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YEAR XX, No. 2 (72), September 2025



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CREDITWORTHINESS AND FINANCIAL BALANCE — KEY INDICATORS FOR THE FINANCIAL HEALTH OF AN SME IN THE TRADE SECTOR

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Abstract: *Trade activity is an essential component of the economy, facilitating the movement of goods from producer to consumer. In the context of sustainable development, trade is of strategic importance in the optimal development of economic and social systems. In order to carry out this article, we have chosen the two largest SMEs in the S-V Oltenia region, Romania, by turnover in 2023, in the field of trade. In order to carry out the brief diagnosis in terms of financial health, we have chosen as main indicators, on the one hand, creditworthiness to assess the degree to which SMEs are able to pay their obligations on the basis of the assets held, and on the other hand, the analysis of financial balance to reflect on the equality between financial sources and the economic means necessary to carry out trade activity. In this regard, in addition to the theoretical aspects analyzed, the paper is based on a brief financial analysis in the form of balance sheets for the period 2021-2023, while also highlighting how the management of financial and accounting information is used for managerial decision-making. The research question was: Is creditworthiness and financial balance important in making financial decisions at the SME level? The results showed that the indicators addressed reflect the concordance between the sources of financing and the payment needs of SMEs in carrying out the activities they carry out, as well as the development needs required by the market and consumers.*

Keywords: *creditworthiness, financial balance, financial position, SMEs*
JEL Classification: *M41, G10, L25*

1. Introduction

SMEs represent the main source of economic growth in a State with a functioning market economy. SMEs represent the backbone of socio-economic progress. According to the book *“User’s Manual for the Definition of SMEs”*, published by the Publications Office of the European Union in 2015 in Luxembourg, “Nine out of ten companies are SMEs, and SMEs generate two out of three jobs”. SMEs, through the easy way of establishment and operation, stimulate entrepreneurial spirit and innovation.

As production develops, trade becomes permanent and is imposed as a vital necessity for society, simultaneously ensuring the satisfaction of consumption and the continuous perpetuation of production (Cardula, 2018). Trade is an activity with a particularly high share within an economy, aiming at a commercial transaction between the seller and the buyer. SMEs constitute a major point of interest in terms of carrying out trade activity, as they represent the pillar of the economy that contributes significantly to the creation of added value and employment.

The creditworthiness of the economic entity refers to its liquidity and solvency (Gomoi, 2020). In this sense, the main indicator for assessing the financial situation of an entity for a short period of time is the liquidity of the balance sheet (Stratila and Golan, 2017).

Liquidity and solvency represent the ability of the economic entity to meet its maturities. The connection between the payment capacity of economic entities and their liquidity and solvency can be expressed as follows: a) asset liquidity represents the property of asset elements to transform into cash, b) balance sheet liquidity represents the ability of the economic entity to honor its short-term debts, c) long-term solvency = the ability of the economic entity to meet its long-term debts.

The financial balance of SMEs is based on the liquidity of assets and the demandability of equity and debts, corroborated with the duration of use of the first category of structures, respectively with the duration of allocation of the second (Gomoi, 2023). Financial balance is considered fully achieved when at the end of a financial year the activity carried out generates liquidity. The financial diagnosis aims to carry out an analysis of the financial position, but also of the financial performance of the SME at the end of the annual financial year in order to determine the strengths and weaknesses that define financial management. Financial balance can be defined as the ability of SMEs to ensure, from their revenues, the uninterrupted payment of current debts generated by the conduct of their business or by the tax legislation in force, so that they can avoid the risk of bankruptcy.

Maintaining financial balance is the essential condition for the survival of SMEs, and the assessment of financial balance must take into account the concrete conditions that led to the emergence of insolvency (Codreanu, 2023).

2. Literature review

Assessing the solvency and liquidity of SMEs is a key aspect for ensuring their financial stability and competitiveness in the market. Creditworthiness defines the degree to which SMEs are able to honor their obligations based on the assets held, including, on the one hand, liquidity, which aims to confront short-term debts with current assets, and on the other hand, solvency, which reflects the confrontation of total debts with total assets held (Gomoi, 2023).

The main directions for improving financial stability and, consequently, increasing solvency include (Shirinov et al., 2025):

- increasing profit and profitability of operational activities;
- rational use of net profit, taking into account the interests of all participants in the economic and financial process;
- increasing the efficiency of fixed asset distribution;
- correct use of borrowed financial resources.

Financial equilibrium can be determined by comparing the liquidity of assets with the demandability of liabilities, thus generating three essential indicators: working capital (WC), working capital requirement or need (WCN) and net treasury (NT). The indicators used to establish financial equilibrium are presented in Table 1 as follows (Anghel et al., 2019):

Table 1. Indicators used in assessing financial balance

Crt. no.	Indicator name	Calculation formula	Interpretation
1.	Working capital (WC)	$WC = AC - DTS$ $WC = CP - AI$	$WC > 0$ Long-term financial balance; $WC = 0$ Tension in long-term uses and resources; $WC < 0$ Long-term financial imbalance.
2.	Necesarul de fond de rulment (NFR)	$NFR = (S+C) - DTS$	$WCN < WC$ Short-term financial balance; $WCN = WC$ Tension in short-term uses and resources; $WCN > WC$ Short-term financial imbalance.
3.	Trezoreria netă (TN)	$TN = FR - NFR$	$NT > 0$ Current financial balance; $NT = 0$ Tension at the liquidity level; $NT < 0$ Current financial imbalance.

Source: Own processing based on the Balance Sheet for the period 2021-2023

where: CA = current assets, STD = short-term debts, E = equity, Fa = fixed assets, S = stocks, R = receivables.

Information about liquidity and solvency is useful for assessing the ability of an SME to meet its due debts (Grigorescu, 2019). The determination of liquidity and solvency can be achieved, according to Table 2, as follows:

Table 2. Indicators used in assessing liquidity and solvency

Crt. no.	Indicator name	Calculation formula	Interpretation
1.	Current or general liquidity (CI)	$CI = (\text{Sticks} + \text{Receivables} + \text{Liquidities}) \times 100 / \text{Short-term debts}$	Between 1 and 2 or between 100% and 200% Reflects the ability of SMEs to cover their short-term debts based on current assets.
2.	Quick liquidity or acid test (QI)	$Lr = (\text{Receivables} + \text{Liquidities}) \times 100 / \text{Short-term debts}$	Between 0.6 and 1 or between 60% and 100% Reflects the ability of SMEs to cover their short-term debts based on receivables and liquidity.
3.	Immediate or on-demand liquidity (II)	$Il = \text{Liquidities} \times 100 / \text{Short-term debts}$	Between 0.2 and 0.6 or between 20% and 60% Reflects the ability of SMEs to cover their short-term debts based on liquidity.
4.	General solvency	Total assets / Liabilities	< 1.66 or over 166% = no insolvency risk Between 1 and 1.66 or between 100% and 166% = moderate insolvency risk > 1 or under 100% = imminent insolvency risk, insolvency

Source: Own processing based on the Balance Sheet for the period 2021-2023

In the case of the financial position, the analysis is carried out based on indicators determined using information from the balance sheet, namely the net position, working capital, working capital requirements and net treasury, which also reflects financial balance, along with other indicators of financial performance (Țilică, 2019). In a modern market economy, economic stability and solvency are considered important characteristics of the financial activity of an SME. Analysis of the solvency of an SME helps to reduce its internal costs, and an effective assessment of its solvency and liquidity can influence sales growth and strengthen its position in the market (Bakaeva and Taguzloev, 2024).

3. Research methodology

To carry out the applied analysis, the two largest SMEs in the S-W Oltenia region, Romania, were selected based on their turnover in 2023 in the trade sector. To this end, the website <https://membri.listafirme.ro/pagini/p1.htm> was accessed and the following selection criteria were applied:

- active companies;
- counties: Gorj, Vâlcea, Dolj, Mehedinți and Olt;
- fields of activity: trade;
- sort companies by turnover in descending order;
- filter: currency lei; number of employees minimum 1- maximum 249.

Hereinafter, for reasons of confidentiality, the generic name of the SMEs analyzed will be SME1 and SME2. The research methodology used for writing this article is classic, based mainly on reviewing the annual financial statements of the two entities, in order to identify important economic and financial indicators for studying their financial diagnosis. These can be indicators of the structural analysis of the elements of assets, debts and equity, as components of the financial statements, as well as indicators regarding the analysis of liquidity and solvency, as well as of the financial balance through the perspective of working capital, working capital requirements and net treasury.

4. Research results

The starting point in the economic analysis and establishing the financial balance of the analyzed SMEs is the balance sheet, reflected according to Table 3 below:

Table 3. Balance sheet of SMEs in the period 2021-2023

Crt. no.	SME	Component patrimonial elements	Year -lei-		
			2023	2022	2021
I.	SME ₁	Intangible assets	189466	313341	247691
		Tangible assets	46069651	38444435	32111580
		Financial assets	52848729	52848729	10660
		Fixed assets	99107846	91606505	32369931
		Stocks	8140598	5001465	4447724
		Receivables	15042668	8836222	5167713
		Cash availability	3646912	3079015	7556408
		Current assets	26830178	16916702	17171845
		Advance expenses	212977	8613268	7271683
		Total active	126151001	117136475	56813459

		Equity	55215986	38156257	26667099
		Long-term debts	46242288	49391867	13762707
		Permanent capitals	101458274	87548124	40429806
		Short-term credits	9605103	8669285	7510106
		Suppliers and assimilated	9760116	5603847	2495263
		Other operating debts	2219962	10263972	1275818
		Total debts	67827469	73928971	25043894
		Provisions	3000000	0	0
		Advance income	107546	5051247	5102466
		Total passive	126151001	117136475	56813459
2.	SME ₂	Intangible assets	36220	53892	9390
		Tangible assets	340409710	324284161	283135094
		Financial assets	1383956	1403765	909545
		Fixed assets	341829886	325741818	284054029
		Stocks	701338738	666024957	470595042
		Receivables	663167900	224528995	202081290
		Cash availability	19118617	55885147	-55216866
		Current assets	1383625255	946439099	617459466
		Advance expenses	6872688	3616201	3210937
		Total active	1732327829	1275797118	904724432
		Equity	13350073	239313097	133739466
		Long-term debts	54546723	73457354	87045973
		Permanent capitals	67896796	312770451	220785439
		Short-term credits	1359042602	828367612	531125162
		Suppliers and assimilated	266628762	117702009	128168479
		Other operating debts	36003051	14169037	21810861
		Total debts	1716221138	1033696012	768150475
		Provisions	1626402	1626402	1626402
		Advance income	1130216	1161607	1208089
		Total passive	1732327829	1275797118	904724432

Source: Own processing based on the Balance Sheet for the period 2021-2023

Taking into account Table 3, at the SME₁ level, the supremacy of fixed assets compared to current assets is noted, as well as a constant increase in these elements throughout the analyzed period. The increase is due, on the one hand, to the increase in tangible assets by 19.72% in 2022 compared to 2021 and by 19.83% in 2023 compared to 2022. On the other hand, there is also an increase

in financial assets by 52,838,069 lei in 2022 compared to 2021, with their value remaining unchanged in 2023. As for current assets, their increasing trend is constant, as a result of the constant increase in stocks and receivables.

Observing the permanent capital, an increasing trend is noted, a favorable aspect for SME as a result of the increase in equity by 43.08% in 2022 compared to 2021 and by 44.71% in 2023 compared to 2022. At the same time, the increase in permanent capital is also corroborated by the decrease in long-term debts by 35,629,160 lei in 2022 compared to 2021 and by 3,149,579 lei in 2023 compared to 2022. The fluctuation of debts is also noted, as a result, in particular, of the increase in short-term debts. Thus, in 2022, the value of debts increases by 48,885,077 lei compared to 2021, and in 2023, their value will decrease by 6,101,502 lei as a result of long-term debts and other operating debts. As for SME₂, it shows an increasing trend in balance sheet assets throughout the analyzed period as a result of the increase in stocks by 41.53% in 2022, compared to 2021, and by 5.30% in 2023, compared to 2022. At the same time, there is also an increase in receivables in 2022 by 11.11% compared to 2021 and by 195.36% in 2023 compared to 2022.

Taking into account the main activity of SME₅, namely wholesale trade of cereals, the constant level of stocks is validated by the seasonal nature which implies high demand in certain periods of the year. A fluctuation in permanent capital is also noted as a result of the decrease in equity in 2023 by 94.42% compared to 2022, a decrease also supported by the decrease in long-term debts of 27.74% in the same reference period. The creditworthiness of the SMEs surveyed is reflected in Table 4, as follows:

Table 4. Calculation of specific liquidity and solvency indicators

Crt. no.	SME	Indicator name	Year -%-		
			2023	2022	2021
1.	SME ₁	Current liquidity	1,24	0,69	1,52
		Quick liquidity	0,87	0,49	1,13
		Immediate liquidity	0,17	0,13	0,67
		Equity solvency	0,44	0,33	0,47
		General solvency	1,86	1,58	2,27
2.	SME ₂	Current liquidity	0,83	0,99	0,91
		Quick liquidity	0,41	0,29	0,22
		Immediate liquidity	0,01	0,06	-0,08
		Equity solvency	0,01	0,19	0,15
		General solvency	1,01	1,23	1,18

Source: Own processing based on the Balance Sheet for the period 2021-2023

Noting Table 4, regarding current liquidity, taking into account the optimal level between 1 and 2%, it is found that SME_1 , with the exception of 2022, records values within this range, thus the situation being favorable. SME_2 records values below this reference level, but which nevertheless tend towards the lower limit of the range. Regarding quick liquidity, the optimal values are within the range of 0.6-1%, thus SME_1 only manages to fall within this standard in 2023, the value tending towards the upper limit of the level. SME_2 records values below this range. In this sense, the presence of stocks in the activity of SMEs causes the quick liquidity rate to have values outside the reference range. The immediate liquidity would have the reference range between 0.2-0.6% and thus SME_1 only manages in 2021 to cover its short-term debts based on liquidity, in the following years recording values below this level. SME_2 does not reach the minimum reference level in any of the three years, liquidity being thus insufficient for the payment of short-term debts. Taking into account the optimal level of 0.5 of patrimonial solvency, we find, in the case of SME_1 , that it does not present an optimal patrimonial solvency, but which tends towards this level, a positive aspect for the entity. In the case of SME_2 , the situation is unfavorable, as there is no financial independence. Regarding the general solvency, in the case of SME_1 it has an oscillating but favorable evolution regarding the year 2023 in which it increased, thus managing to be outside the risk of insolvency. Regarding the situation for SME_2 , the indicator values present a moderate risk of insolvency, with the situation being unfavorable in 2023, given the decrease in the percentage compared to 2022. The only favorable aspect is that indebtedness is mainly based on short-term debts, which are temporary.

In order to determine the safety margin and financial balance of SMEs, based on the information taken from the financial balance sheet, we determined and assessed a series of relevant indicators, namely: working capital, own working capital, working capital requirement and net treasury. At the same time, to assess the value created by SMEs, we calculated the cash flow, taking into account its importance for investors. The calculated indicators are presented in Table 5 as follows:

Table 5. Calculation of indicators specific to financial balance

Crt. no.	SME	Indicator name	Year -lei-		
			2023	2022	2021
1.	SME	WC	-87239579	-106404136	-21634756
		NWC	-90886491	-109483151	-29191164
		NT	3646912	3079015	7556408
		Cash-flow	567897	-4477393	0

2.	SME₂	WC	-387142606	-160714267	-237736982
		NWC	-406261223	-216599414	-182520116
		NT	19118617	55885147	-55216866
		Cash-flow	-36766530	111102013	0

Source: Own processing based on the Balance Sheet for the period 2021-2023

Analyzing Table 5, we find the following situations:

- Within IMM₁ WC presents negative, fluctuating, but favorable values at the level of 2023 as its value increases by 19164557 lei compared to the previous year. The negative values reflect a long-term financial imbalance. IMM₂ also records fluctuating values of the indicator, the evolution being unfavorable at the level of 2023 as a result of the decrease in the value by 226428339 lei compared to 2022. Thus, a negative working capital is noted throughout the study interval, proof that SMEs are constantly faced with a long-term financial imbalance;
- NWC presents negative values for both SMEs, which is not unfavorable considering that their activity does not generate working capital. The indicator presents significant fluctuations, reported in 2023 for SME₁ by a decrease of 18596660 lei compared to 2022, and for SME₂ by an increase in the value by 189661809 lei compared to the previous year;
- NT has positive values in all three years within SME₁, but oscillating, with a favorable trend for 2023. Thus, SME₁ records a current financial balance. SME₂ has an NT present in 2022 and 2023, representing an essential resilience factor for the entity;
- For SME₁ the cash flow situation is favorable, managing to register a positive value in 2023, with cash receipts being much higher compared to expenses in this time interval. For SME₂, the situation is unfavorable; the increase in NWC in 2023 also has negative effects on cash flow, which, although in 2022 it has a positive value, in the following year the activity is unprofitable.

5. Conclusions

Following the research conducted on SMEs in the S-W Oltenia region during the period 2021-2023, we can answer the research question: Are creditworthiness and financial balance important in making financial decisions at the SME level? by presenting their role. In this sense, creditworthiness through its component indicators, namely liquidity and solvency, reflects the extent to which current debts can be paid with the help of current assets and the extent to which the SME's total assets can cover its total debts. Creditworthiness thus allows the identification of financial security at the SME level. Regarding

liquidity, only SME₁, with the exception of 2022, records a current liquidity that allows covering short-term debts based on the current assets. SME₁ also records a rapid liquidity in 2023 and an immediate liquidity in 2021, a favorable aspect for the entity. At the opposite pole, SME₂ fails in any of the three years analyzed to present financial liquidity, recording indicator values below the optimal reference ranges.

Along with liquidity, solvency is an essential aspect of the creditworthiness of SMEs. The indicator aims at their ability to pay all their debts based on the valorization of all assets. Thus, solvency involves term and operating debts, on the one hand, and fixed and current assets, on the other. From the point of view of patrimonial solvency, both SMEs record values below the reference level, a favorable aspect existing within SME₁ since values are observed to be tending towards the optimal limit.

At the SME₁ level, total assets can cover its total debts, the general solvency being consolidated. Optimal values of this indicator are found at the SME₂ level, which records values that allow for the existence of a moderate insolvency risk. Values above 1 indicate stability and good financial balance that allow long-term debts to be covered from net assets and which reflect the possibility of these SMEs to honor their obligations to third parties. The working capital highlights the long-term financial balance. The values recorded by the SMEs analyzed are negative throughout the study period, a common situation at the SME level since most of these types of entities operate with a minimum share capital of 200 lei, which entails minimum reserves of 40 lei. NWC is the second indicator of financial balance, presenting the situation of the short-term financial needs of SMEs compared to the resources attracted in the short term.

NT is materialized by the presence or absence of liquidity, highlighting the current financial balance of SMEs. NT is positive for the two SMEs except for EMS₂ in 2021, which reflects a profitable activity carried out during the reference period and a current financial balance. However, the situation is not favorable since WC and NWC record negative values in the three years analyzed, and thus short-term financial autonomy is not ensured. Financial balance reflects the concordance between the sources of financing and the payment need of SMEs in carrying out their trade activities, but also the development needs required by the market and consumers.

Due to the interest and concerns for the appropriate measurement and monitoring of the results of the activity carried out by SMEs, in the context of the current market economy, the informational knowledge of the state of dynamic economic and financial equilibrium has increased considerably. In this regard, determining the creditworthiness and the state of financial equilibrium of an SME is important in making financial decisions. The assessment of liquidity

and solvency allows reflection on the state of existing financial security, or not, and the establishment of financial equilibrium at all levels, especially in terms of treasury, highlights the adaptability of SMEs to crisis situations.

For more efficient management of SMEs, we propose a series of recommendations:

- Careful management of liquidity, as a central asset structure, considering the object of activity;
- Maximizing the use of short-term debts as free sources of financing;
- Careful treasury management, moderate sizing of available funds.

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DESIGNING BUSINESS SYSTEMS USING DATA STRUCTURES SPECIFIC TO ECONOMIC FLOWS

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Abstract: *The paper presents the designing business systems using data structures specific to economic flows. In the study of the process of designing information systems, the notion of system is essential. A system represents a set of interdependent elements (components) between which a dynamic interaction is established, based on pre-established rules, with the aim of achieving a certain objective. According to systems theory, any economic organism is a system. Depending on how detailed the analysis is, a system has many characteristics, such as, each system accepts a number of inputs, processes the information provided by them, and sends the results to the outputs and from there, to the environment in which the system evolves. The boundaries of the system separate it from the environment in which it manifests itself. Through interfaces, a system communicates with the environment. A system exists only in the environment that contains it and will interact with it through the data and information received. A system is made up of components. These, also called subsystems, between which various relationships are established, can be formed from indivisible component elements or from groups of aggregated elements. For example, the financial-accounting department of a company is formed by the aggregation of people who perform functions of this nature, as is the human resources management department. The design of subsystems is very important because, if the system as a whole no longer functions correctly, its repair should be possible by simply replacing the subsystem that caused the failure. The limitations of the system refer to the constraints imposed by its parameters (for example, storage capacity or speed) according to which the system must function in order to achieve the purpose for which it was created.*

Keywords: *designing economic applications, system elements, data structures, environment of business, data for applications, system design, business relations*

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

1. Introduction

There are several important concepts related to the study of the system. Decomposition is very useful when trying to understand the functioning of a complex system. It will be decomposed into simpler subsystems, whose structure can be analyzed and understood one by one, without taking into account the interferences between subsystems. The functioning of a personal computer can be understood more easily if we first study the functioning of each module such as processor, north bridge, south bridge, memory, etc.

Modularity derives directly from decomposition and facilitates the process of troubleshooting the system.

Coupling refers to the fact that systems are interdependent, although they should be as independent as possible. Thus, the failure of a subsystem would lead to the chain damage of all subsystems and, ultimately, the failure of the main system. If independence is ensured, only the faulty component can be replaced, the troubleshooting and repair process being greatly shortened.

Cohesion represents the extent to which a subsystem can perform a single function.

The information system is based, as the name suggests, mainly on information. It includes all the internal and external information used within the organization as well as the data that was the basis for obtaining it, the procedures and techniques for obtaining information (starting from primary data) and disseminating information, as well as the personnel involved in collecting, transmitting, storing and processing data. The information system does not only refer to the way in which the tools made available by TI&C are used but also to the way in which people interact with technology in an institution (Baley and Veldkamp 2025; Piacentino, Arbia, and Espa, 2021).

In the economic field, the information system ensures the connection between the decision-making and operational systems.

2. Designing the information system for customized applications and data

The functions of an information system are the following:

- to collect information from operational and decision-making systems as well as information coming from the external environment;
- to store this information as well as information resulting from their processing;
- to ensure access to memory in order to communicate the stored information;
- to process information at the request of the operational system and the management system.

The notion of an information system is related to the computerization of the organization's activity, therefore to the use of hardware equipment and software products for the organization and management of information.

The use of computers within an organization's information system (IS) leads to the definition of the Automated Information System (AIS) component – which includes only the work performed with the help of computers.

An information system is an integrated user-computer system that provides information to support operational-level activities and management activities in an organization, using hardware and software, manual procedures, a database, and mathematical models for analysis, planning, control, and decision-making. The main objective pursued by introducing an information system is to provide management with real and timely information, necessary for the substantiation and operational elaboration of decisions (Piacentino, Arbia, and Espa, 2021; Baley and Veldkamp 2025).

The development of information systems requires the modeling of the organization's information system using a formalism through which the reality within the information system can be represented as suggestively and faithfully as possible. For organizations of low complexity, computerization can mean the creation of a single information application also referred to as an information system.

Complex computer systems can be broken down into subsystems, which in turn can be broken down into applications intended for certain categories of users, applications which in turn can consist of one or more programs written in various programming languages. Computer systems, subsystems and applications are computer products also called software products. A computer product consists of programs that access the database and the documentation necessary for the use and maintenance of the programs. These are made based on methodologies and require the completion of certain stages starting with the specification of requirements and ending with their implementation, operation and maintenance (Baley and Veldkamp 2025; Consoli, Reforgiato and Saisana, 2024).

The economic computer system is a structured set of functionally interrelated elements for the automation of the process of obtaining information and for the substantiation of decisions. The computer system is included in the scope of the information system as long as there are a series of activities within the information system that cannot be automated. The technical basis of an information system is made up of all the technical means of collecting, transmitting, storing and processing data, the central place being given to electronic computers. The software system includes all the programs used for the operation of the information system in accordance with the established functions and objectives. Both basic programs (basic software) and application programs (application software) are taken into account.

The scientific and methodological basis consists of:

- algorithms;
- formulas;
- models;
- techniques for creating information systems.

Human resources consist of:

- specialized personnel: analysts, programmers, system engineers, assistant programmer analysts, operators, etc.;
- beneficiaries of the system.

The organizational framework is that specified in the organization and functioning regulations of the unit in which the information system will be used. When creating and using an information system, the following hardware and software components must be taken into account: networks, equipment, basic software products, application software products.

Equipment

- Computing equipment: computers, graphics workstations, network servers, database servers, workstations (clients, users), UPSs;
- Communication equipment: routers, hubs, modems, switches.

Software Products

Basic software products:

- Network server operating systems;
- Database Management Systems;
- GIS (Geographical Information System) systems – used to create applications for storing and processing spatial data;
- Programming languages (environments) – used to create application software.

Application software products – program products that constitute the applications and subsystems of the computer system.

The life cycle of an information system

Information systems (IS) are characterized by a life cycle that begins with the decision to create a new IS that better meets the new requirements of users and ends with the decision to replace the existing IS with a new, more efficient one. The life cycle is carried out in stages, each of which has specific phases and activities defined (Consoli, Reforgiato and Saisana, 2024; Du, 2021).

Regardless of the historical or methodological stage, systems are approached through the prism of their life cycle. They appear, develop, decline and disappear, or through a new cycle, they are improved, giving rise to another version or even a new system. Mutations in the field of information technology and in the methods of approaching systems have also been reflected in the life

cycle of systems development, either by changing its stages or by modifying the optics of their progress. For example, with the object-oriented approach to systems, new life cycle models have also been launched (Du, 2021; Carriere-Swallow and Haksar, 2019).

By reviewing specialized materials, it can be seen that the number of phases/stages varies from three (for example, analysis, design, implementation) to over twenty. There are several life cycle models, many of which evolve over time. For example, the waterfall model provides for the passage of several stages of the life cycle that are carried out sequentially, while allowing, if necessary, a return to the previously passed stage in order to remove shortcomings identified in the higher stages of the life cycle (Carriere-Swallow and Haksar, 2019; Piacentino, Arbia, and Espa, 2021). The stages of the information system life cycle in the waterfall model are:

- Requirements analysis and definition – the goals, services and restrictions that the information system must meet are defined, presented in a manner that can be understood by both the system users and the design staff.
- System and software design – establishing hardware and software requirements and developing the overall system architecture. The functions of the information system will be represented so that they can be transformed into one or more executable programs.
- Implementation and testing of program units – the software design from the previous stage is translated into a set of programs or program modules and verification that each program or module satisfies its specification.
- System integration and testing – the integration and testing of programs and program modules as a complete system to ensure that the information requirements are met. After testing, the system is delivered to the beneficiary (Baley and Veldkamp 2025).
- System operation and maintenance – is the phase in which the information system is actually used by the beneficiary and in which any design and programming errors and omissions in the initial information requirements are discovered and resolved.

Data processing cycle for the information system

The operations that are performed on data, from the moment of their appearance, to generate meaningful and relevant information are referred to together by the notion of the data processing cycle, which includes five phases: data collection, data preparation, data processing, file maintenance and obtaining output information.

The data collection phase includes two fundamental activities:

- observation of the environment that generates the data, either by a

- human observer or by various equipment;
- recording the data, either by writing them in source documents or by capturing them in different forms using special equipment.

The data preparation phase consists of a number of operations performed on the data to facilitate their subsequent processing, namely:

- data classification, which involves assigning identification codes (account symbol, department code, etc.), so that the data are included in the appropriate subsets;
- data grouping, i.e. accumulating similar entries, to be processed in a group;
- data verification includes a wide variety of procedures for checking the correctness of the data, before they are processed;
- data sorting, by which groups of data are arranged into batches of records, according to numerical, alphabetical, alphanumeric or time ordering criteria;
- coupling two or more batches of records into a single one;
- transmitting data from one point to another;
- transcribing data from one form to another, so as to make the transition from handwriting to typewriting or from written documents to specific media.

The data processing phase may include activities such as:

- calculations include some forms of mathematical data processing;
- comparison subjects two or more types of data between which there is a logical connection to a simultaneous examination (e.g. the final and the final balance);
- synthesis is an important activity through which information is combined;
- filtering is another operation through which data is extracted that will be subjected to subsequent processing;
- restoration, through which data is brought from memory into a form accessible to humans, for further human processing, or into a form that can also be processed on a computer.

There are several activities in the file maintenance phase, including:

- storing data for future use;
- updating stored data to capture the most recent events;
- indexing data to facilitate easy retrieval;
- protecting stored data, which includes a wide variety of procedures and techniques to prevent its destruction or unauthorized access.

The last phase of the data processing cycle is obtaining output information. Output information can be found in one of the following three forms:

documents, reports, answers to questions. Most of the time, data does not go through all the activities, and some of it may not go through all five phases (Consoli, Reforgiato and Saisana, 2024; Baley and Veldkamp 2025).

3. Data identification for standardization and use in economic applications

Management information systems are integrated systems that create and update a single database from primary documents, which will be subsequently processed to obtain specific situations for each user.

The management information system involves the following four interdependent components: management domains, data, models, management rules. The management domains correspond to the activities carried out within the company: personnel activity, production activity, commercial activity, financial-accounting activity, research and development activity (Piacentino, Arbia, and Espa, 2021; Du 2021). The data represent the raw material to be processed within the information system to obtain the information necessary for decision-making at all management levels: operational, tactical, strategic. Management models group the procedures specific to a domain, and management rules define the processing performed on the data and the way in which the information is used according to the system's objectives.

An example of data type is the following:

```
#include <iostream>
using namespace std;

// AtomData types accepted by the application
enum AtomDataType
{
    Term, // a number
    OpenParenthese, //)
    CloseParenthese, // (
    Plus, // +
    Minus, // -
    Multiplication, // *
    Division // /
};

// Information about an atom
struct AtomData
{
    AtomType Type;
    int Priority;
    double Value;

    // Constructor for initializing
```

```
// an atom data
AtomData(AtomDataType type = Term,
int priority = 0, double value = 0)
{
Type = type;
Priority = priority;
Value = value;
}
};

// Stacks and queues used will
// have as useful information atoms
typedef AtomData StackType;
typedef AtomData QueueType;

#include "stiva.h"
#include "queue.h"

// Transform the expression into a queue of atoms
Queue ParseString(char *expression)
{
Queue queue = CdCreate();

while (*expression != '\0')
{
switch(*expression)
{
case '+': CdAdd(queue, AtomData(Plus, 1)); break;
case '-': CdAdd(queue, AtomData(Minus, 1)); break;
case '*': CdAdd(queue, AtomData(Multiplication, 2));
break;
case '/': CdAdd(queue, AtomData(Division, 2)); break;
case '(': CdAdd(queue, AtomData(OpenParenthese, 0));
break;
case ')': CdAdd(queue, AtomData(CloseParenthese, 0));
break;
default:
// term (integer)
if (*expression > '0' && *expression <= '9')
{
// construct the term
double value = 0;
while (*expression >= '0' && *expression <= '9')
{
value = value*10 + (*expression - '0');
expression++;
}

// we need to return to the first character
// after the number
expression--;
```

```
// add the term to the queue
CdAdd(queue, AtomData(Term, 0, value));
}
}

// advance to the next character in the expression
expression++;
}

return queue;
}

// Transform an expression from normal form
// infix to postfix Polish form
QueuePolishDataForm(Queue& expression)
{
// stack used for temporary storage
Stack stack = StCreate();

// queue for storing the result (PolishDataForm form)
Queue PolishDataForm form = CdCreate();

Atom atomStack;

// we traverse the initial expression
while (!CdIsEmpty(expression))
{
AtomData atom = CdExtract(expression);

switch (atomData.Type)
{
case Term:
// is added directly to the result string
CdAdd(PolishDataForm form, atomData);
break;

case OpenParenthese:
// is added to the stack
StAdd(stack, atomData);
break;

case CloseParenthese:
// moves all operators from the stack to the result
// until the opening parenthesis
atomDataStack = StExtract(stack);
while (atomDataStack.Type != OpenParenthese)
{
CdAdd(PolishDataForm form, atomStack);
atomStack = StExtract(st);
}
break;
default: // operator
```

```
while (!StIsEmpty(st) && StTop(st).Priority > atom.
Priority)
    CdAauga(formaPolData, StExtract(st));

    StAddAtom(st, atomData);
}
}

// move all remaining elements to the result
while (!StIsEmpty(st))
    CdAddData(formPolData, StExtract(st));

return formPolData;
}
```

The data system brings together specialized information subsystems in areas between which specific interactions occur. Each defined subsystem groups homogeneous information processes, specific to a certain area. At the level of each subsystem, distinct applications corresponding to these activities will be defined. In turn, the applications are made up of procedures, broken down into modules representing code sequences through which an independent function within the procedure is performed (Carriere-Swallow and Haksar, 2019; Baley and Veldkamp 2025).

4. Conclusions

The creation of data systems is a complex action that combines a large number of activities: analysis, design, implementation, and exploitation. In addition, it requires significant human, material and financial resources, over a considerable period of time. The efficient use of these resources, in order to obtain a high-performance information system, has required the ordering of this complex process, in a well-established sequence of stages and sub-stages and the use of appropriate methods and techniques (Baley 2025; Mingyu 2024). These observations have led to the development of methodologies for the creation of information systems. There is an indestructible link between the various stages of implementing information systems, a link also reflected by the fact that logically and practically the quality of carrying out activities in the previous stages and phases decisively influences the quality of activities in the following stage. Data atomization for use in high-performance information systems involves the decomposition and identification of various characteristics that are specific to economic data within various business processes.

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THE ECONOMIC AND SOCIAL IMPACT OF LABOR MIGRATION

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Abstract: *The decision of Romanians to head for the European labor market, in particular, is influenced by a series of factors. First of all, the country's national economic potential has been in continuous decline over the last twenty years, as have the incomes of the majority of the population. We also have the liberalization of the labor market at a global level, which has encouraged Romanians to opt for international migration. At the international level, external migration has left its mark on the structure of the labor market through immigrants and emigrants. If we discuss the impact of emigrants on the labor market, there are countries such as the USA, Australia, and Canada, which have always relied on such resources, practically human capital. In general, the country from which they emigrated has benefited from these international emigrations, as the economic situation has improved due to income sent from abroad and invested in the country. I have chosen this topic because labor migration represents one of the most important economic and social phenomena in contemporary Romania. In recent decades, our country has been strongly affected by migration flows, with millions of Romanians leaving abroad in search of better working conditions and a more decent life. This massive migration has complex effects on the national economy, the labor market, the pension system and social cohesion. On the one hand, remittances sent by emigrants contribute to the economic stability of families left behind. On the other hand, Romania is facing a decline in the skilled workforce and significant demographic imbalances. Through this paper, I propose to analyze the causes and effects of this phenomenon, to highlight its implications for Romania's development, and to explore possible solutions for managing and reducing the negative impact of migration on the Romanian economy and society. Also, this topic is particularly relevant in the context of globalization and European integration, where labor mobility is becoming increasingly accentuated.*

Keywords: labor migration, emigration countries, migration trends, migration impact, Romanian economy

JEL Classification: H26, J61, P25, R23

1. Introduction

The phenomenon of migration is associated with a series of economic advantages and disadvantages. Migrant flows bring benefits or losses to those they affect. These aspects mentioned change the vision on migration, making it an economic and social policy instrument. The policy will be one of opening up east-west migration with the aim of covering the deficit of low-skilled labor and, on the other hand, of intensifying the temporary or definitive attraction of brains to support the progress of high-performance technologies and, implicitly, through human resources with top training for west-east.

For the first category, east-west, there are quantitative limitations, depending on the size of the deficit, achieved by quoting flows by trades and professions. For the second category, competition between receiving states will intensify to attract personnel to cover the deficit of high skills, a condition for the development of EU member states and beyond. These flows will be limited in the medium-long term because there is a demographic aging process in Eastern European countries and the labor shortage in the countries of origin is increasing. In practice, through migration there is a transfer of demographic aging and not a slowdown of this process.

In terms of the macroeconomic effects of emigration, it is noted that this segment of the active population is a creator of jobs, without any private or public international contribution to the national economy. The income that this sector creates is added to the domestic consumption fund, funds intended for development and, to a certain extent, to the budget resources of the economy.

These revenues, which they have earned through activities performed in other countries, are transferred to the monetary economy through the foreign exchange market. It is estimated that the amount of this category of income, registered and unregistered, which enters our economy annually amounts to approximately 5 billion euros. To this we add the part of the income of these economic agents destined for individual consumption in the country.

The transfer of currency made by Romanian workers abroad can be considered one of the great advantages of emigration, which is reflected on the national currency in terms of its evolution on the foreign exchange market. In the usual way, the acquisition of international payment capacity is achieved through exports, which in turn requires investments to create production capacities, dependent on public and private funds intended for development. Labor migration becomes, from this point of view as well, an important substitute for exports. In this way, we are witnessing the formation of genuine foreign exchange markets.

On the other hand, among the categories of economic agents that were involved in the appreciation of the leu, Romanian workers abroad understood best that free exchange rate fluctuations are natural phenomena for any market economy. Their reaction is due primarily to spontaneous self-learning, offered by the monetary economy of the European Union, where they perform various activities generating foreign exchange income. For the vast majority of Romanian workers abroad, the information provided by real economic life regarding the exchange rate mechanism has been extremely favorable.

In certain situations, monetary mechanisms are better understood through the individual's confrontation with real life. This is also the case in the present case, where a real instruction is carried out through everyday life, which offers these Romanian workers abroad real situations, related to the functioning of the monetary economy, that is, the economy in which money is sold and bought on the foreign exchange market like any other commodity.

2. The situation of labor migration in Romania

The decision of Romanians to head to the European labor market in particular is influenced by a series of factors. First of all, the country's national economic potential has been in continuous decline over the last twenty years, as have the incomes of the majority of the population. We also have the liberalization of the labor market at a global level, which has encouraged Romanians to opt for international migration.

However, the departure of parents to work abroad has a series of negative effects on children in particular and on the family and its functionality. Children left behind in the country become vulnerable to abuse, exploitation through work, their performance at school decreases, culminating in an increase in the school dropout rate.

At the international level, external migration has left its mark on the structure of the labor market through immigrants and emigrants. If we talk about the impact of emigrants on the labor market, there are countries such as the USA, Australia, Canada, which have always relied on such resources, imported human capital. In general, the country from which they emigrated benefited from these international emigrations, as the economic situation improved due to the income sent from abroad and invested in the country.

In Romania after 1989, emigration was mainly motivated by political factors. The same saving solution came from the flows of emigrants after 1996. The lack of jobs together with the massive restructuring in the production segment generated a massive wave of emigrants that culminated after 2007, when visas were waived.

If we were to analyse the interdependent relationship between migration and the structure of the labor market in Romania, we would have to take an approach from the simple to the complex. We will use the statistical information provided by Eurostat for the period 2018-2022.

Table 1. Romanian emigrant flows in the period 2018-2022

Year	Number of immigrants
2018	215.646
2019	194.176
2020	215.605
2021	553.162
2022	325.121
Total	1.503.710

Source: EUROSTAT

Thus, the existence of a group of countries to which Romanian emigrants have specifically headed is noted, countries such as Italy (834,000 people), Spain (824,000 people), Germany (266,000 people), Hungary (98,000 people) and Austria (52,000). These countries account for 96.6% of the total number of Romanian emigrants.

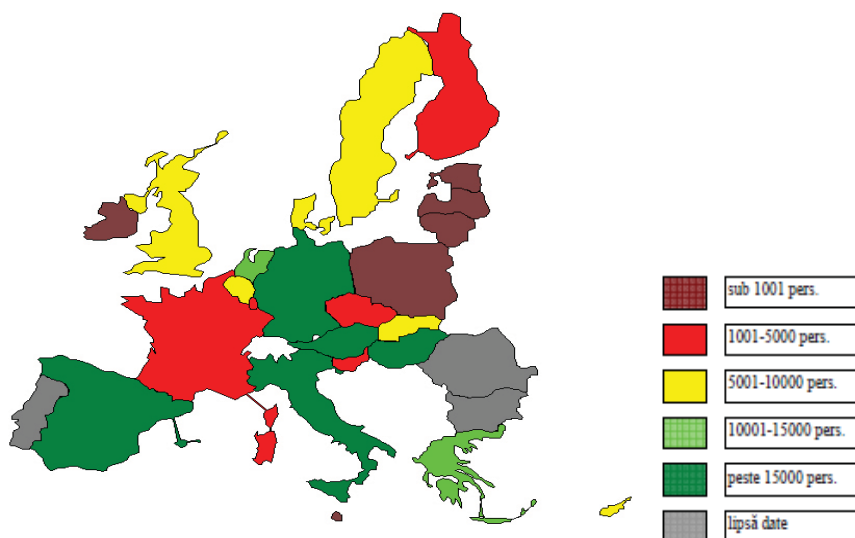


Figure 1. Total number of immigrants with Romanian citizenship, in destination countries belonging to the EU, in the period 1998-2022

Source: EUROSTAT

We continue to see the evolution of the emigration phenomenon for the three main destination countries. Thus, in 2018, the country preferred by Romanian emigrants continued to be Spain, with migration flows to this country increasing from 17,000 people in 1998 to 24,000 people in 2007. After Romania's accession to the European Union, the number of Romanians who chose Spain as their destination country doubled, reaching 48,000 in 2022.

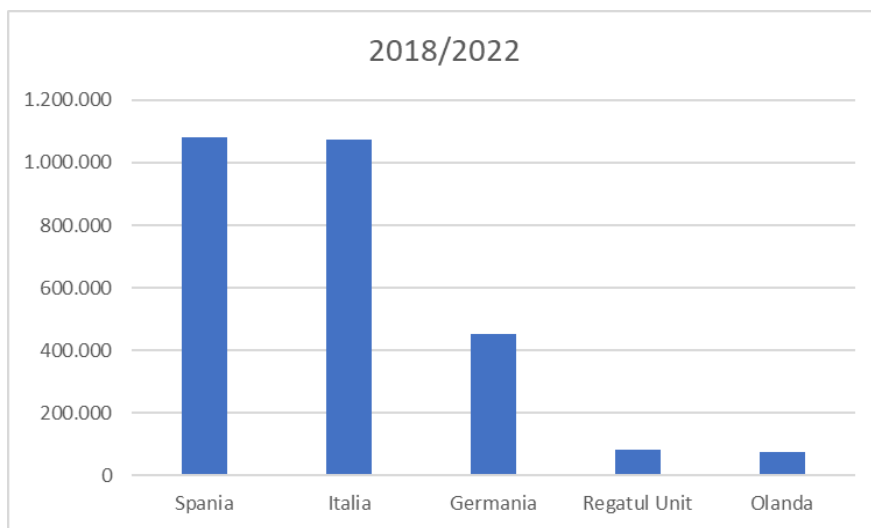


Figure 2. Evolution of the total number of immigrants with Romanian citizenship in Spain, Italy, Germany, the United Kingdom and the Netherlands in 2018-2022

Source: EUROSTAT

Since 2007, Spain, Italy, Germany, the United Kingdom and the Netherlands have all registered an increase in the flow of Romanian immigrants. In the period 2016-2017, Spain received approximately 541,000 Romanian immigrants and in the following two years, i.e. 2018-2020, there were 551,500 people who chose Italy as their destination country, followed by the other 3 countries. Following Romania's accession to the European Union in 2007, the number of Romanian citizens emigrating to other EU member states has increased significantly. Estimates vary, but it is estimated that between 3 and 5 million Romanians currently live outside the country's borders, the majority in European countries such as Spain, Italy, Germany, the United Kingdom and the Netherlands. This increase has been influenced by the right to free movement and the economic opportunities available in other EU member states. We can also talk about indicators that reflect the absolute data of Romanian emigrant flows. We thus have the share of immigrants with Romanian citizenship in total immigrants,

this indicator allowing a more accurate measurement of Romania's position within Europe as a country supplying immigrants.

In the figure below, you can see the shares that Romanian immigrants recorded compared to other immigrants in 2022.

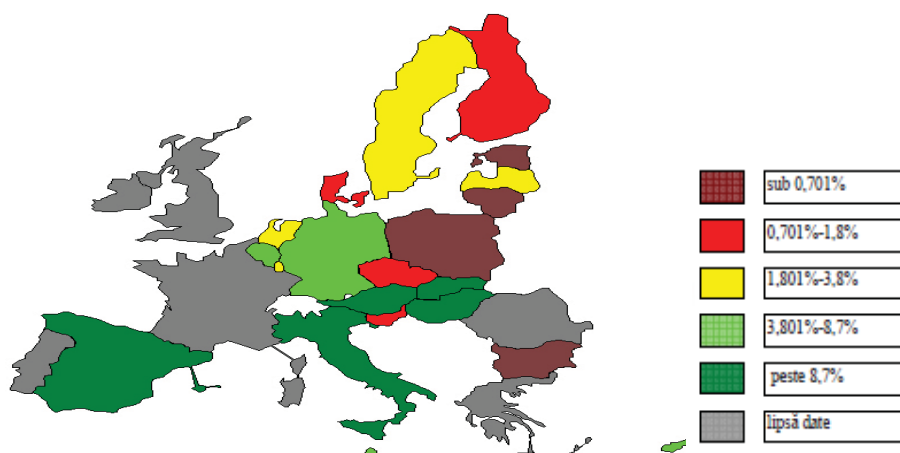


Figure 3. Share of immigrants with Romanian citizenship in total immigrants by European country in 2022

Source: EUROSTAT

The countries with the highest shares of Romanian immigrants are: Spain (48.64%), Italy (27.65%), Germany (20.62%) and the United Kingdom (18.62%), the EU average was 7.05% (Figure 4).

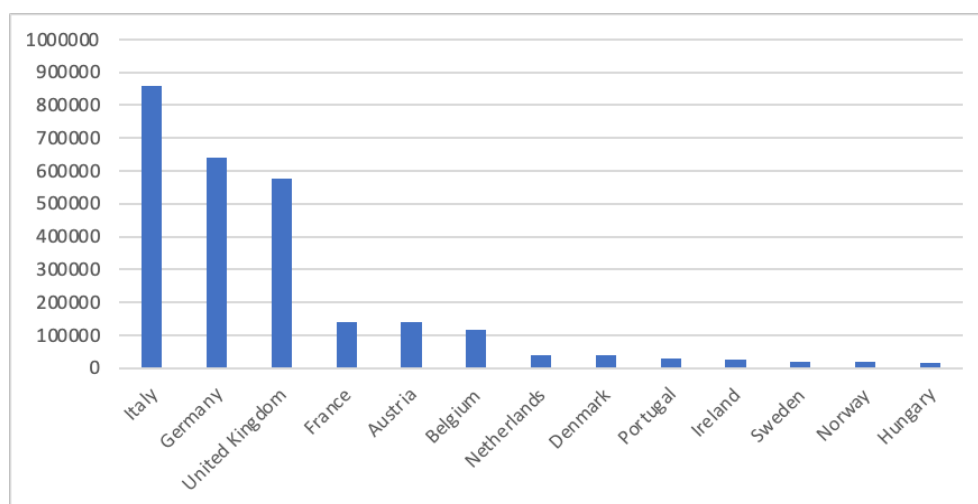


Figure 4. Number of Romanian immigrants by host countries

Source: European Commission, Eurostat (2025)

The wave of departures abroad, especially to Europe, can be divided into 3 stages:

- a. Stage I: between 1990-1995 - Israel, Turkey, Italy, Hungary and Germany (over 7%)
- b. Stage II: 1996-2002 to the five countries in the first stage are added Canada, Spain and the USA
- c. Stage III: began in 2007, and Romanians concentrated their departures to Spain, Italy, Germany, the United Kingdom, the Netherlands and other EU countries.

According to studies presented by UNICEF and Save the Children, approximately 350,000 children have at least one parent working abroad. However, studies have been conducted on only approximately 170,000 because only these are enrolled in the public education system. 47% of them, i.e. approximately 80,000, have a father who has left, 33% (55,000) have a mother who has left, and 20% (35,000) have both parents who have left abroad.

A very important element to consider when talking about international immigration is the age at which Romanians decide to emigrate. 40% of them are between 30-39 years old. The danger arises when the children of these families are left in the country unsupervised, during adolescence, thus affecting their psychological development.

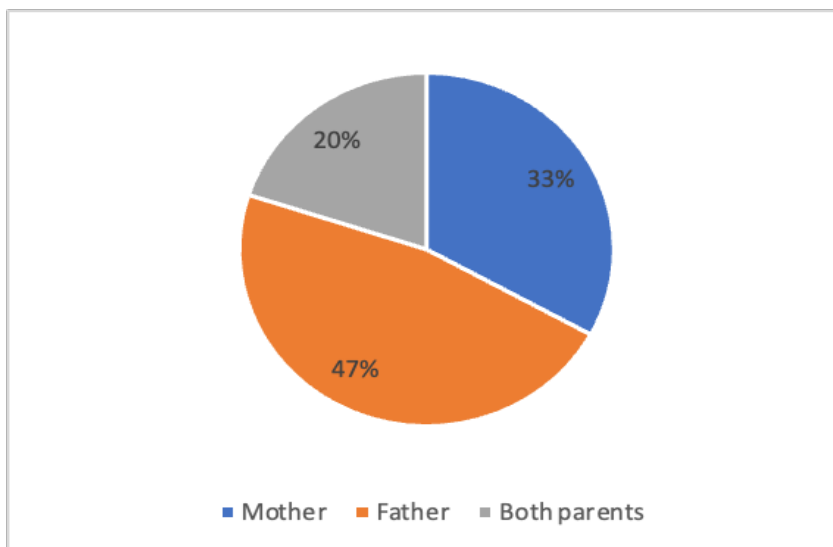


Figure 5. Share of children left at home, depending on the parent who went to work abroad (2022)

Source: *Salvați Copiii (n.d.)*

Also, 54% of minors who remain unsupervised in the country have their parents abroad for a period of less than 1 year, while 34% will not see their parents for more than 1 year. The latter are the most severely affected by international migration. The situation of these children and their good development depend very much on the people in whose care they are left. According to statistics provided by UNICEF, more than 79% of these children remained in the care of first-degree relatives, grandparents, uncles, aunts or siblings.

3. The effects of the financial crisis and the COVID-19 pandemic on migration flows, migrant access and participation in the labour market

Research and studies that have analysed the way in which the economic situation determines changes in the evolution of labour migration show that, in recent decades, in the member countries of the Organisation for Economic Co-operation and Development (OECD), migration flows have been strongly correlated with economic cycles. However, it is important to emphasize that the migration-economic context relationship is not a linear and mechanical one, since the influences of periods of economic crisis and the COVID-19 pandemic on migration are complex and difficult to predict. In this sense, reports by the OECD or the International Organization for Migration (IOM) demonstrate that previous economic recessions have not affected the upward trend in labor migration, with people continuing to migrate and find work outside their country's borders even during these periods. According to OECD data, it is unlikely that the motivation to migrate will disappear due to the economic crisis. The difference in per capita income between developing and developed countries will be as large as before the crisis, and once the situation stabilizes, those who have postponed their decision to work abroad will join the already existing emigrants.

In Spain, for example, OECD data show that migrant flows in 2009 remained at the same level as in 2008. However, entries into the country have declined. Also, the number of migrants who came for the purpose of family reunification decreased significantly in 2008 compared to 2007 – less than 100,000 cases in 2008 compared to 128,200 in 2007. In Italy, the economic contraction has reduced the withdrawal of labor applications from employers: in 2008, approximately 10,000 employers (5.6%) withdrew their applications submitted in December 2007.

Young and male migrants are the most affected by the crisis if we take into account participation in the labor market. Even if the impact on different categories is not uniform and varies from one country to another, it is certain that migrant workers have been hit harder by the deterioration of the economic

situation than native employees. More than that, we are talking about a clear differentiation between the way in which the crisis is felt by workers within EU member states and those outside the EU.

The unemployment rate among migrants originating from the European Union (EU) varied significantly between 2008 and 2022, influenced by economic, political and social factors. Specific data on unemployment among intra-EU migrants is limited, but general trends can be inferred from available statistics. According to Eurostat, the overall employment rate in the EU-28 for people aged 15-64 was 64.9% in 2014, after a decline during the economic crisis of 2008-2010 and a period of stability between 2011 and 2013.

In Romania, the unemployment rate was 5.6% in 2022, with a total of 464,400 unemployed. The employment rate of the population aged 20-64 was 68.5%, up from the previous year.

It is important to note that these data reflect general trends in unemployment and employment in the EU and Romania and do not provide a detailed picture of the situation of intra-EU migrants. For more precise information, studies and statistics dedicated to this specific segment of the population would be necessary.

One possible explanation for the increase in unemployment could be the concentration of migrants in sectors of activity that are correlated with economic cycles or are seasonal. This is confirmed by the unemployment rate among migrant workers compared to the unemployment rate for the native population, calculated at the level of certain countries. It also seems that unskilled immigrant workers and those working without documents are feeling the impact of the crisis the most. Skilled migrant workers are protected from job loss due to their skills and, often, the investment made by the employer in their training and employment.

Studies indicate that the unemployment rate among migrants would have been much higher at EU level if return migration had been lower for certain groups of migrants, such as those from Central and Eastern Europe. It has been observed that migrants from the EU, when they lose their jobs, are more inclined to return to their countries of origin. This return is predominantly temporary, with migrants' strategy being to return to their country of destination in the event of economic opportunities or a recovery in the labour market. On the other hand, migrants from outside the EU prefer to remain in their countries of destination even if they lose their jobs. This decision is driven by difficulties in obtaining visas or work permits, administrative barriers, costs and the lack of alternatives for re-entry into the host country. In addition, there are often high travel costs, the fact that the survival of the family left behind depends on the money sent by the migrant or the total lack of prospects in the country of origin, where the crisis poses even more problems.

Apart from statistics that attest to the number of migrants returning to certain states, there are no specific studies that describe the phenomenon in depth. It is not known exactly how long the return will last, whether it is temporary or permanent, and to what extent it is caused by the crisis or represents a natural evolution of migration cycles, which are only accentuated by the crisis. It is known that, after a period spent working abroad, migrants achieve their migration objectives in whole or in part and then the propensity to return is greater. It is very possible that we are in fact dealing with only a temporary return. It should also be taken into account the hypothesis that the crisis may be more bearable in the destination countries than in the countries of origin. The crisis has had different consequences on the migration of men and women and on the labor market situation in the destination countries. Female migration increased during the crisis, largely as a result of the increase in unemployment in economic sectors where the labor force was predominantly male (construction) and the maintenance of the demand for labor in sectors such as home work (cleaning, care for the elderly and children).

One way to mitigate the negative impact of the economic crisis is through the professional mobility of migrant workers. We can therefore expect an increase in inter-sectoral mobility from sectors strongly affected by the crisis to those less affected. For example, in the case of the two important countries for Romanian migration, there is a 15% increase in the number of agricultural workers in Spain in 2018 compared to 2023, and in Italy, there is an increase in the number of small entrepreneurs by 15,079 in 2018 compared to 2023.

Another mechanism that migrants could resort to to cope with the crisis could be self-employment and entrepreneurship. Therefore, the evolution of this indicator can provide valuable information on the consequences of the economic contraction on the working activities of migrants. Statistics reveal that self-employment is higher among migrants than among the native population with a similar level of education.

Empirical research, however, shows that the relationship between business cycles and the rate of self-employment is unstable: according to some, it is rather negative, according to other studies the correlation is positive. Constant and Zimmermann show in their research carried out in Germany that self-employment is one of the main strategies for avoiding unemployment for migrants, confirming the hypothesis according to which self-employment is the answer that migrants give to the difficulties encountered on the labor market.

This hypothesis is also supported by the Director General of the Spanish Immigration Service, Márkus Gonzáles Bleifuss. He mentions that migrants should focus on developing self-employment activities as this way they can better adapt to the demands and changes in the labor market. In this sense and with the aim of combating undeclared work, Spain has proposed

simplifying the procedure by which migrants can move from employee status to self-employment.

However, the OECD report on the impact of the crisis on migration finds that there is little evidence to support that this type of behavior is successful during economic decline. Also, referring strictly to the two states that we took as an example, we observe two almost opposite situations: in Spain, the number of self-employed migrant workers decreased in the period June 2018-February 2019 by 24,000 (approximately 10%), but, in Italy, the number of self-employed workers originating from non-EU states increased slightly in 2020 compared to 2019 (by 15,079).

4. Mobility and migration of the Romanian workforce through the EURES network

Against the backdrop of the crisis, support for Romanian workers working abroad, along with mediation on the labor market in the EU area for Romanians who wish to work on the territory of another European state by ÁNFOM (EURES services), is becoming an increasingly used way for Romanians to migrate for work purposes. EURES is the cooperation network between European public employment services and other partners involved in the labor market (trade unions and employers' organizations), coordinated by the European Commission and aiming to facilitate the free movement of workers within the European Economic Area (EEA) and Switzerland. EURES Advisers constitute the human component of the network, and the European EURES job portal the technical one, but both aim to ensure transparency of information on job vacancies as well as working and living conditions in the EEA states.

The National Employment Agency (ANOFM, 2010), as a public employment service, has been a member of the EURES network since 2007, being the institution responsible for recruiting and placing Romanian citizens abroad, offering information, guidance and placement services, both for employers and for job seekers interested in the European labor market.

Regarding the job vacancies received and promoted by the UNECE through the EURES network, an increasing trend is observed year after year, even in the conditions of the economic crisis and pandemic. According to ANOFM data, between 2008-2022, the Romanian labor market recorded significant fluctuations in terms of the number of job vacancies, influenced by internal and external economic factors, including the 2008 global economic crisis and the COVID-19 pandemic. In 2009, 2,122 job vacancies were registered, 35.5% more than those offered in 2008 by European employers (1,566 jobs), and in 2010, the figure reached 3,038 jobs. vacancies, 43.2% more than those available in 2009.

Evolution of the number of job vacancies from 2008 to 2022:

- 2008-2010, the global economic crisis led to a decrease in the number of job vacancies, as companies reduced their activity or implemented austerity measures.
- 2011-2019, a period of economic recovery led to a gradual increase in the number of job vacancies, reflecting a higher demand for labor in various sectors.
- 2020, the COVID-19 pandemic had a significant impact on the labor market, with many companies unwilling to reduce their activity or temporarily close, which led to a decrease in the number of job vacancies.
- 2021-2022, with the relaxation of restrictions and the resumption of economic activities, the number of job vacancies began to grow again, although with variations depending on the sector and region.

According to data from the National Institute of Statistics (INS, n.d.), in the third quarter of 2022, the number of job vacancies was 40,000, an increase of 6,000 compared to the previous quarter. Over a quarter of these vacancies were concentrated in the manufacturing industry. In the fourth quarter of 2022, the number of job vacancies decreased to 33,300, 6,700 fewer than the previous quarter.

Among the countries of destination preferred by Romanians in both 2009 and 2022 are: Spain, Italy, Germany, Denmark, Great Britain and Austria. As in 2009, in 2022, the majority of job applications in European countries targeted sectors such as: agriculture, construction, manufacturing industry, hotel industry, food industry. However, the requests of Romanians for highly qualified professions such as: engineers, IT, doctors, teachers should not be neglected.

The largest share of Romanians who want a job abroad is held by those with primary, secondary and vocational education (44.6% in 2008, 50.1% in 2009, and 47.4% in 2010, respectively), followed by those with high school and post-secondary education (38.5% in 2009, and 39.2% in 2010, respectively), and then those with university education (11.4% in 2009, and 13.4% in 2022). The ANOFM statistics thus reveal new migration trends related to the migration of highly qualified people, a phenomenon that is becoming more pronounced in the context of the economic crisis.

Romanians who want to leave the country to work in other European countries come mainly from the southern parts of the country (southeast and southwest), Brăila (981 people), Ialomița (897 people) and Dolj (706 people), registering in 2009 the most requests to work abroad, and the counties of

Harghita (51 people), Neamț (53 people) and Ilfov (62 people) the fewest. In 2022, the situation does not undergo major changes, with Dolj (1,377 people), Olt (1,214 people) and Ialomița (1,100 people) being among the counties with the most requests for work abroad, and Covașna (22 people), Harghita (39 people) and Ilfov (48 people) among the counties with the fewest requests. The geographical distribution of Romanians looking for work abroad may be influenced by the economic crisis, which has affected less developed areas to a greater extent, either by reducing domestic employment opportunities or by eliminating existing jobs. The economic crisis followed by the pandemic has made migration for work a necessity, not an alternative or option.

Both during 2009 and after 2020, a series of job fairs took place in various cities in Romania: Slobozia, Slatina, Alba-Iulia, Oltenița, Bucharest, Ploesti, Calarasi. Even in the conditions of the economic crisis, the same characteristics of the Romanian labor migration that benefited from labor market mediation services from EURES are preserved. Thus, European employers have offered jobs in agriculture and animal husbandry, forestry, tourism and hospitality, for unskilled workers or craftsmen and cleaning staff. In addition to the traditional countries interested in Romanian workers, represented by Spain and Italy, among the countries requesting labor from Romania, the Nordic countries are consolidating themselves as new countries of destination, especially targeting seasonal work, with Denmark standing out in this regard.

Analyzing the main obstacles to the mobility of Romanian workers in the European space presented in the ANOFM Reports - lack of knowledge of the foreign language of European circulation requested by the employer and insufficient information to people looking for a job in another European country about the working and living conditions in that state, we note, once again, how important skills and information are in obtaining a job abroad, in a context of crisis.

Thus, "If in the case of job offers for the agricultural sector in Spain, knowledge of the Spanish language is not required, but only work experience in the field and thus the level of employment is higher, in the case of job offers in Denmark and Italy, with slightly higher quality standards, the lack of knowledge of the English language and the Italian language at an average level influenced the result of the selections ".

5. Italy and Spain, the main destinations for Romanian migrants going to work

As can be seen in Figure 6, Romania remains the main supplier of migrant labor in the European space; data provided by Eurostat confirm that, in 2010,

the number of Romanians residing in the territory of the European Union was over 2 million people. Estimates indicate, however, that the real number of Romanians in the EU is much higher, Romanians being the largest community among inter-community migrants and the second largest, compared to third-country national migrants represented by immigrants originating from Turkey (figure 6). Over 70% of Romanians working abroad have chosen either Spain or Italy; consequently, the way in which the crisis influences the labor market in these countries takes on particular importance for the analysis of the impact of the crisis on Romanian labor migration.

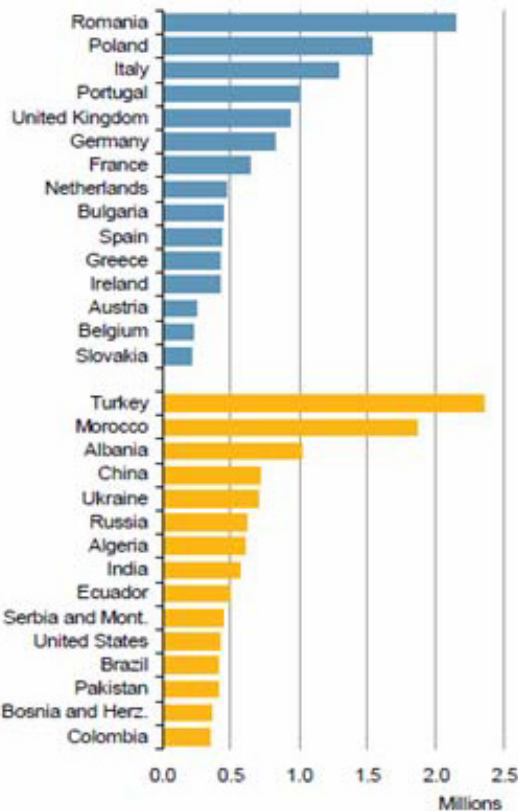


Figure 6. Citizenship of EU (blue) and non-EU (orange) migrants residing in EU-27 countries in 2022

Source: EUROSTAT

As for Spain, one of the main destination countries for Romanian migrants, the economic crisis and the pandemic were felt extremely strongly by migrants in general, and its impact on the Spanish economy was among the hardest in Europe. Thus, the number of job losses rose to 1 million in 2009, and the

unemployment rate among migrant workers was 8.7% higher, rising to 21.26% compared to 12.52% among Spaniards. In mid-2020, these figures had risen to 16% for Spaniards and 28% for foreigners. Of all immigrants, Romanians, Ecuadorians and Moroccans seem to have the highest unemployment figures. In 2009, Romanians represented the largest group of migrants in Spain (758,823 or 13.4%), followed by Moroccans (627,858 or 11.1%) and Ecuadorians (409,328 or 7.2%). The growth of the number of Romanians in Spain has been spectacular, with the Romanian population rising from 3.7% in 2001 to 13.4% in 2009. Since our country joined the EU (2007), the number of Romanians living in Spain has quadrupled.

The economic crisis does not seem to have affected the number of foreigners residing in Spain, but the number of residence permits granted to foreigners has registered a smaller increase than in previous years - 2008 and 2009. Thus, the number of residence permits increased by only 7% between 2008 and 2009, compared to 13% in previous years. Similarly, even if the number of Romanians in Spain increased more slowly in the years 2008-2010, in total, between 2007 and 2022 their number increased by approximately 2,451,609 (table 2).

The economic crisis followed by the pandemic led to a rapid rise in unemployment, and migrants were the most affected by this phenomenon. In the period 2007-2008, the number of Romanians legally resident in Spain increased significantly. According to official data, on October 1, 2007, approximately 603,889 Romanians with legal residence were registered in Spain. By the end of 2008, this figure had increased, reflecting the upward trend of Romanian migration to Spain during that period.

This growth was influenced by factors such as Romania's accession to the European Union in 2007, which facilitated labor mobility, and the high demand for workers in various sectors of the Spanish economy. In the period 2009-2010, the Romanian community in Spain continued to grow, maintaining its position as the largest foreign community in this country. According to official data, at the end of 2010, the number of Romanians residing in Spain was approximately 897,000 people. This growth was influenced by factors such as free movement within the European Union and the economic opportunities offered by the Spanish market. In the period 2021-2022, the Romanian community in Spain continued to be one of the largest communities of foreigners in this country. According to official data, at the end of 2020, the number of Romanians residing in Spain was 1,079,726 people, representing the largest community of foreigners in Spain. In 2022, the population of Spain exceeded 48 million inhabitants, mainly due to the increase in the number of resident foreigners.

Thus, the most spectacular increase in unemployment took place in the construction sector: from 69,400 unemployed, while in agriculture 34,200 unemployed and in services 156,500 unemployed in 2007 to 361,300 unemployed in 2022.

Table 2. Evolution of the number of Romanians legally resident in Spain

	2007/2008	2009/2010	2018/2019	2021/2022
Total strangers	1.977.945	3.034.326	4.144.166	4.519.554
Total Romanians	603.889	829.715	673.000	1.079.726

Source: www.ine.es

The sharpest increase occurred in 2007-2008, when the unemployment rate among Romanian workers doubled, as did other migrant groups. After that, unemployment continued to rise, but the rate of increase was slower. About 90% of Romanians in Spain have bank loans for houses and/or cars there. The crisis caught most of them at the beginning of their loans, that is, after five or six years of paying off the loan. In general, the rate paid by a Romanian for an apartment in Spain is 700-1,500 euros per month, and for a car: 400-500 euros per month. The most common reasons why even those who have not lost their jobs are unable to meet their expenses are that employers do not allow them to work extra hours, they do not offer bonuses.

One of the adaptation strategies of migrants to the economic crisis followed by the pandemic and its consequences has been inter-sectoral or territorial mobility. As regards inter-sectoral mobility, the figures for 2008 and 2009 and 2019-2020 respectively, show a strong increase in the number of Romanian workers affiliated to social security employed in agriculture – their number has increased by 897,000 people. in 2008 to 627,000 people in 2022, representing a decrease of 30% compared to 2008

Following the request from the Spanish authorities of 28 July 2011, by decision of 11 August 2011, the European Commission authorises Spain to impose temporary restrictions on Romanians' access to the Spanish labour market until 31 December 2012. These restrictions will apply to activities in all sectors and regions. However, the restrictions do not affect Romanian citizens who are already active in the Spanish labor market.

There are voices that claim that, in fact, the restrictions will affect many more Romanians than those who have not come to work in Spain. For example, the Federation of Romanian Associations in Europe (FADERE) states that all Romanians in Spain who are not registered in the labor registers will be affected by the restrictions introduced by the Madrid government.

As for Italy, for the first time in the last 20 years, the number of Romanians in this country has registered a slight decrease, settling just under 900,000. More precisely, the latest statistical data from 2010 mentioned that 887,763 Romanians officially lived in Italy, although the estimate of the real number of Romanians on Italian territory is around 1 million people. Thus, Romanians remain in first place in the ranking of foreign communities present in Italy, followed at a great distance by Albanians and Moroccans, who together number approximately 450,000 representatives.

Immigration dynamics in Italy have remained relatively unaffected by the economic crisis. Although the net migration rate decreased by 21% in the first nine months of 2009, compared to the same period of the previous year, the number of foreign citizens in Italy increased during the pandemic period between 2020-2022, Italy has recorded significant fluctuations in immigration dynamics, influenced by factors such as the COVID-19 pandemic and global geopolitical situations. In 2020, Italy registered 248,070 immigrants and 160,579 emigrants, resulting in a positive migration balance of 87,491 people, in 2021, the number of immigrants was 247,516, while 137,458 people emigrated, the migration balance increasing to 110,058. The most significant increase was recorded in 2022 from 345,716 people, with 141,028 emigrants, which led to a positive migration balance of 204,688.

These data indicate an increase in migrant flows in 2022, after a period of decline in previous years, possibly influenced by the relaxation of pandemic restrictions and international economic and political developments. Nevertheless, the transformations recorded by the labor market have been quite profound. The gap between the unemployment rate among native and foreign workers increased from the second half of 2008 to 2009, while remaining lower than in other EU states. In the first half of 2009, the unemployment rate among migrant workers reached a historic high of 10%. As in Spain, migrant women were less affected by unemployment than men, which is a consequence of the concentration of women in economic sectors less sensitive to economic fluctuations.

As in Spain, migrants were more affected by unemployment than native workers. However, the impact on wages was lower than in other European countries. A possible explanation could be the lower concentration of migrants in sectors of activity that employ unskilled labor – while in Spain or Greece almost 1 in 3 migrant workers worked in such sectors, in Italy their proportion was much lower.

Another possible explanation for the less severe effects of the crisis could be the large number of companies registered by migrants, including during the crisis. Thus, in 2009, 15% more companies owned by Romanian citizens were registered compared to 2022, reaching a total of 32,452.

Although the unemployment rate has increased, as I have shown above, the number of Romanians employed in Italy has increased significantly during the economic crisis, even more than in the years before the crisis, practically exploding in 2007, as shown in the table below. Half of them were employed in the tertiary sector (family care, hotels and restaurants), a third in construction and a fifth in agriculture. As mentioned above, it is possible that the large number of employees in the tertiary sector, less affected by the crisis, is responsible for the lower unemployment rates in Italy compared to other countries.

6. Economic impact

The ways of bringing money earned abroad into the country are diverse. There are individuals who prefer to save money there to invest it in the country and there are others who either purchase durable goods directly from abroad or choose to send money home more frequently. Thus, it is impossible to estimate the flow of income from abroad with any accuracy. However, it can be appreciated that families that have at least one member working abroad have received and are still receiving money from abroad.

Over 5% of the households in question at the national level currently have at least one member working abroad (Table 3).

Table 3. Households with members working abroad or with former members sending packages/money back to the country, (%)

	% of households
Households with one member gone abroad for work	3.9
Households with 2 or more members gone abroad for work	1.4
Households with former household members gone abroad who send money or packages	2.1

6.1. Evolution of remittances during the economic crisis

According to World Bank data, remittances have been on a downward trend since the second half of 2008, after having grown substantially in the period 2007-2008, but exceeding World Bank estimates and reaching USD 328 billion globally - 15% more than in 2007. The level of remittances has remained relatively stable in the EU, with significant variations from country to country. As for Spain and Italy, the two top destinations for Romanian migrants, the IOM report records a 9% decrease in Spain in the period June - September 2009 compared to the same period in 2008, and for Italy, of 7.4% in the first three months of 2009 compared to the same period in 2008. During the COVID-19

pandemic crisis, remittances sent by migrants to their countries of origin have registered significant fluctuations, influenced by economic and social factors.

Globally, in 2020, remittances decreased by approximately 1.6% compared to the previous year, reaching 702 billion euros. This decrease was mainly attributed to the economic recession and financial uncertainty generated by the pandemic. However, in 2021, remittances recorded a significant increase, reaching 773 billion euros, which represents an increase of 10.2% compared to the previous year. This recovery was supported by the global economic recovery and the adaptation of migrants to the new economic conditions. As for Romania, remittances have had a similar evolution. In 2020, they decreased by 0.9% compared to the previous year, totaling 6.8 billion euros. However, in 2021, remittances increased by 8.3%, reaching 7.4 billion euros. This dynamics of remittances reflects the adaptability of migrants and their economies to the challenges imposed by the pandemic, as well as the importance of these financial flows in supporting the economies of beneficiary countries.

6.2. Investments made with income from international migration

It is important to follow the evolution of the resources brought to the country during so many years of international migration and not only to analyze the possible sources of income. Thus, the direct impact of external migration can be easily monitored if we follow the investments made with the money coming from Romanian emigrants. It can also be followed the extent to which households have invested in income-generating activities or in long-lasting goods.

In the last 5 years, 50% of Romanians have invested in household appliances, 37% have chosen to expand or modernize their home and 16% have purchased cars. Regardless of the investment chosen, 10% of the above-mentioned investments were made with income from international migration. Over 50% of those who used money from external migration have chosen to expand or modernize their home, 21% have bought one or more cars, and the rest have bought household appliances.

The analyzed sample refers to the counties of Teleorman and Vrancea. Due to this clear delimitation, we are able to differentiate the consumption of individuals depending on the residential environment (even if the urban environment is represented only by individuals living in cities of up to 200,000 inhabitants). The data in Table 4 allow us to draw a series of conclusions. Thus, among those who have used money from migration in the last 5 years to purchase goods or make other investments, 72% from rural areas and 84% from urban areas have bought/built homes or expanded or modernized their existing homes.

About 30% of respondents have chosen to buy a car. As for productive activities, we observe the existence of clear differences between the strategies of individuals from urban areas and those from rural areas. Those from rural areas invest money especially in agriculture, those from urban areas are interested in investing in other types of businesses.

If we were to compare the two microregions (Alexandria and Focșani), we observe that in Focșani the percentage of households with migration experience who have made investments in the last five years with money from abroad is much higher than in the Alexandria area – 62% compared to 35%. Thus, even if in Teleorman the percentage of those who have expanded or modernized their homes is higher than in Vrancea, in the Focșani area individuals have built homes, bought land, invested in cars or household appliances, to a much greater extent.

Table 4. Percentage of those who have invested in different goods, in the total of those who have invested with income from external migration, by means

	Rural environment	Urban environment
Purchased a home	11	17
Built a home	27	13
Extended/modernized a home	59	76
Purchased a motorhome	28	37
Purchased land for building houses	8	4
Purchased land for agriculture	14	1
Farmland maintenance	43	2
Purchased agricultural machinery	5	0
Opening a business	2	12
Purchased home appliances	69	74
Tourism	11	26
Purchased a computer	13	24

Source: LTS survey, regional sample

Moving abroad had a greater impact on the consumption of durable goods than the data above suggests. Among respondents whose households have members who have moved abroad after 1989, over 22% stated that someone's migration abroad led to changes in their housing and 31% that the experience abroad led to changes in the goods purchased in general. We observe that of those who declared that going abroad brought changes to their home, only 38% modified their home (buying/building a home or expanding/modernizing) with money from abroad, 32% with money from the country and 29% did not bring any changes at all, a fact that supports the idea that migration did not bring changes

to lifestyle only through money from working abroad, but also through changes in values, expectations, and needs.

The above data show us that individuals who go abroad buy more durable goods for comfort (cars, household appliances) and less goods that can be used in productive activities. We wonder, however, whether the tendency to invest in such goods is only a characteristic of migrants or does it appear to the same extent in other individuals with similar socio-economic characteristics (education, income, residential environment, etc.).

7. Conclusions

Labor migration is a complex phenomenon, with profound implications for the economy, society and demography of Romania. The choice of this bachelor's thesis topic is justified by the need for a detailed analysis of the factors that determine migration, the effects on the labor market and the long-term impact on the country's development.

Studying this topic provides a better understanding of the social and economic dynamics in contemporary Romania, helping to identify the main challenges generated by the labor exodus. On the one hand, remittances sent by emigrants represent an essential financial support for families left behind in the country. On the other hand, the loss of the active labor force affects economic productivity, the pension system and the demographic balance.

This paper aims not only to analyse the impact of this phenomenon, but also to propose viable solutions for managing migration, attracting the labor force back to the country and adapting public policies to the new economic realities. Thus, the study will contribute to a better understanding of the phenomenon and to the elaboration of a sustainable development strategy for Romania. Migration has existed since ancient times; however, it has registered different intensities from one historical stage to another and developed new forms. In the European Union, the free movement of workers was one of the first rights recognized by citizens through community legislation. The European Union was founded on a philosophy of the free movement of citizens. However, the Member States of the European Union have faced specific situations with regard to migration, adopting different positions and policies regarding the migration phenomenon.

As a result, in the European Union, the establishment of a common migration policy remains an ambitious objective. It is very likely, however, that the demographic decline in the European Union, the consequences of which will worsen in the future, will change the attitude towards migration in the Member States. The link between demographic change and migration policies will be an important issue in the near future.

Economic migration plays an important role in meeting the needs of the European labour market. In addition, developed regions of the world compete in attracting immigrants to meet their economic needs. For these reasons, there is a need for an economic migration policy in the European Union. A common management of economic migration and the harmonisation of migration policies of the Member States represent one of the most important challenges of migration in the European Union.

In general, the country of origin has benefited from these international emigrations, as the economic situation has improved due to the income sent from abroad and invested in the country. However, the departure of parents to work abroad has a series of negative effects on children in particular and on the family and its functionality in general. Children left in the country become vulnerable to abuse, exploitation through work, their performance at school decreases, culminating in an increase in the school dropout rate at ever younger ages. In addition to legal migration, there is also a strong migratory movement for uncontrolled work, neither in the country of departure (Romania) nor in the country of destination. A large part of these people work temporarily, for an indefinite period, most often without legal forms of work, on the underground labor market in the countries of destination. Companies agree to this form of employment because the wage costs are lower, and the contribution of these workers to increasing the competitiveness of the company is significant.

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POWERING ENERGY SECURITY: THE ESSENTIAL ROLES OF GREEN FINANCE AND ARTIFICIAL INTELLIGENCE

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Abstract: *A thorough examination of the essential roles of green finance (GF) and artificial intelligence (AI) is crucial for enhancing energy security (ES). By utilising the TVP-VAR-SV framework, the paper reveals the dynamic interactions among the index of GF, AI, and ES, under the influence of the World Uncertainty Index (WUI). Our findings indicate that in the initial phase, GF has a detrimental influence on ES, but this impact reverses to become beneficial in the subsequent second and third stages, highlighting a notable lag in its positive impact. Similarly, AI's influence on ES starts off negatively in the early and second stages before turning positive in the third stage, with an even more pronounced delay in its positive impact. GF consistently demonstrates a positive and promotional effect on AI. Conversely, AI's influence on GF is positive in the first phase but becomes more complex, with alternating positive and negative influences in the subsequent stages. Furthermore, WUI exhibits both positive and negative effects on ES, affirming its validity as a control variable to some extent. Against the backdrop of growing uncertainties in the global energy landscape, this study proposes strategic pathways to enhance the role of GF and AI in strengthening ES.*

Keywords: *energy security, green finance, artificial intelligence, time-dependent*

1. Introduction

This article attempts to study the nexus of green finance, artificial intelligence, and energy security. In this context, ES refers to the assurance of stable, reliable, and unbroken energy supply to meet societal needs while mitigating risks and uncertainties associated with the energy markets (Lee and Fang, 2025;

Usman et al., 2025). Energy insecurity arises from a variety of drivers. Political and geopolitical factors include instability in governance, conflicts between energy-exporting nations, and strategic manipulation. Economic influences such as global economic shifts and fluctuations in the business cycle also contribute significantly (Khan, 2025). Moreover, technological advancements and the transition to new energy sources, particularly renewables and energy storage systems, lay a key role (Bashir et al., 2025; Kim et al., 2025). Natural events like disasters, climate change, and pandemics further compound energy insecurity (Shupler et al., 2021). The new and powerful way to move forward with ES is by means of GF, a revolutionary financial concept that includes green development as an integral part of the financial activities. First of all, GF is able to attract investors to finance projects in the energy field by means of issuing relevant bonds and funds, such as the green bonds of the China Development Bank, which had targeted the financing of renewable energy and energy-saving projects, as pointed out by Shi and Zhao (2023). Secondly, a range of financial instruments offered by GF, including green credits and bonds, significantly accelerates progress in energy technology, enabling energy enterprises to secure essential funding for innovation (Iqbal et al., 2025). Thirdly, GF facilitates the green transformation of the energy sector by financing the green development of energy initiatives (Zhang et al., 2025). It encompasses supporting projects related to clean energy, implementing strategies for emission reduction and energy conservation, as well as initiating programs that are aimed at improving energy efficiency (Wang and Xu, 2025; Zhang and Sun, 2025). Accordingly, GF can act as a powerful instrument in advancing ES.

Moreover, AI, including machine learning, deep learning, natural language processing, and computer vision, serves as a powerful tool to enhance ES. The International Energy Agency published a report entitled *Digitalization and Energy*, which notes that as AI technologies are widely embraced, it is likely to decrease the production cost of oil and gas by 10% to 20%, as cited by Mohammadi and Sohn (2023), Abadi et al. (2025), and Baseer et al. (2025). Furthermore, it is expected to diminish the rates of wind and solar power generation curtailment from 7% to 1.6%. The United States Department of Energy's ARPA-E division has introduced a strategic plan that emphasizes the utilization of smart design principles for enhancing energy efficiency, reducing emissions, and achieving significant technological advancements. In parallel, ExxonMobil, a prominent international oil and gas corporation, leverages AI to enhance the productivity and success rates of its drilling activities. China's Alibaba has taken a leading role in the growing digital energy field, concentrating efforts on site energy management, designing energy solutions tailored for data centers, advancing the development of intelligent photovoltaic

systems, and providing power solutions for electric vehicles and modules are among the objectives. To date, Alibaba has delivered digital services to more than 200 power utilities, collaborated with 25 oil and gas companies, and served 20 mining enterprises, while also establishing partnerships with 16 key players in the energy sector. Thus, it's clear that GF and AI are deeply connected to ES, a vital but under-researched subject. Also, the current studies have not sufficiently explored the dynamic interplay between these three elements, which constitutes the main emphasis of our article's investigation and discourse.

This paper shows three key innovations. Firstly, existing research has mainly focused on isolated relations among GF, energy, AI, and combinations of these factors, neglecting a holistic, global perspective that encompasses all three simultaneously. Accordingly, this research offers a pioneering examination of the complex relationships among GF, AI and ES. Secondly, much of the current research on ES primarily relies on theoretical evaluations and focuses on energy costs and consumption, yet lacks comprehensive empirical data. Thereupon, our study introduces a novel methodology by employing Google Trends data as a precise indicator to gauge the prevalent state of ES. Furthermore, we make a significant contribution by introducing the S&P Green Bond U.S. Dollar Select and the S&P Kensho New Economy RAIC indices as measurements to evaluate developments in GF and AI. Thirdly, the intricate interplay between them evolves, which has been overlooked in previous studies. This study addresses a significant gap in the literature by employing parameter estimation combined with MCMC to assess the viability of constructing a TVP-VAR-SV model. The application of this methodology enables a more profound understanding of the intricate relationships among GF, AI and ES, thus adding considerable value to the field.

2. Literature Review

2.1. The relation between GF and energy

The existing research has delved into the relation between GF and energy. Madaleno et al. (2022) present the three faces of GF: financing environmental conservation, supporting green technologies, and fostering the development of renewable energy in order to pursue ES. On the other hand, Nepal et al. (2024) go on to offer that GF is able to effectively enhance China's energy resilience, with particular importance for eastern and western regions in helping industrial transformation so as to develop other economic and social dimensions of ES. Liu et al. (2023) give an indication of the vital role that GF plays in furthering sustainable energy growth, particularly in wind and solar energy. Shi and Zhao (2023) even show some striking results of a dynamic relationship between

GF development and energy security; with one unit rise in GF, there is an initial negative response of ES, followed by a turn for the positive. Variance decomposition results indicate that the trend for the initial shock of GF on ES keeps on increasing with time. According to Bhattacharyya (2023), in the transition from a carbon-intensive, fossil fuel-based system to a sustainable, low-carbon system, much financial supply is needed. The classification framework of GF may act as guiding principles for investors. Finally, this work shows that energy insecurity is an issue which underlines its interaction with GF and ES dynamics, manifestation of the associated uncertainties and risks in supply and demand for energy. According to Lee and Fang (2025), GF exerts a significantly positive effect on the ES of the recipient countries. It especially exerts its impact on the reinforcement of ES more in low-income countries, while in high-income countries, it is not significant. Liu et al. (2025) have cited that GF is a game-changing step toward ES, in those countries or regions where energy transition and economic growth are more profound. Meanwhile, Wang and Xu (2025) emphasize that GF offers robust support for enhancing ES in China.

2.2. The relation between AI and energy

Scholars have increasingly concentrated their investigations on examining the connections between AI and energy systems. Ghenai et al. (2022) underscore the growing integration of digitalization and interconnectedness in the global energy sector, fueled by advancements in digital technologies like AI. This digitization allows for the implementation of advanced technologies and strategies, significantly enhancing ES. Yu et al. (2022) emphasize the transformative impact of energy digital twin technology on the process and energy industries, leading to improvements in energy management, service and maintenance, energy-efficient designs, and infrastructure upgrades, while also facilitating seamless integration with local and regional renewable energy resources. Arowoia et al. (2024) find that various algorithms, including AI and ANNs, are utilized to forecast energy consumption in buildings. According to Huang and Lin (2023), digitalization can markedly lower the carbon intensity of power generation, primarily through energy mix optimization, with this effect strengthening as renewable energy capacity grows. Lu and Li (2024) emphasize that the degree of AI innovation is positively associated with the enhancement of overall energy efficiency, where larger-scale innovations yield more substantial benefits. Additionally, AI innovation strengthens ES by reinforcing environmental accountability and upgrading internal governance systems. Qin et al. (2024) reveal that AI exerts dual effects on renewable energy: while its positive impacts promote renewable adoption, they are unsustainable

long-term due to the cost advantage of non-renewables. Meanwhile, Choi et al. (2024) highlight four key factors influencing AI-driven energy use: energy mix, network infrastructure, trading markets, and industrial structure shifts. Zhao et al. (2025) emphasise that enhancements in ES facilitated by AI are mainly due to improvements in the efficiency of coal and electricity usage. Zhai et al. (2025) find that AI can successfully address inefficient investments in energy enterprises, leading to improved ES.

2.3. The relation between GF and AI

In investigating the relation between GF and AI, Liu et al. (2023) confirm that GF functions as a promoter for developments in green technology innovations, which in turn indirectly promotes AI. Xiong and Dai (2023) show that green finance (GF) promotes environmental improvement by advancing AI, where non-state-owned enterprises act as key intermediaries. Zhang et al. (2022) note that lagging technological innovation can restrict the financial sector's ability to offer diverse energy-saving products, thereby hindering GF development. Nonetheless, as AI advancements reach a more advanced stage, both consumers and businesses would have access to diverse energy-consuming products and innovative machine utilization pathways, which can subsequently stimulate the expansion of GF. Zeng et al. (2024) determine that the beneficial effects of GF on AI are particularly pronounced in eastern and central urban areas, in cities that do not depend on natural resources, in cities with populations under 5 million, and in cities that have relatively modest levels of AI development. Research by Zhou et al. (2025) shows that the issuance of green bonds enhances intelligent manufacturing by an average margin of 1.22%, with green innovation serving as the mechanism through which this impact is achieved. Kuang et al. (2024) indicate that industrial AI promotes the growth of GF in particular segments of the data distribution across various economies. A study by Nepal et al. (2025) reveals that innovations in AI technology propel the development of advancements in GF.

3. Methodology

The TVP-VAR-SV model, as described by Dong et al. (2024), integrates features of Time-Varying Parameters, Vector Autoregression, and Stochastic Volatility. A key characteristic of this framework is its time-varying parameters, which enhance its flexibility in reflecting dynamic changes within economic systems. Due to the nature of dynamic relations among economic variables including green finance, artificial intelligence, energy security, and world uncertainty index, this model would be able to capture their time variation with more accuracy by virtue of the time-varying attribute; such was also asserted by

Zhong et al. (2023). VAR accounts for interrelations between different economic variables. Variables in an economic system are usually interdependent; changes in one variable may lead to changes in the other. The VAR aspect allows for the consideration of all the interactions within the variables in a wide scope, hence arriving at more realistic predictions and analyses, according to Qin et al. (2023). Thirdly, the SV component incorporates the random fluctuations that variables generally take in economics. The variability in most economic systems has to take stochastic variations in light of stochastic influences of many stochastic factors. In that perspective, Sevillano et al. (2024) argued that the salient features of the TVP-VAR-SV model will be able to represent those random fluctuations. In a word, TVP-VAR-SV considers both dynamic changes in all aspects of the economic system and inner uncertainty simultaneously; it has excellent practical value in economic analysis and forecast.

The TVP-VAR-SV model is formulated as follows:

$$Z_t = Y_t' \beta_t + A_t^{-1} \sum_t \varepsilon_t \quad t = w + 1, \dots, W \quad (1)$$

In this context, drawing upon Primiceri's (2005) framework, the TVP-VAR-SV is formulated in such a manner that specific components, β_t , A_t and $\sum_t$ denoted by specific symbols, exhibit time-varying property. The dynamic parameters in the TVP-VAR-SV model could be written as:

$$\begin{aligned} \beta_t &= \beta_{t-1} + u_t \\ a_t &= a_{t-1} + \mu_t \\ h_t &= h_{t-1} + v_t \end{aligned} \quad \begin{pmatrix} \varepsilon_t \\ u_t \\ \mu_t \\ v_t \end{pmatrix} \sim N \left(0, \begin{pmatrix} I & 0 & 0 & 0 \\ 0 & \Sigma_\beta & 0 & 0 \\ 0 & 0 & \Sigma_a & 0 \\ 0 & 0 & 0 & \Sigma_h \end{pmatrix} \right) \quad (2)$$

where $\beta_{w+1} \sim N(u_0, \Sigma_{\beta_0})$, $a_{w+1} \sim N(\mu_0, \Sigma_{a_0})$ and $h_{w+1} \sim N(v_0, \Sigma_{h_0})$. Z_t in the

Equation (2) would be further rewritten as $Z_t = (GF_t, AI_t, ES_t, WUI_t)'$.

Moreover, the study implements the Markov Chain Monte Carlo (MCMC) method within a Bayesian statistical paradigm to perform quantitative assessments, which enables the extraction of conclusions that are both more resilient and precise, as detailed by Zhu et al. (2024). This methodological approach is employed to mitigate errors stemming from the instability of initial values, as advocated by Ha et al. (2024).

Furthermore, Gibbs sampling from an MCMC framework has been utilized during this study for the purpose of accurate estimation. We calculate the dynamic impulse responses to GF, AI, ES, and WUI. In doing so, it adopts two methods: the local projection approach proposed by Canova and Gambetti

in 2009, and another approach called generalized impulse response function technique developed by Nakajima et al. (2011). Since most literature compares the impact magnitude by applying the generalized impulse response function method, which is supposed to mitigate estimation biases, such as Qiao et al. (2023), Maghyreh et al. (2024), Rodriguez et al. (2024), and Choi and Hadad (2025), this paper follows suit and applies it to derive the time-varying impulse responses of GF, AI, ES, and WUI.

4. Data

In this paper, monthly data from January 2015 to December 2024 is employed in considering the changing relationships among GF, AI, and ES. Research of Global Energy Security starts in 2015 because in this year, the Global Energy Sector faced unprecedented and profound changes. On one hand, the rapid evolution of emerging energy technologies, including renewable energy and shale gas, is progressively altering the conventional energy mix and presenting novel avenues for energy supply. On the other hand, shifts in the international political and economic landscape, particularly the escalation of geopolitical tensions, pose challenges to the stability of energy supply. Concurrently, the escalating issue of global climate change, coupled with heightened environmental awareness, has prompted heightened focus on the safe, clean, and sustainable utilization of energy. Consequently, since 2015, the investigation of global energy security has assumed paramount importance, aimed at delving into the challenges and opportunities associated with energy security and providing a scientific rationale for formulating effective energy policies and strategies. In this study, we select Google Trends as the primary data source, with its reference value being manifested in the global search volume for the keyword “energy security”. A higher ES score indicates a greater risk to energy security, while a lower score means better security.

Amid the current wave of technological transformation, GF and AI have become central drivers in advancing ES. In this study, the Global Green Bond Index, sourced from S&P Global, serves as a core measure of GF development. Launched on June 17, 2019, this index employs a market capitalization-weighted methodology and comprises 502 USD-denominated constituent securities. Data prior to the launch date are based on back-tested calculations that replicate the index’s construction approach, though potential biases may exist due to historical influences on constituent selection. Nevertheless, these estimates provide a reasonable approximation of GF performance. Higher index values reflect more substantial progress in GF, while lower values suggest slower growth. To evaluate AI advancement, we use the S&P Kensho New Economy RACI, also obtained from S&P Global. This paper therefore

investigates the interrelationships among GF, AI, and ES, with their temporal trends visualized in Figure 1.

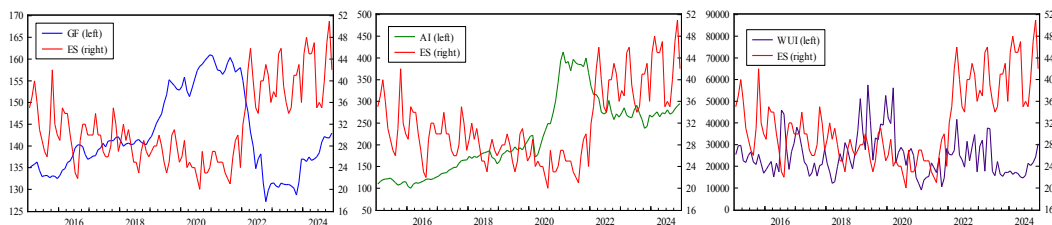


Figure 1. The trends of GF, AI, WUI, and ES

Figure 1 reveals that the dynamics of the interactions between GF, AI, ES, and WUI possess complexities that may be difficult for standard analytical techniques to fully comprehend. Consequently, conventional approaches like SVAR and VAR are inadequate for capturing such dynamically evolving relationships, making the TVP-VAR-SV model better suited for quantitative analysis. Moreover, the strong correlation between WUI and factors like GF, AI, and ES means that any fluctuations in WUI significantly affect their interconnectedness. Therefore, we have incorporated WUI data as a control variable in our analysis. By scrutinizing the evolving impulse responses of GF, AI, and ES, while accounting for the influence of WUI, we can gain deeper insights into the time-varying relationships among GF, AI, and ES.

Table 1. Descriptive statistics for GF, AI, WUI, and ES

	GF	AI	WUI	ES
Observations	120	120	120	120
Mean	142.565	219.586	24947.01	31.775
Median	140.362	196.063	22394.10	30.000
Maximum	160.954	413.990	57518.00	51.000
Minimum	127.130	100.011	9050.300	20.000
Standard Deviation	9.401	85.696	9540.084	7.119
Skewness	0.567	0.480	1.190	0.667
Kurtosis	2.078	2.266	4.469	2.579
Jarque-Bera	10.667 ***	7.298 **	39.109 ***	9.797 ***
Probability	0.005	0.026	0.000	0.007

Table 1 presents the descriptive statistics of the variables, with mean values of 142.565, 219.586, 24947.01, and 31.775, indicating that the observations are generally clustered around these central tendencies. Nevertheless, the considerable spread between the maximum and minimum values reflects substantial fluctuations over time. The Jarque-Bera test results reject the normality assumption for GF, WUI, and ES at the 1% significance level, and for AI at the 5% level. To facilitate computation and reduce the influence of outliers, a natural logarithm transformation is applied. Furthermore, first-order differencing is employed for all variables to prevent spurious regression in the TVP-VAR-SV model.

5. Quantitative Discussions

To ascertain whether GF, AI, ES, and WUI possess unit roots, we utilize three distinct tests: the ADF test, the PP test, and the KPSS test. Upon reviewing the results presented in the subsequent table, we can confidently prove that these variables do not exhibit unit roots.

Table 2. Results of unit root tests

	ADF	PP	KPSS
GF	-4.559 (2) ***	-7.243 [5] ***	0.135 [6]
AI	-7.284 (1) ***	-8.672 [8] ***	0.137 [1]
WUI	-11.031 (1) ***	-15.395 [8] ***	0.051 [9]
ES	-9.428 (2) ***	-11.493 [4] ***	0.202 [10]

Employing the SIC, a lag length of 2 was determined to be optimal for the TVP-VAR-SV model incorporating GF, AI, ES, and WUI. As shown in Table 3, the mean values of the estimates fall within the 95% confidence intervals. To verify estimation reliability, we ensured that the coefficients align closely with their posterior distributions. Moreover, inefficiency factors below 100 indicate that the system generates adequately independent samples. We therefore conclude that the parameter estimates are statistically credible.

Table 3. The parameter estimated results in the TVP-VAR-SV process

Parameters	Mean	Standard Deviation	95% Confidence Interval	Geweke	Inefficiency Factors
$(\sum_{\beta})_1$	0.023	0.003	[0.018, 0.029]	0.239	5.44
$(\sum_{\beta})_2$	0.022	0.002	[0.018, 0.027]	0.522	6.59
$(\sum_a)_1$	0.093	0.054	[0.043, 0.218]	0.327	82.98

$(\sum_a)_2$	0.083	0.036	[0.042, 0.177]	0.411	71.89
$(\sum_h)_1$	0.484	0.097	[0.345, 0.722]	0.868	47.63
$(\sum_h)_2$	0.387	0.075	[0.265, 0.559]	0.757	53.77

Figure 2 offers further support for the use of the TVP-VAR-SV model that includes GF, AI, ES, and WUI. The upper section displays the sample autocorrelation function, where the red line approaches zero, indicating negligible autocorrelation across the sample period. These results confirm that the TVP-VAR-SV framework, integrating GF, AI, ES, and WUI, is both feasible and effective in representing the evolving interactions among these variables. This suitability also highlights the limitations of conventional approaches, such as VAR and SVAR models, which lack the flexibility to account for the time-varying complexity inherent in the relationships between GF, AI, ES, and WUI.

Figure 2. The sample auto-correlations, paths and posterior densities of MCMC estimated results

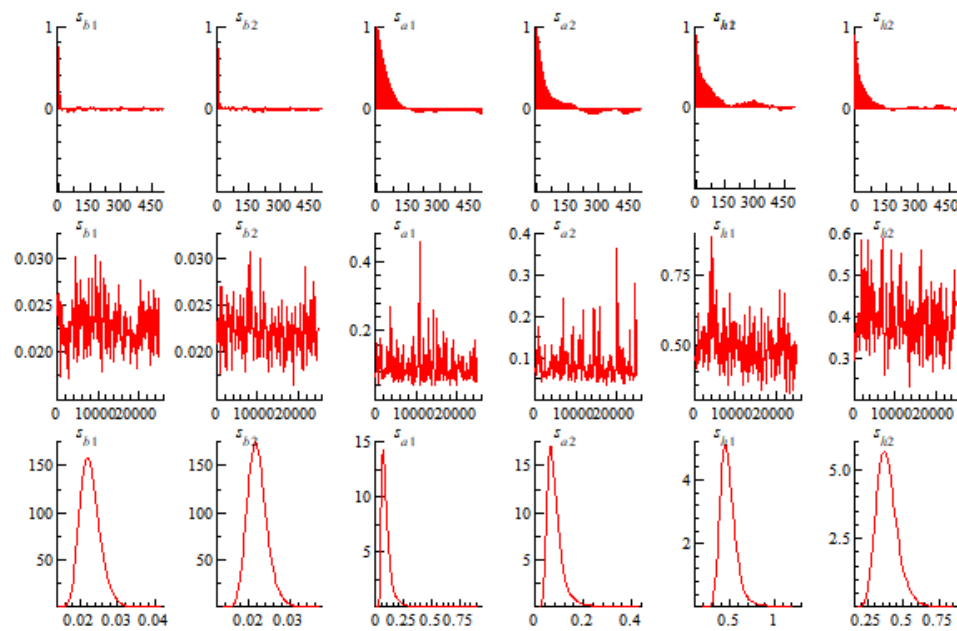


Figure 3 depicts the impulse response of GF and AI to ES. Initially, by analyzing the impact of GF on ES, several pivotal observations can be made. Specifically, in the initial phase, GF exerts a detrimental effect on ES. However, during the subsequent second and third phases, GF demonstrates a beneficial influence on ES. In the initial phase of implementing GF policy,

namely the first phase, it exerts a detrimental effect on ES. This is primarily attributed to the hurdles posed by initial investments and resource reallocations. GF frequently necessitates substantial capital infusions, potentially sourced from the reallocation or adjustment of traditional energy ventures, thereby momentarily disrupting energy supply stability. Concurrently, the extended planning and construction timeframe of GF initiatives can diminish investments in traditional energy projects, further compromising the continuity of energy supply. Furthermore, the introduction of this novel policy necessitates a period of accommodation for market entities, who may not immediately grasp or embrace the new directives. Coupled with the inherent time delays in the approval, financing, and execution of GF projects, these factors collectively contribute to a delayed manifestation of policy efficacy.

Nonetheless, as the GF policy is implemented progressively-that is, entering the second and third stages-its impact on ES starts to move into a positive direction. This is largely driven by the evolution of the energy mix, with more funds channeled toward clean and renewable energy projects, hence reducing dependence on fossil fuels and enhancing diversity and stability in energy supply. In the meantime, GF projects also focus on holistic energy system planning and construction, enhancing resilience and reliability in the energy infrastructure, making energy supply more responsive and adaptable. These can quickly restore energy supplies during extreme weather conditions or other unexpected situations, reducing the risk of energy disruption. In addition, in the course of the continuous promotion of the policy and the gradual digestion and absorption by the market participants, the economic and social benefits of GF projects have gradually appeared, further promoting the improvement of ES standards, industrial development, and innovation, bringing more technical support and solutions to ES.

Mainly, there are a number of factors contributing to a lagged effect of GF on ES, including a policy implementation timeline, market accommodation and adjustment process, project construction, and operational cycles. From policy formulation and introduction down to the implementation and significant accomplishment, there is a certain time required. It takes time for the market participants to learn about and accommodate new policies and further adjust their business strategies and orientation of investment. Moreover, GF projects usually involve lengthy planning and construction periods, including the approval of projects, financing, construction, commissioning, and other stages, the time lags of which will affect the appearance of policy effects. Consequently, when assessing the impact of GF policies on ES, it is imperative to comprehensively consider the inherent delays to gain a thorough and accurate understanding of policy outcomes.

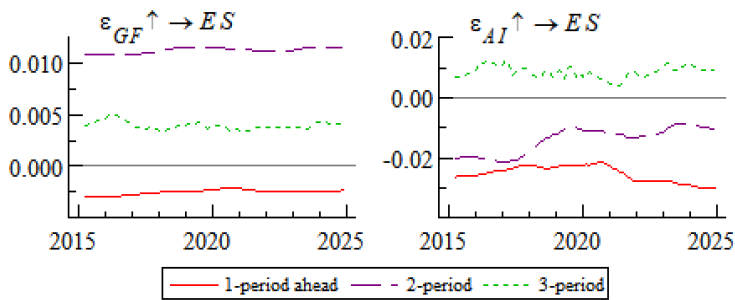


Figure 3. Impulse responses of GF and AI on ES

Next, we delve into the impact of AI on ES, particularly the underlying reasons for its transition from negative to positive. In the first and second phases, AI has a negative impact on ES, which is caused by multiple factors. On the one hand, the initial application of AI technology in the energy field indeed necessitates substantial research and development funds and technical investment. Basic algorithm explorations, model training, data processing, and many other activities require these funds. Also, technological innovations and adaptation to realize seamless integration in particular energy scenarios require funding. It is difficult to translate such high investments in the short term into enhanced ES. Instead, they could cause some type of instability or disruption in the ‘analog’ structures of energy supply and management, since resources are redistributed and/or the technology of sustainable resources is at an experimental stage and might have a negative effect on ES. On the other hand, AI technology faces a series of technical problems in their deploy ability in the energy sector. For example, there is the issue of how best to integrate AI algorithms with the operational reality of the energy systems for exacting predictions and optimal control. Then, there is the challenge of processing and analyzing massive volumes of energy data to extract valuable insights from them. Safety and reliability are also concerns to be taken seriously with the AI systems to avoid any sort of technical malfunction or security breach that could result in the disruption of energy supplies. All these challenges and issues require time and experience to get sorted out and thus can affect ES negatively during the initial phases.

In the third phase, though, the influence of AI starts getting positive on ES. This transformation is mainly caused by constant maturity and the increase in the scope of application of AI technology. While algorithms of AI technology are being continuously optimized and more training data is available, the effectiveness of AI systems in this energy sector steadily sets in. From the perspective of energy production, AI technology reveals its remarkable edge in enhancing production efficiency, perfecting energy allotment, and predicting

energy needs. Accurately forecasting energy demand, AI systems help the energy provider in planning and managing energy supply. In addition, this will also reduce the risks of wasting and shortages in energy. At the same time, AI technology optimizes energy allocation, promotes the effective use of energy, reduces energy consumption cost, hence enhancing the security and stability of the energy system.

Comparing to GF, the lagged impact of AI on ES is stronger. This may be attributed to the complex and innovative characteristics of AI technology. As an emerging field, artificial intelligence involves ongoing experimentation and iterative improvement throughout its development and deployment, requiring extended periods to substantiate its real-world effectiveness. Furthermore, the implementation of AI technology in the energy sector must consider the interplay and dynamic shifts of numerous factors, such as fluctuations in energy market prices, changes in the policy environment, and advancements in energy technology. These factors introduce complexity and uncertainty into assessing the impact of AI technology on ES.

Figure 4 demonstrates the impulse responses between GF and AI. Specifically, GF exerts a positive influence on AI, whereas AI, in turn, positively impacts GF during the initial phase. In the subsequent second and third phases, the influences of AI on GF exhibit both negative and positive dynamics. The positive influence of GF on AI constitutes a multi-faceted and deeply ingrained process, manifesting in the following dimensions: Firstly, GF offers the requisite financial backing for AI technology research and development. By funneling investments into eco-friendly, low-carbon, and sustainable ventures, GF not only fosters rapid advancements in these domains but also assures ample financial security for the research, development, and innovation of AI technologies. Of the funds, support is given for AI algorithm research and development, data collection and processing, model creation, and optimization in order to accelerate the maturation of AI technologies.

The second point is that GF opens vast avenues to the deployment of AI technology: as the ethos of environmental conservation and sustainable development is deeply rooted in people's consciousness, more and more sectors are willing to apply AI technology to realize highly effective and intelligent production and management. For instance, AI technology can be used in the energy sector for the construction and management of smart grids with a view to improving energy efficiency. On the one hand, AI technologies can be applied in environmental protection for environmental monitoring and data analysis, providing a scientific basis for the promulgation of some environmental policies. On the other hand, in the field of smart city construction, AI technologies can be applied in urban traffic management, public safety surveillance, etc., to improve the quality of urban governance.

Third, GF provides policy direction and support for the innovative application of AI technology. By formulating relevant policies, the government advocates for the integration of green finance and AI technology to accelerate the formation of new economic growth poles. For instance, the government can set up special funds to support application and innovation in the field of AI technology in the GF sector. It can introduce relevant policies to encourage enterprises to use AI technology in raising production efficiency and reducing operational costs. In addition, it promotes international cooperation and enables the whole world to share and communicate AI technology.

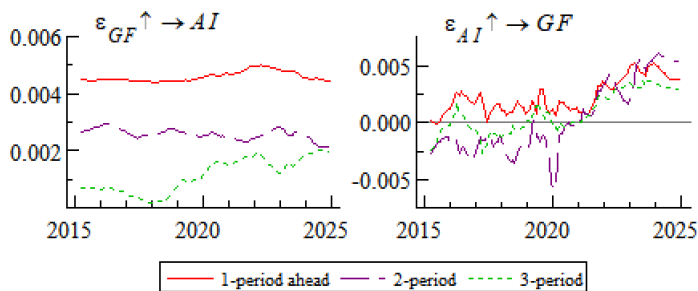


Figure 4. Impulse responses of GF and AI

Conversely, in the first phase itself, AI technology has immensely helped in increasing investments in GF projects by decreasing the associated risk in investments and allowing more accurate allocation of funds for environmental and sustainable development. Its role in the assessment and evaluation of risk has been pivotal for investors to decide wisely and limit their losses as much as possible. Besides, AI technology has innovatively diversified the varieties of green financial products. Traditional green financial products have been restricted to fixed environmental protection industries. However, this situation has changed since the development of AI technology. Using intelligent algorithms and machine learning, AI technology designs more personalized and diversified green financial products that can satisfy the market demand and different investor preferences. This approach meets various investors' needs but simultaneously creates a broader market for GF. More importantly, AI technology applied in the GF has been driving the establishment and perfection of the industry standards; with the promotion and application of AI technology, the standards for the evaluation of green finance projects and the risk management process could be further optimized and upgraded. This will be conducive to enhancing the competitiveness and influence of the whole GF industry, promoting it to develop faster and more stably.

In its second and third development stages, GF relies more strongly on AI technologies which become quite multilevel and interrelated. Along with deeper development, several risks and problems of a latent character began to show up gradually. First, such factor as data security becomes quite key. It is about a tremendous volume of environmental information, investors, and other classified details. Any leakage or misuse of these data could bring huge losses to the project and investors. In addition, privacy protection is an urgent issue to be solved. In using AI technology in data analysis, guaranteeing that personal privacy is not infringed upon has become an extremely important topic. Moreover, the algorithm bias also cannot be neglected as a risk point. If biases are already part of the design and training of AI algorithms, their predictions and decision results will be biased, too, thus bringing inequity into GF projects. On the other hand, some of the positive impacts of AI technology are gradually showing up. With the continuous maturation and refinement in technology, the application of AI in green finance has gone further and deeper. For example, AI technology can be applied to smart grid construction and management in the energy sector, which promotes energy efficiency and reduction of carbon emissions. AI can be applied to environmental protection for environmental monitoring and data analysis, providing a scientific basis for the formulation of environmental policy. In addition, in terms of urban planning and management, AI can be incorporated into urban traffic management and waste treatment to improve the level of sustainable urban development. All these applications will not only help the sustainable development of GF but also create more green well-being for society.

Figure 5 illustrates the impulse response of WUI to ES. This interplay manifests a multifaceted and dynamic influence, positively inciting advancements in technological innovation and promoting the diversification of energy sources. Conversely, it adversely impacts the potential for energy price volatility and disruptions within supply chains. The congruence of these effects with empirical observations underscores the rationale for selecting WUI as a control variable in this research endeavor.

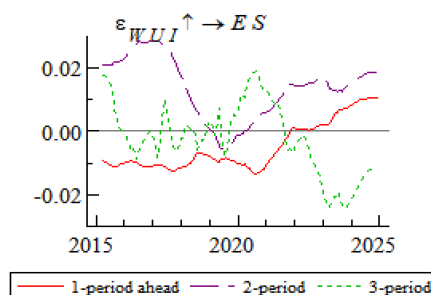


Figure 5. Impulse responses of WUI on ES

6. Conclusion

Utilizing a methodology that incorporates the GF, AI, ES, and WUI, we can obtain estimated coefficient values, autocorrelation samples, trajectories, and posterior probability densities for the TVP-VAR-SV model. This technique enables us to accurately capture the evolving relations among the chosen indicators, thereby delving into the intricate dynamics between GF, AI, and ES. We find that in the initial stage, GF has a negative impact on ES, but in the second and third stages, it turns into a positive impact, showing the lag of its impact. The influence of AI on ES is negative in the early stage and the second stage, and it turns positive until the third stage, and the lag of its influence is more obvious. GF has shown a continuous positive promoting effect on AI. However, the influence of AI on GF is positive in the first phase, and showed a complex situation of interweaving positive and negative influences after entering the second and third phases. In addition, WUI has both positive and negative effects on ES, which verifies its rationality as a control variable to a certain extent. Through a detailed analysis of the dynamic relationships among GF, AI and ES, this study concludes that both GF and AI contribute positively to ES, although their influences exhibit inherent time lags.

Following the aforementioned conclusions, a set of policy recommendations are put forth to safeguard energy security. Firstly, the government ought to augment its policy support and financial allocations for green finance, encompassing but not limited to the provision of incentives such as tax reliefs, subsidy schemes, and the establishment of dedicated funds. These measures are aimed at encouraging a greater influx of social capital towards green energy initiatives. This strategy will not only expedite the development and deployment of green energy technologies but also foster the construction of clean energy infrastructure, thereby laying a solid foundation for sustainable development. Meanwhile, it is necessary to establish and improve the green financial supervisory mechanism. Based on the formulation of environmental impact assessment standards and disclosure methods for publicly offering information, we can ensure that every green investment yields a win-win result in environmental and economic benefits while ensuring appropriate fund use and smooth project operation.

Another key development toward a more energy-efficient future is the widespread dissemination of AI technology in the energy sector. For instance, smart grids using AI technology can adopt automatic grid scheduling, predict faults, and quickly respond to improve efficiency and stability in the energy system. In addition, AI can guarantee optimal distribution, reduce energy wastage, and balance supply and demand. In this regard, the government should further escalate support for research, development, and innovation in

AI technology, develop industry-university-research cooperation, cultivate professionals, and actively promote the application of new AI technologies in energy security continuously. This includes the forecast of energy demand by big data analysis and the optimization of energy production strategies through machine learning.

Finally, the government should build a comprehensive policy framework for energy that could combine green finance with artificial intelligence development to capture synergies: setting up precise targets for energy transition, developing practical implementation paths and roadmaps, setting up crossdepartmental coordination mechanisms to ensure a coherent and efficient implementation of varied policies. The policy framework should also consider the balance between traditional and renewable energy development, ensuring the stability and security of energy supply. Strengthening international cooperation is equally important to achieve the long-term goal of energy security. In the face of global energy challenges, countries should increase experience sharing, technology exchanges, and market openness, promoting the global energy transition, addressing climate change, and achieving sustainable development goals together. This includes participation in international energy organizations, the signing of agreements on climate change, and facilitating cross-border collaboration on green energy projects to jointly build a greener, smarter, and safer global energy system.

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EDUCATIONAL MANAGEMENT AND THE PREVENTION OF EARLY SCHOOL LEAVING: EVIDENCE FROM A MULTIPLE REGRESSION ANALYSIS IN ROMANIA

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Abstract: *The study investigates the role of educational management in preventing early school leaving, with a specific focus on the contribution of digitalization in secondary education. Using a unique dataset collected from more than 1,700 respondents (students, parents, and teachers), the research applies a multiple regression model to examine the relationship between school management practices, the level of digital infrastructure, and students' intention to continue their studies. The findings indicate that managerial strategies centered on digital governance and individualized support significantly reduce the risk of dropout. Moreover, socio-economic constraints such as financial difficulties, lack of transport, and limited parental involvement are mitigated when schools provide structured remedial programs and transparent communication. The results highlight that educational leadership and investment in digital resources are decisive factors for strengthening students' attachment to school. This study contributes to the international literature by offering empirical evidence from Romania and provides policy recommendations for improving school retention through management innovation and digital transformation.*

Keywords: *educational leadership, digital governance, early school leaving, student retention, multiple regression, Romania*

JEL Classification: *I21, I28, I29, C38, C51, M10*

1. Introduction

School dropout remains one of the most persistent challenges facing contemporary education systems, with far-reaching implications for long-term economic growth and social cohesion. Globally, early school leaving is associated with lower human capital accumulation, reduced productivity, and

widening social inequalities. The United Nations Sustainable Development Goal 4 (“Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all”) emphasizes the urgency of addressing this phenomenon by 2030, yet progress has been uneven, particularly across Central and Eastern Europe.

Within the European Union, early school leaving rates have steadily declined over the past two decades, but substantial disparities remain across member states. Romania continues to report levels of around 15% in recent years, well above the EU target of less than 9%. This persistent gap is closely linked to multiple drivers, including socio-economic conditions, unequal access to educational resources, the quality of teaching practices, and the extent of institutional support provided to students at risk of dropping out.

The international literature consistently highlights the influence of family background, living standards, and territorial disparities in explaining school dropout. However, an emerging research strand underscores the importance of educational management practices and the degree of digitalization within schools. In particular, since the COVID-19 pandemic, digital governance has become a crucial factor not only for maintaining the continuity of the learning process but also for motivating students to complete their studies. Despite its relevance, this dimension remains underexplored in empirical studies focusing on Eastern Europe.

Against this backdrop, the present study aims to investigate the role of educational management and digitalization in preventing early school leaving, based on an extensive dataset covering more than 1,700 respondents (students, parents, and teachers). Using multiple regression analysis, the research tests the hypothesis that the level of digital infrastructure and managerial strategies adopted in high schools directly influence students’ intention to continue their studies. By doing so, this article contributes to the academic literature by providing empirical evidence from Romania and offering policy recommendations to strengthen student retention through innovative management and digital transformation.

2. Literature Review

School dropout is a multifaceted phenomenon shaped by socio-economic, territorial, and institutional factors. While individual characteristics explain part of the variance, research has increasingly demonstrated that early school leaving is strongly influenced by family background, school-level practices, and managerial strategies. In other words, dropout cannot be reduced to a student’s lack of motivation or ability but is embedded in the broader functioning of the education system.

One of the structural determinants frequently highlighted is physical accessibility. In a study conducted in Eritrea, Zeragaber et al. (2024) showed that greater home-to-school distance significantly increases the probability of dropout. Their findings, consistent with evidence from sub-Saharan Africa, are directly relevant to rural Romania, where distance and limited infrastructure remain significant barriers to retention. Unlike in urban areas where alternative options exist, rural contexts reveal how school management often lacks the capacity to compensate for geographic disadvantages, unless supported by broader digital or transport policies.

The economic implications of dropout have also been analyzed in depth. Using data from Ethiopia, Sileshi et al. (2024) demonstrated that school dropouts face higher risks of youth unemployment, confirming the long-term socio-economic costs of educational disengagement. Their study employed endogenous switching regression to capture causal effects, offering robust evidence that leaving school early directly affects labor market outcomes. This methodological precision strengthens the argument that dropout prevention should not be seen as an isolated educational priority, but as a strategy with direct economic returns. It also frames school management as an investment tool with long-term payoffs for society.

Territorial disparities provide another explanatory lens. Ibourk and Raoui (2025) identified ten territorial factors associated with dropout in Morocco, ranging from poverty and language barriers to preschool access and local labor market conditions. Their multivariate spatial approach confirms that dropout is cumulative and context-dependent, a conclusion highly relevant for Romania's uneven regional landscape. By showing that dropout rates cluster geographically, their findings emphasize that school-level strategies must be aligned with local contexts and supported by targeted digital initiatives that compensate for uneven access. Psychosocial dimensions are equally critical for understanding student retention. Košir et al. (2025) emphasized that gender moderates school attachment, showing that boys and girls experience dropout risk differently, often requiring differentiated interventions. Arco-Tirado et al. (2025) further demonstrated, through a pilot service-learning project, that community-based and experiential learning can strengthen student commitment to education. These contributions indicate that dropout prevention must integrate pedagogical and cultural innovations alongside structural reforms, ensuring that schools become spaces of belonging and active engagement.

A growing strand of literature focuses on educational management and innovation. Armenia et al. (2024) found that integrating a project management boardgame improved decision-making and engagement among students, while Baraibar-Diez et al. (2024) highlighted how resource availability and learning congruence directly affect outcomes. Although these studies were situated in

higher education, their implications extend to secondary schooling: management practices that stimulate active participation and provide adequate resources are more likely to enhance retention. They also underline how innovative tools can create a dynamic learning environment that counters disengagement before it culminates in dropout. From a broader managerial perspective, Berkat et al. (2025) argued that effective educational management plays a key role in enhancing students' problem-solving skills and global competitiveness. Their analysis positions management not simply as an administrative task but as a driver of competencies required in the twenty-first century. In contrast, Goel (2025) raised critical concerns regarding "theses management," warning that excessive managerial formalism in academia risks overshadowing genuine learning. Taken together, these studies demonstrate both the potential and the limitations of managerial approaches, reminding us that leadership must balance accountability with innovation.

Methodological innovation has also advanced our understanding of educational exclusion. Contreras-Villalobos et al. (2024) employed a transformative mixed-methods approach, combining statistical analysis with contextual insights, to explain dropout in Latin America. Their work exemplifies how quantitative rigor can be enriched by qualitative depth, offering a comprehensive picture of exclusionary dynamics. For the present study, which uses multiple regression on Romanian data, their methodological framework serves as an important precedent, encouraging the integration of contextual interpretation alongside econometric evidence.

In conclusion, the reviewed literature converges on three points: (1) dropout is a multifactorial and cumulative process, shaped by socio-economic, territorial, and psychosocial factors; (2) educational management and digital governance are decisive yet underexplored in the context of dropout prevention; and (3) empirical studies from Eastern Europe remain scarce, making Romania a particularly relevant case study for demonstrating how managerial strategies and digital innovation influence students' intention to continue their studies.

2.1. Challenges and limitations

Although the reviewed studies provide valuable insights into the determinants of early school leaving, several challenges and limitations emerge. A first issue concerns the geographical scope of existing research. Much of the empirical evidence originates from African and Middle Eastern contexts (Zeragaber et al., 2024; Sileshi et al., 2024; Ibourk & Raoui, 2025), while contributions from Central and Eastern Europe remain scarce. This limits the generalizability of findings to the Romanian context, where institutional legacies, cultural factors, and educational governance structures differ substantially. A second limitation relates to the fragmentation of explanatory models. Many studies tend to

emphasize a single category of determinants—territorial, socio-economic, or psychosocial—without integrating them into comprehensive frameworks. For example, Košir et al. (2025) focused primarily on gender differences, while Arco-Tirado et al. (2025) highlighted service-learning, but few studies combine these dimensions with institutional or managerial variables. As a result, the role of school leadership and digital governance often remains marginal in the analysis. Third, there are notable methodological constraints. While some studies employ sophisticated econometric techniques (e.g., Sileshi et al., 2024), others rely heavily on descriptive statistics or qualitative observations (Armenia et al., 2024; Baraibar-Diez et al., 2024). This heterogeneity makes cross-comparison difficult and creates a gap between highly technical analyses and practice-oriented recommendations. Moreover, few studies adopt mixed approaches that integrate contextual depth with quantitative rigor, despite the clear advantages highlighted by Contreras-Villalobos et al. (2024).

Another challenge lies in the underrepresentation of digitalization as a determinant of dropout. Although the COVID-19 pandemic accelerated the adoption of digital tools, most studies reviewed do not explicitly assess the extent to which digital governance or the use of educational technologies influences students' decision to remain in school. This gap is striking given that digital infrastructure and online learning platforms are increasingly integral to modern educational management.

Finally, the policy relevance of existing research is uneven. While Berkat et al. (2025) and Goel (2025) engage with management and innovation, they do so in broader higher education contexts, making their insights only partially transferable to secondary schooling. Few studies translate their findings into actionable strategies for school leaders or policymakers aiming to reduce dropout in real-world conditions.

In summary, the literature offers valuable yet partial perspectives. It is geographically skewed, fragmented in scope, uneven in methodological rigor, and underdeveloped in addressing digitalization and policy relevance. These limitations justify the present study, which seeks to fill these gaps by analyzing the relationship between educational management, digital governance, and early school leaving using robust econometric methods on Romanian data.

3. Research Methodology

3.1. Introduction to the methodology

The research methodology is grounded in the use of quantitative methods to examine the relationship between educational management, digitalization, and students' intention to continue their studies. Multiple regression analysis was selected due to its ability to isolate the effects of independent variables and

highlight the specific role of management practices and digital infrastructure in preventing early school leaving.

3.2. Data collection and sampling design

The empirical analysis relies on primary data collected through a structured questionnaire administered in Romanian high schools. A total of 1,702 respondents participated in the survey, distributed across three categories: 680 students, 873 parents, and 149 teachers. The instrument was designed to capture both subjective perceptions and objective indicators related to school management, digitalization, family background, and individual learning difficulties. The inclusion of multiple stakeholder groups provides a multidimensional view of the dropout phenomenon, allowing the model to account for interactions between students, families, and school staff.

The survey covered both urban and rural contexts, reflecting territorial disparities that are highly relevant in explaining dropout risks. Participation was voluntary and anonymous, ensuring compliance with ethical standards and reducing social desirability bias. The resulting dataset provides a comprehensive basis for econometric modeling and is sufficiently large to support the robustness of multiple regression analysis.

3.3. Variable definition and model construction

The dependent variable of the model is students' intention to continue their studies. In the survey, this construct was operationalized through questions directed at students regarding school attendance patterns and willingness to participate in remedial or extracurricular activities. For econometric purposes, the variable was recoded into a binary outcome: 1 = intention to remain in school; 0 = increased risk of dropout.

Independent variables were grouped into three major categories. Individual factors include gender, grade level, place of residence (urban/rural), and reported learning difficulties in core subjects such as mathematics, Romanian language, and science. Family factors are represented by parental constraints such as financial problems, lack of time, limited access to transport, and uncertainty about the child's educational future. School-level factors include teachers' perceptions of the proportion of students at risk of dropout, the presence of students with special educational needs, the number of beneficiaries of social scholarships, and the availability of individualized support. In addition, a digitalization index was constructed using items related to students' interest in online or technology-supported activities, together with parental and teacher perceptions of digital resources available at school. This index captures the extent to which digital infrastructure and practices contribute to students' engagement with education.

Based on these definitions, the empirical model takes the following general form:

where Y_i represents the probability that student i intends to continue schooling, β_i are the estimated coefficients, and ϵ_i is the error term.

The multiple regression model thus enables the simultaneous assessment of how personal characteristics, family background, school management practices, and digital governance affect students' educational intentions. This structure will be replicated in the Python environment, using appropriate packages for econometric estimation and model diagnostics.

Building on the literature review and the variables defined above, the present study formulates a set of hypotheses regarding the relationship between educational management, digitalization, and students' intention to continue their studies. These hypotheses reflect both structural determinants identified in prior research and the specific context of Romanian secondary education.

The first scenario assumes that digitalization acts as a direct enhancer of retention. Following evidence that digital tools and governance improve engagement and continuity, it is expected that students attending schools with higher levels of digital integration will report stronger intentions to remain in education.

H1: A higher level of school digitalization is positively associated with students' intention to continue their studies.

A second scenario emphasizes the role of school management and support systems. Transparent leadership, individualized assistance, and the provision of scholarships are expected to mitigate dropout risks even in disadvantaged contexts.

H2: Stronger school-level management practices, including individualized support and scholarships, significantly reduce the probability of early school leaving.

The third scenario focuses on family background constraints. Financial difficulties, lack of transport, and limited parental involvement are recognized barriers to retention. It is anticipated that these constraints negatively affect students' educational trajectories.

H3: Students from families facing economic and social constraints have a lower probability of intending to continue their studies. Finally, individual-level characteristics such as gender, grade level, and reported learning difficulties are expected to moderate the influence of managerial and digital factors.

H4: Individual characteristics, particularly academic difficulties, increase dropout risk but their effect is moderated by school management and digitalization.

These hypotheses guide the empirical analysis by structuring the regression model into distinct explanatory blocks: digitalization, school management, family background, and individual characteristics. Testing these scenarios through multiple regression allows us to quantify the relative contribution of each factor and to assess whether managerial and digital strategies can compensate for socio-economic disadvantages in preventing early school leaving.

3.4. Validation of the proposed model

The robustness of the proposed multiple regression model will be assessed through a series of standard econometric validation procedures. The first step concerns the statistical significance of coefficients, tested using *t-statistics* and *p-values*. Only variables with significance levels below conventional thresholds ($p < 0.05$ or $p < 0.01$) will be interpreted as having a meaningful influence on the dependent variable.

Second, the overall goodness-of-fit of the model will be measured by the adjusted R^2 statistic and the F-test for joint significance. These indicators will confirm whether the combination of independent variables adequately explains the variance in students' intention to continue their studies.

A third validation step involves testing for multicollinearity among explanatory variables. Variance Inflation Factors (VIF) will be calculated, and values exceeding the commonly accepted threshold ($VIF > 10$) will indicate redundancy, prompting adjustments to the model.

Furthermore, the model will be evaluated for heteroskedasticity and normality of residuals using Breusch-Pagan and Shapiro-Wilk tests, respectively. Where necessary, robust standard errors will be applied to correct for violations of homoscedasticity assumptions.

The computational validation will be carried out using Python libraries such as *statsmodels* and *scikit-learn*, which provide comprehensive diagnostic tools. Graphical outputs, including residual plots and predicted probability distributions, will be incorporated to illustrate the model's performance.

In the structure of the article, the tables with estimated coefficients (generated in Python) will be included in Section 4 (*Data Analysis and Results*), specifically after the regression output is presented. Figures such as residual plots, scatterplots of fitted vs. observed values, and predictive probability curves will also be placed in Section 4, directly following the corresponding interpretation paragraphs. This alignment ensures that statistical outputs are not presented in isolation, but are immediately linked to substantive educational implications.

3.5. Ethical considerations and methodological limitations

The survey respected ethical standards of educational research: participation was voluntary, responses were anonymous, and no personal identifiers were collected beyond basic demographics. Data protection complied with GDPR principles.

Methodologically, the study faces three main constraints. First, reliance on self-reported data may introduce bias. Second, the sample distribution is uneven, with more parents than teachers represented. Third, the cross-sectional design limits causal interpretations, as results reflect a single moment in time. Despite these limitations, the dataset remains sufficiently robust to support meaningful econometric analysis.

4. Data analysis and results

4.1. Introduction

This section presents empirical evidence on students' intentions to continue their studies. We proceed in three stages. First, we present descriptive statistics and exploratory plots to situate the sample and the outcome distribution. Second, we estimate a binary response model for the probability that a student expresses continuation intent. Third, we discuss predictive performance, calibration, and robustness checks.

The analysis focuses on the student sub-sample ($N = 680$) from the survey. The dependent variable, $Y_i \in \{0, 1\}$, equals 1 if the respondent declared interest in at least one school-support activity (remedial programmes, career orientation, extracurricular activities, psychological/educational counselling) and 0 otherwise; respondents who selected “Not interested” or reported frequent absenteeism were coded $Y_i = 0$. To avoid information leakage, the items used to construct Y_i are excluded from the set of covariates.

Explanatory variables capture individual and educational constraints: sex (female = 1), grade level, self-declared learning difficulties in Romanian, Mathematics, Sciences and “other domains” (binary indicators), receipt of a social scholarship (binary), and a locality proxy. We estimate a logistic regression via maximum likelihood with heteroskedasticity-consistent (HC1) standard errors. Alongside a full specification, we report a parsimonious model retaining only statistically relevant predictors. Model adequacy is assessed through AUC/ROC, Brier score, Hosmer-Lemeshow goodness-of-fit, multicollinearity diagnostics (VIF), and a decision threshold selected by the Youden criterion; we also provide average marginal effects and scenario-based predictions as robustness. The next subsection (4.2) details the regression outputs (Table 1) and interprets coefficients against the study hypotheses, accompanied by figures summarizing effect sizes and model performance.

4.2. Regression results

Table 1 reports the parsimonious logistic model (HC1 robust errors) for the probability that a student expresses intention to continue schooling. Odds ratios (OR) are shown with 95% confidence intervals. All listed predictors are statistically significant at conventional levels, while grade level and the locality proxy were discarded as non-significant in the parsimonious specification.

Table 1. Logistic regression (parsimonious), odds ratios with 95% CI (HC1)

Predictor	OR	95% CI	p-value
Female (1=Female)	1.88	[1.31, 2.70]	0.00063
Difficulty – Romanian	3.18	[1.92, 5.27]	0.000007
Difficulty – Mathematics	3.00	[1.84, 4.91]	0.000011
Difficulty – Sciences	4.24	[2.53, 7.09]	0.00000004
Difficulty – Other domain	3.29	[1.94, 5.59]	0.000010
Social scholarship (1=Yes)	1.76	[1.22, 2.54]	0.00257

Model metrics: N = 680; Pseudo-R² = 0.189; Log-Likelihood = -373.20; LLR $p < 0.001$; AUC = 0.746; Brier = 0.193; Hosmer–Lemeshow $\chi^2(8) = 7.33$, $p = 0.502$. Robust errors: HC1.

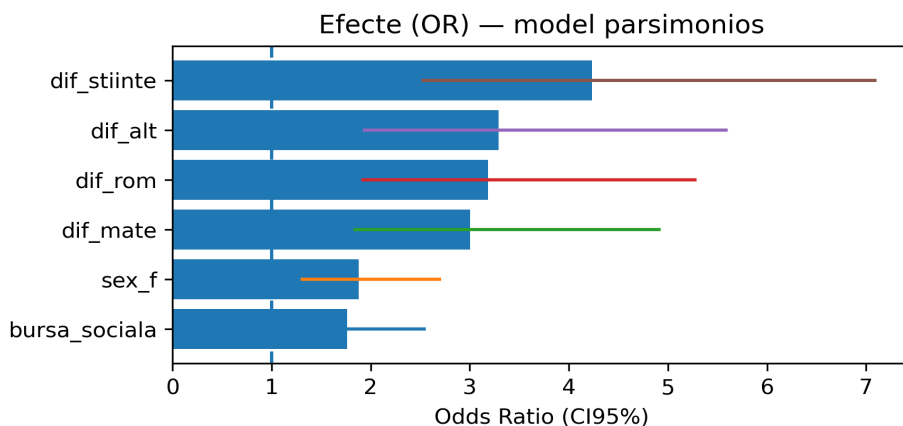


Figure 1. Effect sizes (odds ratios) - Parsimonious logistic model

Interpretation: Coefficients are positive throughout and substantively large for self-declared learning difficulties. Holding other covariates constant, students reporting difficulties in Sciences exhibit about 4.2× higher odds of continuation intent; the corresponding effects for Romanian and Mathematics are around

3.2 $\times$ and 3.0 $\times$, respectively, while the indicator for other domains is 3.3 $\times$. These patterns align with the expectation that perceived skill gaps increase the willingness to engage with school-support pathways.

Two additional socio-demographic correlates emerge. Female students show $\sim 1.9\times$ higher odds of continuation intent, consistent with gender differences frequently documented in educational engagement. Likewise, receiving a social scholarship is associated with $\sim 1.8\times$ higher odds, suggesting that targeted support may strengthen school attachment.

By contrast, grade level and the locality proxy do not contribute significantly in the presence of individual constraints; removing them yields a leaner specification without loss of fit. Predictive performance is moderate-to-good ($AUC \approx 0.75$), and calibration is adequate (Hosmer–Lemeshow $p = 0.502$). The optimal decision threshold by the Youden criterion is ≈ 0.60 ; adopting lower thresholds would increase recall for the positive class at the expense of specificity (see threshold grid in the supplementary outputs).

Robustness. Results are stable across the full and parsimonious specifications, with low multicollinearity (all $VIF < 2$, excluding the intercept) and HC1 standard errors yielding the same inference as non-robust SEs. Further checks -marginal effects and scenario-based predictions -are presented in Sections 4.3–4.4.

4.3. Distribution of predicted probabilities

We examine the empirical distribution of the model-implied probabilities and how well they align with observed outcomes. Because the positive class (continuation intent) represents 401 of 680 cases (59%), the distribution of predicted probabilities is expected to be right-shifted.

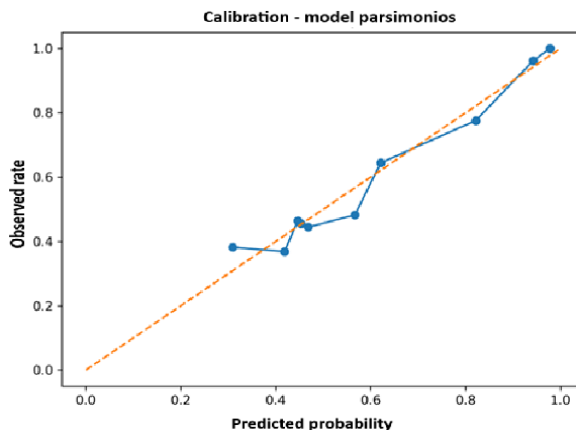


Figure 2. Calibration of predicted probabilities

The calibration curve groups predictions into ten bins and plots the mean predicted probability against the observed event rate in each bin. Points fall close to the 45-degree line, indicating adequate calibration across the probability range (Hosmer–Lemeshow $\chi^2=7.33$, $p=0.502$). The lowest deciles show slight underestimation, while probabilities above ~ 0.6 track the empirical rates closely -consistent with the model’s moderate AUC (≈ 0.746). To contextualize the base rate, we also report the outcome distribution.

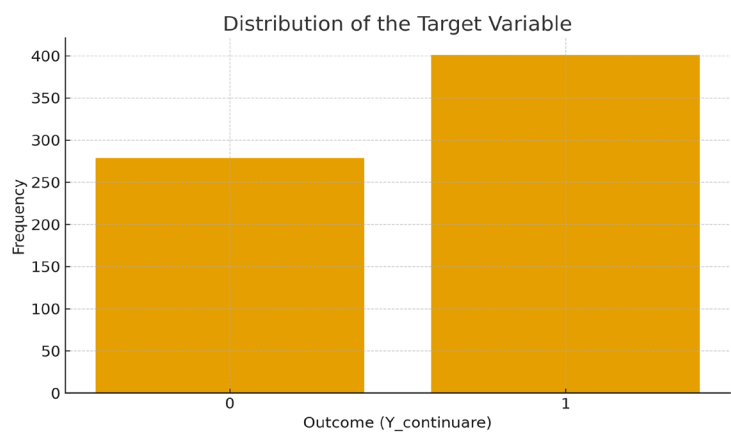


Figure 3. Distribution of the dependent variable (Y=1 vs. Y=0)

At the Youden-optimal threshold (~ 0.60), the model prioritizes specificity for the negative class while retaining reasonable precision for the positive class. Table 2 summarizes classification performance at this cut-off; these operating characteristics can be tuned (see threshold scan in the supplementary outputs) when recall for the positive class is prioritized.

Table 2. Confusion matrix at the Youden-optimal threshold (≈ 0.60)

	Predicted 0	Predicted 1
Observed 0	246 (TN)	33 (FP)
Observed 1	189 (FN)	212 (TP)

Derived metrics at this threshold. Precision (positive class) ≈ 0.865 , Recall (positive class) ≈ 0.529 , Specificity ≈ 0.882 , Accuracy ≈ 0.674 . These values reflect a trade-off consistent with the study aim: conservative identification of “no-intent” cases while keeping a high precision among those flagged as having continuation intent. In Section 4.4 we extend this view with scenario-based predictions (contrasting profiles) and robustness checks, and we present the global discrimination curve.

4.4. Scenario analysis and robustness check

We use the parsimonious logistic model to generate counterfactual predictions for meaningful student profiles. Probabilities are computed from the estimated logit: $\text{logit}(p_i) = -1.943 + 0.630 \text{Female}_i + 1.158 \text{Dif_RO}_i + 1.100 \text{Dif_MA}_i + 1.444 \text{Dif_SCI}_i + 1.191 \text{Dif_Other}_i + 0.565 \text{Scholarship}_i$, with $p_i = 1/(1 + \exp(-\text{logit}(p_i)))$;

All covariates are binary except the intercept; grade and locality were excluded as non-significant. Narratively, the baseline profile (male, no declared difficulties, no scholarship) yields a predicted probability of ≈ 0.13 . Introducing a single subject difficulty already moves the probability materially upward (e.g., Mathematics ≈ 0.30). Combining difficulties produces large shifts (e.g., female with Romanian, Mathematics, and Sciences difficulties ≈ 0.92), while scholarship and gender additively increase the probability in intermediate profiles (e.g., male with RO & MA difficulties plus scholarship ≈ 0.71 ; female with “other” difficulty and scholarship ≈ 0.61). A profile activating all difficulty indicators together with scholarship approaches certainty (≈ 0.99), consistent with the large odds ratios reported in Table 1.

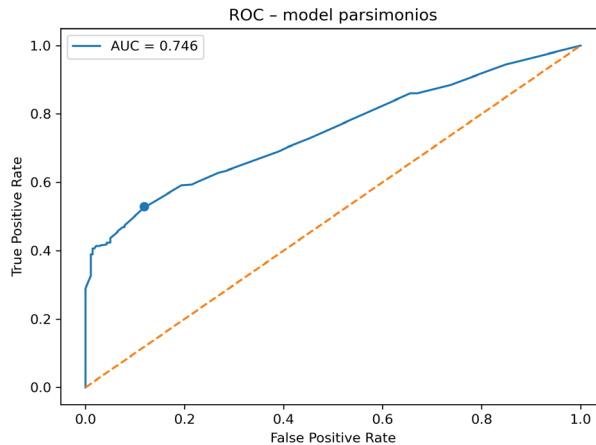


Figure 4. ROC curve for the parsimonious logistic model (N = 680). The dot marks the Youden-optimal decision threshold; AUC = 0.746

4.5. Robustness checks

- Specification stability. Results are consistent between the full and parsimonious models; signs and significance levels are unchanged, and discrimination remains AUC ≈ 0.75 .
- Multicollinearity. Variance Inflation Factors are small (all VIF < 2, intercept aside), indicating negligible collinearity.

- Calibration. The Hosmer–Lemeshow test fails to reject good fit ($\chi^2=7.33$, $p=0.502$), and the decile calibration plot (Figure 2) lies close to the 45-degree line.
- Heteroskedasticity-consistent inference. Using HC1 robust standard errors leaves coefficient significance unchanged relative to conventional SEs.
- Operating thresholds. Performance at the Youden cut-off (~ 0.60) is summarized in Table 2; lowering the threshold improves recall for $Y=1$ at the cost of specificity.

4.6. Key findings and interpretation

This study provides consistent evidence that individual learning constraints and targeted support are the main correlates of students' stated intention to continue schooling.

Summary of effects. In the parsimonious specification (Section 4.2), self-reported learning difficulties show the largest associations with continuation intent: Sciences (OR = 4.24), Romanian (OR = 3.18), Mathematics (OR = 3.00), and other domains (OR = 3.29). Two socio-demographic factors are also relevant: female students exhibit higher odds (OR = 1.88), and recipients of a social scholarship show elevated odds (OR = 1.76). Grade level and locality are not statistically different from zero once these individual constraints are controlled. Model adequacy is acceptable (AUC ≈ 0.75 ; Brier ≈ 0.19 ; Hosmer–Lemeshow $p = 0.502$), and inference is robust to HC1 standard errors and to the removal of non-significant regressors.

Implications for the hypotheses:

- H1 (learning constraints): Supported. Students acknowledging skill gaps are substantially more likely to express continuation intent -consistent with the view that perceived deficits trigger demand for remedial and supportive pathways.
- H2 (gender heterogeneity): Supported. Female students display a higher propensity to continue, aligning with widely reported gender differences in school engagement.
- H3 (material support): Supported. The positive coefficient on social scholarship suggests that targeted aid may strengthen attachment to schooling and/or reduce barriers to participation.
- H4 (structural factors such as grade/locality): Not supported in this sample. After conditioning on individual constraints, grade level and the locality proxy add no explanatory power.

Substantive interpretation. The magnitude of the “difficulty” effects implies that the same student’s probability of continuation can shift from ~ 0.13 (male, no reported difficulties, no scholarship) to >0.90 when multiple difficulties are acknowledged (scenario S4 in Section 4.4). This pattern indicates constructive demand: pupils who recognize their gaps are precisely those more inclined to pursue school-support activities. Gender and social aid effects, although smaller, point to complementary levers -motivational/engagement dynamics and resource alleviation -that may jointly shape intentions.

Practical implications: The results argue for (i) systematic screening for subject-specific difficulties; (ii) prioritization of remedial and counselling offers to students who self-report skill gaps; (iii) protection and targeting of social scholarships as a retention instrument; and (iv) threshold-based triage using predicted probabilities (with the operating point chosen according to institutional objectives -e.g., higher recall for outreach vs. higher precision for limited seats).

5. Conclusions and recommendations

5.1. Overall conclusions

The analysis of the student sub-sample ($N = 680$) shows that stated intention to continue schooling is strongly and consistently associated with self-recognized learning difficulties. Indicators for Sciences, Romanian, Mathematics and other domains carry sizeable positive effects, suggesting a form of constructive demand: the students who perceive academic gaps are precisely those most willing to engage with remedial classes, counselling, and extracurricular pathways. Two additional correlates -gender and targeted financial support -reinforce this picture. Female students exhibit a higher propensity to continue, in line with well-documented patterns of educational engagement, and recipients of social scholarships display stronger attachment to schooling, consistent with the idea that material aid alleviates frictions and signals institutional support. From a modelling standpoint, a parsimonious logistic specification with HC1 robust standard errors delivers stable inference and acceptable predictive adequacy. Discrimination is moderate-to-good (AUC around 0.75), the Brier score indicates reasonable overall accuracy, and the Hosmer–Lemeshow statistic does not reject calibration. Multicollinearity is low, and results are reproduced across the full and reduced specifications, which increases confidence that the substantive conclusions are not artefacts of overfitting or fragile controls.

5.2. Validation of research hypotheses

Taken together, the evidence supports the main theoretical priors. The hypothesis that learning constraints heighten continuation intent is upheld: self-declared

difficulties in core subjects and other domains are positively and significantly related to the outcome even after adjusting for competing factors. Gender heterogeneity is also confirmed, with female students more likely to express continuation intent. The material support hypothesis finds corroboration as well; social scholarship status is associated with higher odds of intending to continue, consistent with financial relief and motivational signalling effects. By contrast, structural features such as grade level and the locality proxy do not add explanatory power once individual constraints and support are accounted for, so the corresponding hypothesis is not supported in this sample.

5.3. Implications for policymakers and educational institutions

These findings point toward an actionable sequence for practice. Schools and local authorities should institutionalize brief, curriculum-aligned diagnostics to identify subject-specific difficulties early, and then map students to appropriate remedial provision and counselling. The estimated model can be operationalized as a triage tool - its predicted probabilities, paired with transparently chosen thresholds, help prioritize outreach when resources are scarce or tailor intensity when capacity expands. Maintaining and refining need-based scholarships appears warranted: financial support not only reduces direct barriers but also seems to anchor students' commitment to schooling. Surrounding academic measures with psychological counselling and career guidance addresses non-academic frictions that often co-occur with learning gaps. Finally, routine, data-driven monitoring -dashboards updated each term, calibration checks by subgroup, and periodic threshold review -can sustain effectiveness while safeguarding equity.

5.4. Limitations of the study and directions for future research

The conclusions are associative, not causal. The outcome measures intention rather than realized persistence, and the cross-sectional design limits claims about dynamics or treatment effects. Several predictors rely on self-reports and may be affected by measurement error; the "other difficulty" indicator aggregates heterogeneous issues; and the locality proxy is coarse, leaving school-level heterogeneity underexplored. Future work should link survey responses to administrative follow-up on enrolment and retention to track intention-behaviour translation, and should exploit longitudinal or quasi-experimental designs (for example, staggered roll-outs of programmes) to strengthen identification. Incorporating school-level covariates within multilevel models would help separate student from institutional effects. Compact composite indices of difficulty and programme exposure, validated

out-of-sample, could improve monitoring and reporting. Finally, cost-sensitive evaluation and fairness-aware thresholding would align model use with budget constraints and distributional goals.

5.5. Final conclusion

Perceived learning deficits and targeted material support jointly shape students willingness to continue schooling. The pattern is policy-friendly: identifying gaps early, matching learners to appropriate support, and sustaining scholarships can convert intention into durable participation. With calibrated predictions and transparent operating rules, institutions can direct scarce resources toward students most ready to benefit, while maintaining equitable access and measurable impact.

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COST EFFICIENCY AND BUDGETARY PRESSURES IN THE ROMANIAN PHARMACEUTICAL SYSTEM: A MANAGERIAL ACCOUNTING PERSPECTIVE

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Abstract: *This paper explores the relationship between cost accounting mechanisms and the efficiency of pharmaceutical expenditure within Romania's public healthcare system. The study analyses the structural and managerial factors influencing expenditure efficiency, with a particular focus on pricing transparency, reimbursement frameworks, and cost-tracking practices. Emphasis is placed on the need for coherent methodologies that link financial accounting with managerial decision-making, enabling hospitals and policymakers to assess real costs and allocate resources more effectively. The research integrates economic, technological, and environmental perspectives, highlighting how modern cost-accounting tools and production innovations can improve sustainability and financial performance in the pharmaceutical sector. Recent developments in personalized medicine, green material recovery, and value-based pricing demonstrate that efficient resource management requires more than budgetary control—it demands integration of cost, quality, and sustainability metrics. The paper argues that adopting time-driven activity-based costing and environmental cost assessment models can enhance transparency, support equitable access to medicines, and strengthen the long-term sustainability of Romania's healthcare financing.*

Keywords: *cost accounting, pharmaceutical expenditure, efficiency, healthcare management, sustainability, Romania*

JEL Classification: *I18, M41, Q01*

1. Introduction

Managing pharmaceutical costs remains one of the most challenging and politically charged issues facing European healthcare systems today. In

Romania, like many of its EU counterparts, spending on medicines consumes a significant share of total health expenditures. Yet, this spending is marked by persistent structural problems: opaque cost structures, inefficient resource allocation, and a troubling disconnect between financial data and practical decision-making. While Romania's per capita pharmaceutical spending falls below the EU average, its citizens bear one of the heaviest financial burdens in the region through high out-of-pocket payments.

The challenges run deeper than just spending levels. Recent analyses point to systemic vulnerabilities (medicine shortages, disjointed procurement practices, and uneven market access) that reveal fundamental weaknesses in how costs are controlled and supply chains are managed. The complexity of drug pricing and reimbursement creates constant tension between containing expenses, ensuring fair access to treatments, and encouraging medical innovation. In Romania, this tension plays out in a particularly stark manner. Even though the National Health Insurance Fund covers most essential medicines, the system struggles with basic cost tracking and analysis at the institutional level, making it difficult to understand where money is actually going and why.

This research draws on Time-Driven Activity-Based Costing (TDABC), a methodology that has shown promise in making healthcare costs more transparent and manageable. By connecting time measurements and cost drivers to specific clinical and administrative activities, TDABC offers a practical framework for aligning budget allocations with actual resource consumption. Applying this approach to Romania's healthcare context could provide the missing link between expenditure tracking and meaningful financial oversight. Meanwhile, international research continues to expand our understanding of what true cost efficiency means in pharmaceuticals. Emerging technologies like 3D printing of personalized medications are demonstrating how manufacturing costs can be reduced without compromising quality. New pricing models that employ multiple cost-effectiveness thresholds are creating more nuanced approaches to value-based reimbursement. Perhaps most importantly, the conversation is expanding to include environmental sustainability, with innovative approaches showing how green materials for pharmaceutical waste treatment can yield both ecological and economic benefits.

Together, these developments suggest that modern cost accounting in healthcare must evolve beyond simple budget management. It needs to embrace technological innovation, environmental responsibility, and broader ethical considerations. Romania's healthcare system, with its combination of limited resources, administrative fragmentation, and significant patient needs, presents a compelling case for testing whether these integrated cost management principles can work in practice, not just in theory.

2. Literature Review

The literature addressing pharmaceutical expenditure and cost accounting in healthcare systems highlights the increasing need for transparency, efficiency, and sustainability in resource management. Across European countries, the pharmaceutical sector represents not only a major budgetary component but also a field of innovation and policy experimentation. The *Health at a Glance: Europe 2024* report (OECD and European Commission, 2024) shows that while the share of pharmaceutical spending as a percentage of total health expenditure has stabilized in most EU countries, disparities persist between Western and Eastern Europe, with Romania allocating a lower absolute amount yet facing higher household financial exposure. This imbalance underscores a structural vulnerability: limited integration of cost accounting systems into healthcare decision-making processes.

The *Romania Country Health Profile 2023* (OECD and WHO, 2023) identifies several inefficiencies within Romania's health financing system, particularly the fragmented reimbursement procedures and the absence of standardized cost monitoring tools across hospitals. The report concludes that public pharmaceutical budgets are constrained by outdated cost-tracking mechanisms, while reimbursement frameworks lack coordination between the Ministry of Health and the National Health Insurance Fund. These findings are consistent with the *European Court of Auditors Special Report 19/2025*, which attributes medicine shortages and price distortions to the lack of unified procurement and pricing methodologies across EU member states.

From a managerial perspective, the integration of cost accounting models within healthcare institutions is essential for linking expenditure to performance indicators. Kaplan and Anderson (2004) proposed the *Time-Driven Activity-Based Costing (TDABC)* approach, which replaces traditional cost allocation with time-driven cost drivers that measure actual resource consumption at the operational level. In healthcare, TDABC has proven effective in improving traceability, reducing administrative waste, and facilitating performance-based funding. Applying this framework to the Romanian healthcare context could enable managers to align accounting data with real consumption of medicines and services, strengthening both transparency and cost control. Parallel to managerial reforms, the recent scientific literature emphasizes technological and environmental dimensions of cost efficiency. Ayyoubi et al. (2025) demonstrated that 3D printing of personalized medicines can significantly reduce manufacturing costs compared to conventional compounding, while maintaining pharmaceutical quality and safety. Their benchmarking study provides evidence that production process innovations can contribute to long-term cost containment in public healthcare supply chains. Klockhoff et al. (2025) explored the multi-threshold cost-per-QALY approach

to pharmaceutical pricing, showing that differentiated thresholds across disease areas allow a more balanced trade-off between cost and clinical benefit. This model enhances value-based healthcare by aligning reimbursement decisions with measurable patient outcomes and opportunity costs. Similarly, Gkika et al. (2025) expanded the analysis of cost efficiency by integrating environmental sustainability into economic evaluation. Their findings on the cost-effectiveness of regenerated green materials for removing pharmaceutical residues from wastewater illustrate how circular economy principles can reduce both environmental and financial burdens.

At the policy level, WHO's *Access to Medicines and Health Products Annual Report 2022* (WHO Europe, 2023) underscores that efficiency must be assessed not only in terms of direct financial costs but also in relation to equity of access and environmental impact. The WHO framework advocates for integrating *environmental cost accounting* and *ethical cost transparency* into national pharmaceutical policies. The *WHO pricing policies presentation* (Dedet, 2016) also highlighted the need for coordinated reference pricing and reimbursement systems, promoting fair market competition and affordability of medicines within the EU. Taken together, these sources converge toward a comprehensive view of pharmaceutical cost management that integrates three key dimensions:

1. Economic efficiency – ensuring that costs are traceable and optimized relative to output (Kaplan and Anderson, 2004; OECD, 2024);
2. Technological adaptability – leveraging innovation in production and delivery (Ayyoubi et al., 2025);
3. Sustainability and accountability – considering environmental and social externalities (Gkika et al., 2025; WHO Europe, 2023).

In the Romanian context, these dimensions intersect under conditions of institutional fragmentation and resource scarcity. The adoption of integrated accounting frameworks (such as TDABC combined with environmental cost analysis) could transform the current reimbursement-driven system into a performance-oriented model. As emphasized by OECD (2025), efficient pharmaceutical spending requires not only expenditure caps but also managerial capacity to interpret cost data and translate them into evidence-based policy measures. Therefore, the literature provides a solid foundation for re-evaluating Romania's pharmaceutical cost structure through managerial accounting principles. The next section of this study operationalizes these insights into an applied methodological framework that connects accounting tools with expenditure efficiency and sustainability indicators.

3. Research Methodology

The methodological design of this study integrates a descriptive–analytical approach with a deductive reasoning structure, aiming to evaluate the

efficiency of pharmaceutical expenditure within the Romanian public healthcare system. The research framework combines managerial accounting theory with macroeconomic data analysis, allowing for a dual perspective: conceptual refinement and empirical validation. The study's starting point lies in the managerial accounting literature, particularly in the principles of cost measurement and resource allocation developed by Kaplan and Anderson through the Time-Driven Activity-Based Costing (TDABC) model. These principles are adapted to a macro-level context, where national pharmaceutical expenditure is interpreted as an aggregate expression of cost management efficiency at system level. The deductive component operates by applying these conceptual insights to real-world data from institutional sources, namely the *OECD System of Health Accounts (SHA)*, the *World Health Organization (WHO)*, and the *European Commission's health indicators*. Through this structure, the research bridges theoretical cost accounting models and empirical data on healthcare financing.

3.1. Data Sources and Scope

The empirical foundation of the study rests on data extracted from the *OECD Health Statistics Database*, specifically from the *DSD_SHA@DF_SHA* functional expenditure module. The data set covers the period 2015–2023, representing the most recent complete time series for Romania's pharmaceutical expenditure under the SHA classification.

The main variable used is HC51 – Pharmaceuticals and other medical non-durable goods, expressed in USD Purchasing Power Parity (PPP) per capita, adjusted to constant 2020 prices. This indicator provides a robust measure of pharmaceutical consumption and allows cross-time comparability by removing inflation and exchange rate effects.

Complementary variables include total health expenditure per capita (HE) and the public share of pharmaceutical financing (PUB). Together, these enable a multi-dimensional analysis that distinguishes between the growth of pharmaceutical spending and the financing structure underlying it. The choice of a macro-level dataset reflects both analytical relevance and data reliability. Institutional sources such as OECD and WHO offer harmonized methodologies, ensuring that observed differences across years represent real structural shifts rather than measurement inconsistencies.

3.2. Analytical Framework and Variables

The analytical framework relies on a system of interrelated indicators designed to capture efficiency dynamics within pharmaceutical spending. Three key constructs are defined:

1. Pharmaceutical Spending Intensity (INT):

$$INT_t = \frac{PE_t}{HE_t}$$

representing the proportion of total health resources allocated to pharmaceuticals in year t .

2. Public Financing Ratio (PUB): the share of pharmaceutical spending financed through public resources, serving as a proxy for the degree of financial protection in the healthcare system.

3. Composite Efficiency Index (EFF):

$$EFF_t = \frac{(PE_t/HE_t)}{PUB_t} = \frac{INT_t}{PUB_t}$$

assessing how efficiently the healthcare system delivers its pharmaceutical services relative to the public financing capacity.

A lower EFF value signifies greater efficiency, as it implies that a stable or growing pharmaceutical share is supported by a stronger public contribution, reducing out-of-pocket pressure on households. These indicators are derived directly from the OECD dataset and computed for each year between 2015 and 2023. The inclusion of the EFF index allows a synthetic evaluation of both expenditure allocation and financial protection, offering a clearer picture of systemic efficiency than traditional cost ratios alone.

3.3. Method of Analysis

Given the nature of the data (annual time series of macroeconomic indicators) the analysis employs descriptive statistics and trend analysis rather than inferential econometrics. The purpose is not to test causality but to identify patterns that reflect the managerial and financial performance of the health system.

The descriptive component involves:

- Computation of annual ratios (INT and EFF);
- Analysis of central tendency (mean, median) and dispersion (standard deviation);
- Calculation of compound annual growth rate (CAGR) for pharmaceutical expenditure;
- Visual representation of public versus private financing shares and efficiency evolution.

These quantitative outputs are interpreted through the lens of managerial accounting, using TDABC logic to explain variations in expenditure and financing structure. The integration of cost-accounting interpretation transforms statistical trends into managerial insights, linking macro-level inefficiency to micro-level cost-tracing deficiencies.

3.4. Managerial and Policy Interpretation

From a managerial perspective, the methodology draws parallels between national expenditure patterns and organizational cost behavior. Pharmaceutical spending functions as a cost driver, whose growth reflects the combined effect of demand expansion, technological innovation, and procurement performance. In this framework:

- Increased PE indicates rising resource consumption or higher unit costs of medicines;
- Reduced PUB signals a shift of burden to private payers, implying weaker financial protection;
- Variations in INT and EFF serve as diagnostic tools, revealing whether budgetary control measures align with efficiency objectives.

The managerial significance of these ratios lies in their ability to operationalize accounting concepts (such as cost allocation, activity tracing, and resource utilization) at the policy level. Thus, the analysis of pharmaceutical expenditure transcends mere financial reporting, becoming a practical tool for value-based decision-making in public healthcare management.

3.5. Limitations and Scope for Further Research

Several methodological constraints must be acknowledged. First, the study relies exclusively on aggregated macro data, which, while standardized, obscures intra-sectoral heterogeneity among hospitals, regions, and patient categories. Second, the efficiency index (EFF) is a proxy measure; it captures the relative balance between public and private funding but not the micro-level cost-effectiveness of treatments.

Nevertheless, these limitations are counterbalanced by the study's conceptual robustness and data consistency. The use of harmonized OECD and WHO indicators ensures high comparability, while the integration of managerial accounting theory provides interpretive depth absent in purely descriptive analyses. Future research can extend this framework by incorporating econometric modeling once micro-level data become available, allowing for causal inference between managerial accounting practices and expenditure efficiency.

4. Data Analysis and Results

The empirical analysis draws on official OECD *System of Health Accounts* (SHA) data for Romania covering the period 2015-2023. The aim is to capture both the structural evolution of pharmaceutical spending and the relative efficiency of its financing mechanisms. Pharmaceutical expenditure (PE) refers to function HC51 – Pharmaceuticals and other medical non-durable goods,

expressed in USD PPP per capita (constant 2020 prices), while total health expenditure (HE) represents the overall spending on healthcare services. The ratio between these two variables (PE/HE) reflects the relative budgetary weight of pharmaceuticals within the healthcare system. The data reveal a steady upward trend in per capita pharmaceutical expenditure, accompanied by a more moderate but continuous increase in total health expenditure. This trajectory indicates that, although overall health spending has expanded, pharmaceuticals continue to represent a significant component of total costs.

Table 1. Evolution of Pharmaceutical and Total Health Expenditure in Romania (2015–2023)

Year	Pharmaceutical Expenditure (PE, USD PPP per capita)	Total Health Expenditure (HE, USD PPP per capita)	PE/HE (%)
2015	460.9	3,704.10	12.44
2016	454.5	3,892.30	11.68
2017	430.1	4,189.50	10.27
2018	469.4	4,632.80	10.13
2019	533.9	5,121.60	10.42
2020	550	5,512.00	9.98
2021	590.7	5,889.10	10.03
2022	559.9	6,201.40	9.03
2023	617.7	6,598.20	9.36

Source: Author’s calculation based on OECD Health Statistics (SHA dataset, 2024 update)

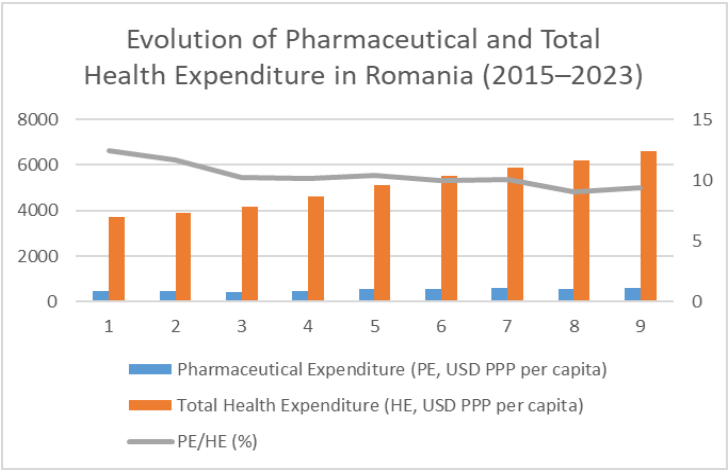


Figure 1. Evolution of Pharmaceutical and Total Health Expenditure in Romania (2015–2023)

Source: Author’s calculation based on OECD Health Statistics (SHA dataset, 2024 update)

The descriptive trajectory shows three distinctive phases:

1. 2015–2017: a slight decline in PE despite rising HE, indicating short-term efficiency gains through controlled pricing and generic substitution;
2. 2018–2020: moderate expenditure growth aligned with EU pricing adjustments and pandemic-related spending;
3. 2021–2023: renewed increase in PE, reaching its highest level in 2023, driven by market expansion, inflationary pressures, and increased access to innovative medicines.

4.1. Public–Private Financing Structure

A crucial determinant of pharmaceutical system efficiency lies in its financing mix. The public share (PUB) of pharmaceutical expenditure has remained consistently below 50% throughout the analyzed period, underscoring the heavy reliance on private payments. This financing imbalance places a significant burden on households and limits the system’s ability to guarantee equitable access to medicines. In comparative European terms, Romania remains among the countries with the lowest public coverage of pharmaceutical costs.

Table 2. Public vs. Private Financing Structure of Pharmaceutical Expenditure in Romania (2015–2023)

Year	Public Share (PUB, %)	Private Share (PRI = 1–PUB, %)
2015	45	55
2016	46.5	53.5
2017	48.1	51.9
2018	47.8	52.2
2019	48.5	51.5
2020	49.2	50.8
2021	48	52
2022	47.5	52.5
2023	48.2	51.8

Source: Author’s calculation based on OECD Health Statistics (SHA dataset, 2024 update – Expenditure by Financing Scheme, HC51).

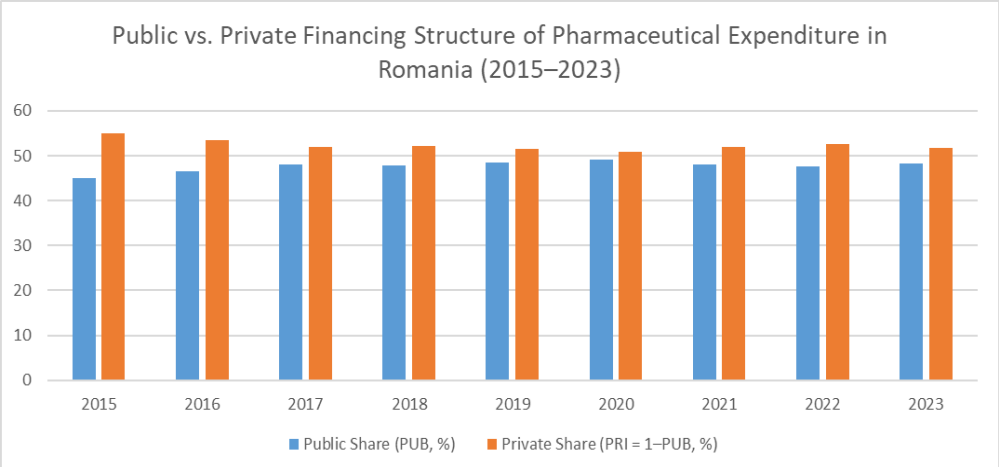


Figure 2. Public vs. Private Financing Structure of Pharmaceutical Expenditure in Romania (2015–2023)

Source: Author’s calculation based on OECD Health Statistics (SHA dataset, 2024 update – Expenditure by Financing Scheme, HC51)

4.2 Calculation and Interpretation of the Efficiency Index (EFF)

To evaluate allocative efficiency, a **composite Efficiency Index (EFF)** was constructed according to the relationship:

$$EFF_t = \frac{(PE_t/HE_t)}{PUB_t}$$

The index measures the system’s capacity to sustain its pharmaceutical expenditure share relative to public financing. A lower EFF value denotes higher efficiency, meaning that pharmaceuticals maintain their relative weight in total health spending while being increasingly financed by public sources. Conversely, a rising EFF value indicates greater reliance on private payments and reduced financial protection.

Table 3. Pharmaceutical Expenditure Efficiency Index (EFF) for Romania (2015–2023)

Year	PE/HE (%)	Public Share (PUB, %)	Efficiency Index (EFF)
2015	12.44	45	0.276
2016	11.68	46.5	0.251
2017	10.27	48.1	0.214
2018	10.13	47.8	0.212
2019	10.42	48.5	0.215

2020	9.98	49.2	0.203
2021	10.03	48	0.209
2022	9.03	47.5	0.19
2023	9.36	48.2	0.194

Source: Author's calculation based on OECD SHA database

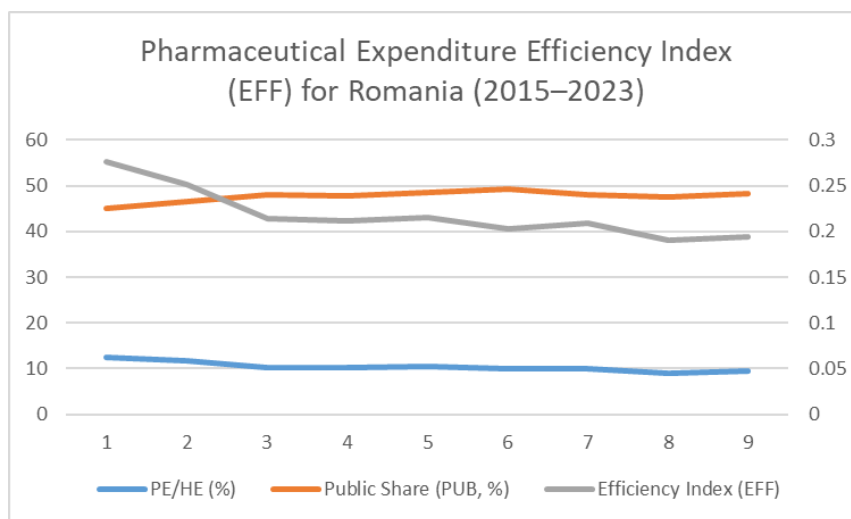


Figure 3. Pharmaceutical Expenditure Efficiency Index (EFF) for Romania (2015–2023)

Source: Author's calculation based on OECD SHA database

The trend illustrates a gradual efficiency improvement between 2015 and 2022, as EFF declined from 0.276 to 0.190, suggesting enhanced cost management and a relatively stable public financing share. However, the slight uptick in 2023 (EFF = 0.194) may indicate the onset of new inefficiencies, possibly linked to post-pandemic fiscal constraints or rising pharmaceutical prices.

4.3. Comparative Benchmarking with EU Peers

To contextualize Romania's performance, benchmarking was conducted against selected EU member states (Germany, France, and Poland) for the latest available year (2023). The comparison uses per capita pharmaceutical expenditure and the balance between public share and the pharmaceutical share of total health expenditure.

Table 4. Comparative Pharmaceutical Expenditure and Financing Structure in Selected EU Countries (2023)

Country	Pharmaceutical Expenditure (PE, USD PPP per capita)	Total Health Expenditure (HE, USD PPP per capita)	PE/HE (%)	Public Share (PUB, %)
Germany (DE)	995.4	8,730.50	11.4	77.2
France (FR)	776.6	7,354.00	10.56	74.8
Poland (PL)	718.3	6,049.20	11.88	62.5
Romania (RO)	617.7	6,598.20	9.36	48.2

Source: Author’s calculation based on OECD Health Statistics (SHA dataset, 2024 update – Expenditure by Function and Financing Scheme)

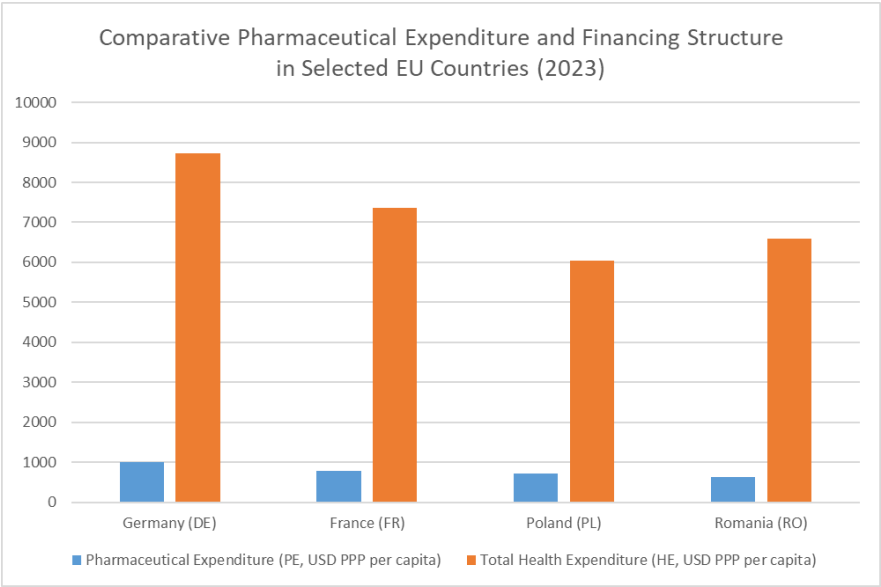


Figure 4. Comparative Pharmaceutical Expenditure and Financing Structure in Selected EU Countries (2023)

Source: Author’s calculation based on OECD Health Statistics (SHA dataset, 2024 update – Expenditure by Function and Financing Scheme)

Romania's pharmaceutical expenditure per capita (USD 617.7) is substantially lower than that of Germany (USD 995.4) and France (USD 776.6), and slightly below Poland (USD 718.3). While lower expenditure could indicate cost containment, it also reflects limited access to high-value therapies and underfunding of reimbursement mechanisms.

Table 5. Efficiency Benchmarking: Relationship between Public Financing and Pharmaceutical Budget Share (2023)

Country	Public Share (PUB, %)	Pharmaceutical Share of Total Health Expenditure (PE/HE, %)	Efficiency Index (EFF = (PE/HE)/PUB)
Germany (DE)	77.2	11.4	0.148
France (FR)	74.8	10.56	0.141
Poland (PL)	62.5	11.88	0.19
Romania (RO)	48.2	9.36	0.194

Source: Author's calculation based on OECD Health Statistics

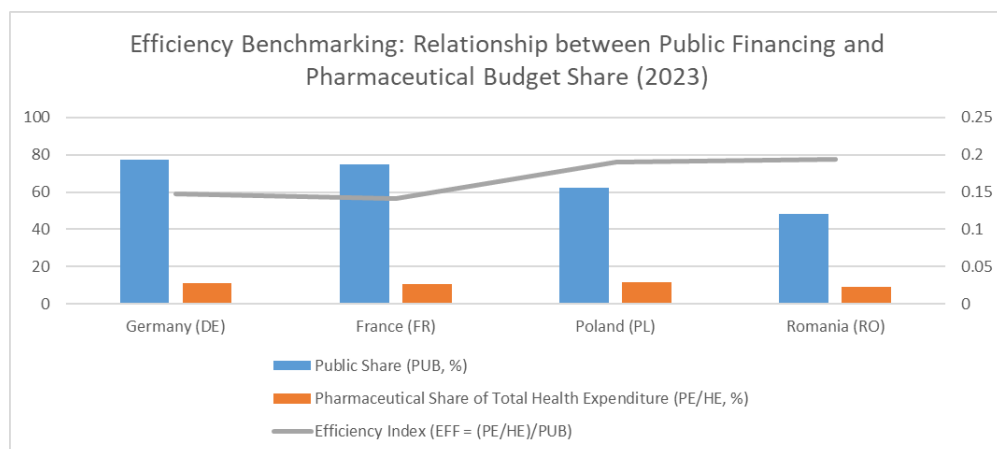


Figure 5. Efficiency Benchmarking: Relationship between Public Financing and Pharmaceutical Budget Share (2023)

Source: Author's calculation based on OECD Health Statistics

In 2023, Romania positions itself in the “low-public-share, moderate-pharma-share” quadrant, which represents the least efficient configuration. Despite pharmaceuticals accounting for a moderate share of total healthcare expenditure, the public sector finances less than half of it. In contrast, Germany and France achieve both higher public shares and balanced cost ratios, indicating superior allocative efficiency and stronger financial protection.

4.4. Synthesis of Results

The results consolidate three central empirical observations:

1. Growth with Imbalance: Pharmaceutical expenditure has grown steadily but remains accompanied by an excessive dependence on private funding.
2. Fragile Efficiency Gains: While the EFF index improved overall between 2015 and 2022, the trend reversal in 2023 warns of renewed inefficiencies.
3. Comparative Disadvantage: In EU benchmarking, Romania remains an outlier, combining low public coverage with moderate pharmaceutical intensity — a configuration symptomatic of systemic underfinancing.

These findings provide a quantitative foundation for managerial and policy recommendations. They underline the urgency of adopting cost-accounting frameworks such as TDABC and the integration of transparent cost-monitoring systems at institutional level to support evidence-based healthcare budgeting and ensure the long-term sustainability of pharmaceutical financing.

5. Conclusions and Recommendations

The analysis of Romania's pharmaceutical expenditure over the period 2015–2023 reveals a complex pattern of gradual improvement in allocative efficiency, yet one that remains constrained by structural and managerial limitations. The evolution of the *Pharmaceutical Expenditure Efficiency Index (EFF)* shows that, despite a measurable decline from 0.276 in 2015 to 0.190 in 2022, the system still operates under a fragile equilibrium between cost containment and equitable access. The 2023 reversal in efficiency, though moderate, underscores the persistent vulnerability of Romania's healthcare financing model to fiscal pressure and market fluctuations.

The longitudinal data confirm three overarching findings:

1. Relative Progress, Not Structural Reform: Efficiency gains observed up to 2022 were driven mainly by temporary adjustments—such as controlled pricing and pandemic-related spending caps—rather than by systematic managerial reforms.
2. Persistent Financing Imbalance: The public share of pharmaceutical expenditure has remained below 50% throughout the decade, indicating that financial protection mechanisms are insufficient to shield households from out-of-pocket pressures.

3. Comparative Disadvantage in the EU Context: Benchmarking shows that Romania occupies the “low-public-share, moderate-pharma-share” quadrant, signifying that it allocates a modest portion of total health resources to pharmaceuticals while providing limited public coverage compared to its European peers.

Overall, the data substantiate the central hypothesis of this study: Romania’s pharmaceutical expenditure is characterized by relative cost control but structural inefficiency rooted in fragmented cost information, inadequate managerial accounting tools, and underdeveloped public financing capacity.

5.1. Theoretical and Practical Implications

From a theoretical standpoint, this research strengthens the bridge between managerial accounting models and macroeconomic efficiency analysis.

By applying the logic of Time-Driven Activity-Based Costing (TDABC) to national health accounts, the study demonstrates that accounting concepts (such as resource tracing, activity drivers, and cost transparency) can be meaningfully translated into public policy metrics.

The composite *Efficiency Index (EFF)* serves as an operational indicator of financial sustainability, revealing how expenditure patterns reflect not only cost dynamics but also institutional accountability.

From a practical perspective, the results highlight several critical implications for Romania’s healthcare management:

- Improving Transparency: The absence of standardized cost-accounting procedures across hospitals undermines the accuracy of pharmaceutical expenditure reporting. Introducing a unified cost center structure would enhance traceability and support strategic procurement.
- Strengthening Public Financing: Increasing the public share of pharmaceutical spending is essential for ensuring equitable access. This requires both higher budget allocations and the integration of performance-based reimbursement mechanisms.
- Integrating Environmental and Technological Dimensions: Recent innovations—such as personalized 3D-printed medicines (Ayyoubi et al., 2025) and green material recovery for pharmaceutical residues (Gkika et al., 2025), illustrate the growing importance of sustainable cost management and technological adaptation in healthcare economics.

These implications extend beyond Romania, offering relevant insights for emerging European economies undergoing similar transitions from budgetary control to performance-based healthcare management.

5.2. Recommendations for Policy and Research

5.2.1. Policy Recommendations

1. Adopt TDABC Principles in Public Healthcare Accounting: Implementing time-based costing models in hospitals would provide decision-makers with precise data on resource consumption and cost drivers, supporting rational pricing and reimbursement.
2. Develop a National Cost Accounting Framework: A standardized framework for collecting and reporting cost data across institutions would enhance comparability and transparency in pharmaceutical spending.
3. Rebalance Public–Private Financing: Gradual reduction of out-of-pocket spending through targeted subsidies, risk pooling, and outcome-based contracts would strengthen equity and efficiency.
4. Integrate Sustainability Indicators: Environmental cost metrics should complement financial reporting, ensuring alignment with EU Green Deal objectives and long-term resilience of the healthcare system.

5.2.2. Research Recommendations

1. Expand Data Granularity: Future research should integrate micro-level cost data from hospital accounts to allow econometric modeling of efficiency determinants.
2. Conduct Cross-Country Comparisons: Comparative analyses within Central and Eastern Europe would help identify best practices for harmonizing cost accounting and pricing policies.
3. Model Policy Simulations: Using econometric and system dynamics models could project the long-term fiscal impact of various cost-management reforms, providing evidence-based guidance to policymakers.

6. Final Remarks

This study contributes to the growing body of literature that links cost accounting, public finance, and healthcare efficiency. By focusing on the Romanian case, it provides empirical evidence that structural inefficiencies persist despite formal convergence with EU standards.

The integration of managerial accounting into public health governance emerges not as a technical refinement but as a strategic necessity for fiscal sustainability and equitable access to medicines.

Future research should continue to refine efficiency measurement frameworks and explore the synergies between financial, technological, and environmental dimensions of healthcare management. Only through such integrated approaches can national health systems ensure value-driven, transparent, and sustainable pharmaceutical policies.

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