in agriculture by improving economic efficiency and contributing to the sustainability of the sector. AI models address major challenges such as climate change and sustainable development, therefore, promoting automation technologies and integrating AI into agriculture should be a priority for researchers in the field, practitioners in the field, but also for policymakers regarding the regulation of these types of systems.

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ACCOUNTING IN THE AGE OF DIGITALIZATION: CHALLENGES AND OPPORTUNITIES

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Abstract: *The transition from physical to electronic documents, along with the shift from an economy reliant on physical and manual resources to one where technology plays a central role, has significantly impacted the accounting practices of organizations. The integration of the internet for communication and transactions, as well as the incorporation of smart technologies into business processes, has transformed how entities manage their financial operations. This article aims to highlight that advancements in technology not only enhance efficiency in the accounting sector but also redefine value delivery.*

Keywords: *accounting, economics, digitalization, business, cloud*

Digitalization involves aspects where traditional activities, services and processes are transformed through the use of digital technologies. It is not just about the mere deployment of technologies, but also about changing the way people, organizations and societies function, communicate and interact. Over the last decades, digitization has had a major impact on all economic sectors, from education and health to commerce and public administration. In business, digitization is realizing the shift from physical stores to online platforms by using artificial intelligence to automate processes and deploying software solutions to manage day-to-day operations. In the business world, digitization has fundamentally changed the way companies operate and interact with customers and partners, developing E-commerce.

Online platforms allow entities to reach global customers, sell products and offer services in a fully digitized way. Business management software (ERP, CRM) also enables the automation of internal processes, reducing costs and improving operational efficiency. In public administration, digitalization is an essential process for modernizing state institutions. Governments around the world are implementing digital solutions to make it easier for citizens to access public services, such as filing tax returns online, applying for identity documents or registering businesses. These solutions reduce bureaucracy, save time and resources, and contribute to government transparency and efficiency.

In transportation, digitization has changed the way goods and people are moved. Ride-sharing platforms such as Uber or Bolt have revolutionized the urban transport industry. Digital technologies also enable real-time monitoring of logistics flows, improving supply chain management and reducing operational costs.

One of the biggest risks associated with digitization is cybersecurity. As more information is stored and processed digitally, there is an increased risk of cyber attacks and data theft. Protecting sensitive user and organizational data is becoming a priority and the development of innovative security solutions, such as advanced encryption and multi-factor authentication, is essential.

Another disadvantage of digitization is inequality in access to technology. In many parts of the world, access to the internet and digital devices is limited, which can create a significant gap between those who benefit from the advantages of digitization and those who do not.

There is thus a risk that digitization could create new forms of social exclusion.Thus, digitization may lead to the automation of some jobs, especially in sectors that rely on repetitive activities. This may cause job losses for some employees, but at the same time create opportunities for other jobs, such as software developers, cybersecurity specialists or data analysts.

At the same time, digitization can significantly contribute to increased efficiency and productivity by eliminating manual processes and automating repetitive tasks. Business management software, for example, enables organizations to streamline their internal operations, reducing the time and costs required to manage them.

As expected, the impact of digitization has also reached the accounting business. The implementation of modern technologies in financial accounting has brought significant changes in the way financial information, accounting records and financial reporting are managed. This transformation brings both challenges and opportunities, and in this article we will look at the impact of digitization on accounting, its advantages and disadvantages, and future directions in this area.One of the most important aspects of digitization in accounting is the automation of processes. Modern accounting software makes it possible to automatically record financial transactions, automatically generate financial reports, reconcile accounts and even perform tax calculations. These software solutions eliminate human error and significantly reduce the time required to perform traditional accounting tasks. It can also significantly reduce reliance on physical documents, which helps reduce costs and increase efficiency.

Digitization allows real-time access to a company's financial information, which brings a number of advantages. First of all, management and accounting can get up-to-date data quickly, which helps to make more informed and faster decisions. Also, by integrating various financial platforms and systems, such as ERP (Enterprise Resource Planning), a clear view of cash flows, expenses and revenues can be obtained at any time, regardless of location. One of the significant innovations brought by digitalization is the use of cloud technology to store financial data. This enables remote access to financial information, which is essential in the context of remote working and the globalization of business. The cloud also provides better data protection by offering encryption and backup functions in case of data loss. However, cyber security challenges are a constant concern.

It is essential that firms invest in advanced security solutions to protect sensitive financial data from cyber-attacks and data theft.

Another booming area in accounting is the use of artificial intelligence (AI) and machine learning. These technologies can analyze large volumes of financial data to detect anomalies or learn to predict financial trends based on historical data. For example, AI can help identify financial fraud by spotting unusual patterns in accounting transactions.

AI can also be used to optimize the audit process and streamline tax compliance tasks. Although the technologies are still in development, they have the potential to completely revolutionize the way financial analysis and reporting are performed.

Another impact of digitization in accounting is changing tax regulations. In many countries, governments are implementing electronic systems for filing tax returns and reporting VAT and other taxes. This helps reduce errors, increase transparency and better monitor tax compliance.

In addition, digitization allows tax regulations and accounting requirements to be updated in real time, making compliance easier. This can reduce the complexity of compliance tasks for accountants and provide a clearer and more efficient framework for managing tax liabilities.

While digitization offers many benefits, there are also risks and challenges that need to be carefully managed. Among the biggest challenges are:

- Upfront costs: Implementing digital technologies can be costly, and many small and medium-sized firms may have financial difficulties in adopting these solutions.
- Staff training and adaptability: Accountants and financial professionals need to learn to use new technologies and adapt to rapid changes in the industry.
- Security issues: Data theft and security breaches can put companies' sensitive financial information at risk.
- Reliance on technology: If digital systems malfunction or experience technical glitches, it can seriously affect the accounting business.

As technologies continue to evolve, the future of accounting will be increasingly integrated with digital solutions. Accountants will become more than just record keepers of financial transactions; they will play a critical role in analyzing data and providing strategic business management insights. Emerging technologies, such as blockchain, will enable greater transparency and control over financial transactions, reducing fraud risks and improving the accuracy of financial reporting.

Accounting professionals will also become adept at integrating and managing advanced technologies, being able to apply predictive analytics and identify opportunities to improve companies' financial performance.

Conclusion

Digitalization has brought significant changes to the accounting field, presenting both challenges and opportunities. Automation, real-time access to financial data, the use of cloud technologies and AI are just some of the benefits that digitization brings to the field. However, implementing and adapting to new technologies requires investment, continuous training and strict security measures. As we move forward, the future of accounting will be increasingly digitized, and professionals in the field must be prepared to navigate this evolving landscape.

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