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HUMAN CAPITAL AND THE PHENOMENON OF INCREASING RETURNS IN ECONOMIC GROWTH MODELS

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Abstract: The paper investigates the historical preconditions underlying the emergence of the concept of the principle of diminishing returns to factors of production. An analysis of the manifestation of this principle in the scope of all factors of production is carried out. In light of the analysis of the characteristics of human capital, an approach has been proposed in which the principle of diminishing marginal returns is not applicable to investments in human capital at the macroeconomic level in the long run. Human capital generates increasing returns on investment while alleviating the impact of diminishing returns on other factors of production. In general, while accepting the principle of diminishing returns to factors of production, it should be noted that the mechanical extension of this principle to all types of economic activity is not scientifically justified. There are certain types of activities and economic sectors to which, in our opinion, this law does not apply. Moreover, these types of activities hinder the manifestation of the principle of diminishing returns to other factors of production. In particular, it is known that increased investment leads to diminishing returns on investment. However, this pattern applies to investment in physical capital. In our opinion, this pattern does not apply to investment in human capital. Moreover, investment in human capital is presumably expected to provide increasing returns. However, it should be emphasized that this approach lacks a clear system of evidence and is based on empirical observations. Furthermore, the principle of increasing returns to investment in human capital has a long-term lag in its impact on economic variables and manifests itself in the long term and primarily at the macro level.

Key words: *factors of production, principle of increasing returns, human capital, investments in human capital, physical capital, knowledge, economic cycle, economic growth.*

Introduction

Economic theory encompasses a set of principles that appear foundational and the continued advancement of the economic science is grounded in these fundamental axioms. Among these foundational principles is the principle of diminishing marginal returns to the factors of production. In accordance with the principle of diminishing marginal returns, as the quantity of a variable factor increases, while holding the quantity of all other factors constant, a threshold will be reached, beyond which the marginal

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product of the variable factor will start to diminish. It is noteworthy that this law lacks a well-defined systematic approach to evidence and is grounded on empirical observations.

The methodological foundations of this principal stem from the concept known as the law of diminishing soil fertility, which was initially formulated in the 18th century by the French economist J. Turgot and at a later stage – by the English economist E. West (*Rumyantsev, 1972*). E. West and D. Ricardo attempted to elucidate the tendency for profit rate to decline related to this "law" and leveraged it to support the theory of differential rent. T. R. Malthus applied this principle to validate his theory of population (*Malthus T.R.*, 1868). At the turn of the 19th and 20th centuries, among the leading proponents of this law were L. Brentano and M. Zering - in Germany, S. N. Bulgakov, M. I. Tugan-Baranovsky, P. B. Struve, P. P. Maslov - in Russia. Within the first half of the 20th century A. Marshall, B. Clark and others expounded upon the law of diminishing marginal productivity as a fundamental law that is relevant not only in agriculture, but also in industry and holds comprehensive significance (*Manuelli R.E., Seshadri A.* 2014). Subsequently, the principle of diminishing marginal returns expanded to cover all types of economic activity: savings, investment in physical capital, investment in human capital, etc. Currently, the law of diminishing returns is one of the essential laws underpinning the economic science. From a general perspective, accepting this principle, we should highlight that the automatic extension of this principle to all types of economic activity is devoid of scientific justification. Different types of activities and areas of the economy can be identified where we contend that this law is not relevant. Moreover, these specific activities hinder the manifestation of the principle of diminishing returns of other factors of production. (*Mayilyan F. N.*, 2021). Specifically, it is established that the expansion of investments leads to diminishing returns on investments. However, this pattern is applicable to investments in physical capital. From our standpoint, this pattern is not applicable to investments in human capital. Moreover, investments in human capital are expected to generate increasing returns. It is noteworthy that human capital, in our view, refers to a combination of inherent and developed abilities, knowledge, skills, and motivations resulting from investments that are effectively employed in the labor process, thus supporting the growth of its productivity. The course of history and development in human society contradicts the theory of T.R. Malthus, and, in our opinion, it can be attributed to the fact that the increasing return of human capital hinders the manifestation of diminishing returns of other factors of production. However, it is crucial to highlight that the increasing return on investment in human capital is observable only within the scope of the entire economy, but not at the level of distinct individuals, specifically in the long-run perspective. The phenomenon of increasing returns in models of economic growth can be attributed to the increasing returns of human capital (*Mayilyan F. N.*, 2021).

The main objective of this article is to substantiate the author's approach, which explains the increasing returns to investing in human capital over the long term and at the macro level, based on a critical analysis of generally accepted theoretical approaches in economic theory. According to these theoretical foundations, the law of diminishing returns applies to all types of investment, including investments in human capital. The author attempts to propose a new approach that contradicts this generally accepted approach.

Literature Review

Since the mid-20th century, particularly during the 1950s and 1960s, scholars have increasingly focused on the role of human capital in driving the economic growth of different countries, a trend that has been reflected in the advancement of endogenous growth models. The emergence of a new class of economic growth models incorporating endogenous technological progress has led to a heightened interest in the issues of economic dynamics. Three key implications of these models, which could have considerable practical significance, had a pivotal role in this. Specifically: 1. economies of scale stemming from the growth in resources involved in the process of new knowledge acquisition; 2. the ability to impact the rate of long-term economic growth by fostering the increase rate of human capital accumulation; 3. the impact of human capital growth rates on the structure and scope of international trade and globalization processes. In the 1960s and 1970s, extensive debate emerged concerning the inclusion of education in the model's economic growth. Consequently, two methods for integrating education into the models of economic growth have emerged, which differ substantially from each other. One approach is to conceptualize human capital as one of the factors in the production function that is not directly associated with the technical progress (G. Uzawa, 1965; R. Lucas, 1988; Menkiw, P. Romer, D. Weil, 1992). In this case, the growth rate of the economy is determined by the growth rate of human capital. An alternative approach is to consider that the growth rate of the technological progress is determined by the aggregate level of the human capital.

The founding figures of these theories are P. Romer, R. Lucas, S. Rebello, who, through their models, provided a theoretical foundation for the approach according to which economic growth is explained by investments in human capital, the acquisition of experience and on-the-job training. They also underlined that positive externalities arising from the training prevent a decrease in the marginal productivity of human capital.

P. Romer classifies the economy into three primary sectors. In the first sector, the research sector, as a result of the concentration of human capital ($H_{A)}$ usage within it and the current repository of knowledge (A), new knowledge is acquired, which is subsequently materialized in the form of new technologies. The expansion of new knowledge is expressed by the formula:

$$A'=ϭH_AA \qquad (1)$$

where

ϭ is a parameter of scientific productivity.

P. Romer points out that graduates of engineering universities a century ago possessed the same level of human capital as current graduates, as they studied for approximately the same duration lacking practical work experience. However, the labor productivity of a modern engineer is considerably higher, as they have access to a more extensive repository of knowledge. Knowledge is regarded in this context as a non-competitive production factor that is simultaneously and equally accessible to everyone with the capacity and intention to use it.

Firms in the secondary sector of the economy acquire scientific knowledge obtained within the research domain for the production of the factors of production. Every enterprise within this sector is a monopolist: it holds a patent for the manufacturing of its products and, therefore, can derive a monopoly profit from its realization. The patent

is considered as lasting indefinitely. The tertiary sector of the economy, based on the available factors of production, labor costs (L) and human capital (Hy), ensures the production of final consumer goods. The relevant production function is:

$$Y(Hy, L, x) = Hy^{\alpha}L^{\beta}\sum_{i=1}^{\infty} Xi^{1-\alpha-\beta} \quad (2)$$

where

i - is the index assigned to each distinct type of the factors of production;

x_i - is the listing of the factors of production used by a company for the production of final goods;

α and β - are certain technological parameters.

The acquired level of expertise in P. Romer's model aligns with a specific level of technological advancement, which varies with the accumulation of new knowledge and the emergence of new technologies. According to the model, the technological aspect of knowledge is a non-competitive good, unlike the competitive aspect of knowledge, i.e., human capital. However, if, within the research sector, each specialist has access to the comprehensive knowledge base, subsequently, in the secondary and tertiary sectors the use of a specific idea (development) is regulated by the current patent legislation framework. Once an enterprise in the secondary sector acquires and masters an innovative and cutting-edge technological idea, it protects its monopoly right and control to use it under a patent and arranges the production of pertinent factors of production for tertiary sector enterprises specializing in the production of final goods.

K. Arow (. *Arrow K. J.* 1962) and G. Uzawa (*Uzawa H.* 1965) underlined the importance of considering the positive externalities of education and on-the-job training in the models of economic growth. H. Uzawa, in his studies, proposed to include the education sector in the model of economic growth, in which the employment determines the factor of labor productivity. Accordingly, labor efficiency was growing in line with the increasing employment in the education sector. R. Lucas, in his studies, (*Lucas R. E.* 1988) while investigating the relationship between investments in human capital and economic growth, justified the differences between the rates of economic growth of countries based on the amount of investments in human capital. By studying the relationship between the stock of human capital in individual firms, the economy-wide average of human capital resources, and the level of output, he concluded that, as a consequence of individual decisions, comparatively lower investment is made in human capital than required to foster sustainable growth. R. Lucas clarified the underlying reason for this phenomenon by the fact that individuals, when making decisions pertaining to investments in human capital, do not consider the impact of individual investments in human capital that will increase the level of productivity of other individuals. Specifically, the rate of social return on investment in human capital exceeds the individual return rate on human capital. R. Lucas presumed that an increase in the average level of human capital across the entire economy results in an increase in the level of labor productivity of all employees. The study of Lucas outlines a dual-sector model of economic growth where human capital is introduced into the Cobb-Douglas production function as a factor similar to productive capital:

$$Y = AK^{\alpha}(uhL)^{1-\alpha} h_{\alpha}{}^{y} \quad (3)$$

where

$0 < \alpha < 1$;

A, K and L are the levels of technological advancement, physical capital and labor force, respectively;

U - is the proportion of aggregate labor time allocated to work;

h - is the rate of human capital accumulation;

h_a^y - is the average positive external effect of human capital.

In the second part of the model, Lucas incorporates the share of human capital that is not applied in the manufacturing sector. Endogenous growth is only feasible if the development of additional human capital provides constant returns:

$$h_i^{\cdot} = h_i B(1 - u_i) - \delta h_i \qquad (4)$$

where

δ - is the decline in human capital value;

B- is a parameter that defines the rate at which investments in the manufacturing sector are converted into human capital growth;

$(1 - u_i)$ - is the segment of the population pursuing self-guided education.

In the neoclassical model developed by Lucas, the assumption of constant marginal returns to scale in production is retained while assuming the irrelevance of non-reproducible factors. As equation (4) indicates, an increase in the stock of human capital occurs regardless of its level. Based on this assumption, Lucas develops a growth model as follows:

$$g_h = \frac{hi^{\cdot}}{hi} = B(1 - u_i) - \delta \qquad (5)$$

In comparison with the Solow model, the driver of the economic growth in this model is not technological advancement, but individual investments in human capital.

However, R. Lucas's model generally aligns with constant growth, on the premise of a time-dependent production function, and is often applied to represent the effects of technological advancement, according to which production parameters, investment, and consumption can increase at a rate of *g*. Therefore, in this model, the accumulation of human capital is a universal factor of production, while the growth rate of human capital establishes the rate of the economic growth. Concurrently, as we have underlined above, R. Lucas highlights the heterogeneity of the positive effects of human capital within the national economy, therefore; as outlined in the model above, the benefits from the accumulation of human capital are not confined solely to the direct impact on the economic growth.

R. Nelson and E. Phelps have investigated the role of human capital as a factor of economic growth, which contributes to the generation of technological changes and their further implementation (*Sharaev Y.V.*, 2006). They assumed that a global repository of knowledge base exists and is accessible to all countries. However, the capabilities of countries to introduce new technologies depend on their capacity to absorb, which is directly determined by the educational level of the employees, i.e., the level of human capital accumulated through their efforts. I. Benhabib and M. Spiegel further developed the model of R. Nelson and E. Phelps, underlining that the gap between the theoretically feasible and the actual level of knowledge in developing countries can be diminished by introducing technological innovations. On the basis of the analysis of the extended production function, they arrived at the conclusion that the stock of human capital has a considerably stronger effect on the growth of the per capita GNP rate than the rate of its formation and accumulation. G. Barro, H. Sella and G. Martin, on the basis of an analysis of extensive statistical resources from 87 countries (1965–1975) and 97 countries (1975–

1985), identified a significant correlation between the economic growth and the educational level of the population (*Sharaev Y.V.*, 2006). Moreover, according to the study, the growth in public expenditure on education has a significant impact on the economic growth. Therefore, an increase in the specific share of government spending on education within the GNP structure by 1.5% induces a faster rate of economic growth by 0.3%. A practical model of economic growth considering the contribution of human capital was developed by G. Menkiw, D. Romer and D. Weil (1992), which is primarily a modification of the Cobb-Douglas production function and the fundamental Solow model grounded in human capital (*Sharaev Y.V.*, 2006).

The production function in this expanded Solow model is structured as

$$Y(t) = K(t)^{\alpha} H(t)^{\beta} (A(t)L(t))^{1-\alpha-\beta} \quad (6)$$

where

H(t) - is the stock of human capital at time t;

α and β - are the shares of the impact of physical and human capital on output growth;

A(t) - is the level of technology varying over time at a rate of *g*, that is

$A(t) = A0e^{g}$.

The model was tested in 1960–1985 across three groups of countries (developed countries, countries with an average level of development and oil-exporting countries). The data obtained indicated the significant role of human capital in the economic growth of all countries involved in the study. In the developing countries, 80% of variations in per capita income were stemming from differences in the levels of human capital. The Mankiw-Romer-Weil (MRW) model has gained considerable prevalence and constituted the basis for research and further development of economic growth models considering the human capital, which, consequently, adopt alternative methods for the evaluation of the human capital.

The returns to education have been estimated in a large number of studies since the late 1950s. A number of studies have generalized existing estimates at the global level. For example, according to calculations by (Psacharopoulos and Patrinos, 2018), each additional year of education leads to an 8.8% increase in income. These global returns estimates are stable over time, although education may have different effects on income depending on the country, region, demographic group, and duration of schooling. Jones (Jones, 2019) noted that existing reviews of the literature estimating returns to education using instrumental variables indicate not only comparable returns—around 10%—but also a causal effect of education on income.

Returns to experience contribute to economic growth, and work involves learning new knowledge and skills, as well as refining existing ones. From this perspective, work can also be considered a form of education—usually much longer than formal schooling (Jedwab et al., 2021). Due to limited data availability, the literature often uses potential rather than actual labor market experience. In its basic formulation, potential experience is calculated as the difference between a worker's age, the length of their education, and preschool age (six years). The lower the likelihood of underemployment or temporary withdrawal from the labor market, the closer the estimates of potential and actual experience will be.

Demirguc-Kunt and Torre (Demirguc-Kunt, Torre, 2020) proposed a method for accounting for the prevalence of three key adult health risk factors characteristic of European and Central Asian countries: obesity, smoking, and alcoholism, as important

constraints on economic growth. These factors are associated with various diseases (primarily cardiovascular diseases) and mortality risks. Estimates of the calibration coefficients were based on median effect sizes obtained in various microeconomic studies. Because the actual impact of these factors on morbidity and mortality is also influenced by the quality of the healthcare system, the calculations also included indicators of child stunting and adult mortality, which more closely reflect the actual health status (rather than the risks) of the population. However, there was no correlation between per capita income levels and the resulting estimates of health-related human capital.

It should be noted that modern models of economic growth that take human capital into account, despite the diversity of approaches, assessment methods, and mechanisms for the influence of human capital on economic growth, are united in one thing: they are all based on the principle of diminishing returns to human capital. We believe that human capital from the macroeconomic standpoint and in the long run (in the context of prolonged economic cycles) demonstrates a trend of increasing returns. Furthermore, it is attributed to the increasing returns on investment in human capital that obstructs the manifestation of diminishing returns on other factors of production (*Mayilyan F. N., 2021*).

Methodology

Currently, the interest of economic science in human capital has increased significantly, but the mechanism and underlying fundamental causes of the beneficial effects of human capital on the long-term rate of economic growth remain the subject of ongoing discussions and research. For instance, in the works of the following scientists (Jones, 2014; Manuelli, Seshadri, 2014; Lucas, 2015; Jones, 2019), it is underlined that human capital has a pivotal role in the economic development across various countries. Even among proponents who assert that human capital is the main cause of economic growth, there is disagreement concerning numerous significant issues, namely: how human capital at the individual level shapes the relevant aggregate macroeconomic indicator; if human capital affects the aggregate output of the economy or its growth rate; how exactly are human capital, knowledge and technological advancement related in the economy? To adequately address these questions, it is crucial to distinguish between the return of human capital at the micro and macro level, as well as between private and social norms regarding the return on education. Current approaches to assessing private rates of return on education generally do not acknowledge its impact on the direct and indirect benefits to the population, its monetary and non-monetary returns, or the contribution of educational policies towards enhancing the social cohesion. Therefore, estimates regarding the private rates of return on education can be considered as the lower limit of social benefits that arise from investments in human capital (*Mankiw G., Romer D., Weil D., 1992*). Since macroeconomic estimates incorporate the majority of the induced externalities, and microeconomic estimates include a partial share of the benefits that could emerge from direct individual investments in one's own human capital, the distinction between the two estimates can be interpreted as an indicator of the magnitude of externalities arising from human capital. According to A. de la Fuente and A. Ciccone, the majority of the credible sources of such externalities result from the correlation between human capital and the rate of technological innovation, as well as

the indirect effect of education on labor productivity and employment through its influence on the quality of social institutions, which may be regarded as a constituent of social capital (*Mankiw G., Romer D., Weil D., 1992*). Certain theoretical models also suggest that the accumulation of human capital can increase its externalities, since some benefits arising from a more educated labor force will dissipate from it and generate benefits that cannot be claimed by those who have made relevant investments in human capital in the form of higher wages and other incomes as a result of the growing gap between the relevant private and social rates of return (*Manuelli R.E., Seshadri A., 2014*).

In this paper, based on historical and logical methods of scientific research, on the basis of the findings of a critical comparative analysis of contemporary theories of growth including the component of human capital, an attempt is undertaken to theoretically validate the distinctive characteristic of human capital, which enables us to elucidate the phenomenon of increasing returns while conducting empirical testing of economic growth models, explains the reasons for the cyclical development of the economy in terms of the aggregate effect of investments in human capital, and provides insights into the question of how exactly human capital, knowledge and technical advancement are interrelated in the economy.

It is assumed that the following mechanisms operate through which investments in human capital affect the productivity of other factors of production; moreover, they prevent the implementation of the law of diminishing returns: 1) investments in human capital enhance the effectiveness of research activities and ensure scientific and technological advancement; 2) education contributes to the formation of human capital, which directly affects the accumulation of knowledge and, consequently, the expansion of productive capacity of all factors of production. Meanwhile, knowledge is perceived as a universally accessible public good; specifically, it can circulate freely from organizations and people that develop it to those organizations and people that utilize it, thus generating beneficial externalities in social production. Due to the existence of positive externalities of new knowledge and human capital, increasing returns to human capital should be observed on the macro level. Therefore, it may be inferred that an increase in per capita human capital within any country also leads to an increase in investment in physical and human capital, contributes to higher rates of per capita income growth, and, ultimately, is realized in higher labor productivity and compensation per employee.

Results

The findings from a wide range of empirical studies on the economic growth of countries contradict the principle of diminishing returns, as well as constant returns to scale. Empirical evidence consistently implies increasing returns to scale in the models of economic growth. Therefore, M. Todaro underlines that across the entire economy, the evidence and outcomes of empirical testing of endogenous growth models refute the principle of diminishing marginal returns to capital and indicate that at the macroeconomic level the principle of increasing returns, determined by positive externalities, functions (*Todaro M.P., 1997*). P. Romer further did not exclude the possibility that the aggregate production function may be identified by increasing returns to scale (*Romer P. M., 1986*). But P. Romer clarifies this by stating it as the increasing return on physical capital.

D. Acemoglu (*Acemoglu D., 1996*) strives to formulate a theoretical justification for increasing social returns generated by the accumulation of human capital. He postulates a mechanism of monetary externality that is determined by the interaction of investment and resource-intensive search in the labor market. This mechanism is demonstrated in practice as follows: despite the absence of technological externalities and the fact that all employees compete for the same jobs, the effects of inclusion of investments in human capital increase due to external factors generated in the course of human capital accumulation (*Mayilyan F. N., 2021*).

We consider that increasing returns to scale are governed by the principle of increasing returns, not based on physical capital, but rather on human capital. However, increasing returns on human capital can be realized only at the macroeconomic level across the entire economy, and not at the individual level, and only in the long run perspective. Naturally, at the level of individuals there may also be deviations from this pattern. (*Mayilyan F. N., 2015*). For instance, if an individual is characterized by extraordinary talent, then relatively small investments in human capital can produce considerable returns compared to larger investments in the human capital of less talented individuals. However, at the macro level, these differences are equalized, since the accumulation of human capital is ongoing - retiring human capital is replaced by the incoming employees. Furthermore, human capital has the potential not only to accumulate, but also to be transferred through the application of formalized knowledge, experience and skills in the production process. Increasing returns on human capital are guaranteed through the accumulation, implementation and transfer of new knowledge. But to explicitly illustrate this pattern, the continuous accumulation of knowledge at a "decisive point" is crucial, which fosters the rapid economic growth. We believe that this precisely clarifies the fact of increasing returns in empirical tests of the models of economic growth.

However, it should be emphasized that the process of human capital accumulation itself does not automatically ensure increasing returns on investment in human capital and does not contribute to self-perpetuating economic growth. To ensure sustainable economic growth, it is first and foremost necessary to create the necessary institutional conditions for the full realization and effective use of human capital. This is especially relevant for developing countries, where the level of accumulated human capital may be high, but its contribution to economic growth may be insignificant. Furthermore, this leads to an outflow of human capital and a distortion of the entire structure of human capital reproduction. Therefore, it is crucial to develop a program at the state level aimed at improving the conditions for reproduction, and, in particular, the conditions for the effective realization of human capital. This will ensure that investments in human capital are capable of ensuring high rates of economic growth due to their unique characteristics.

The reasons for the increasing return on human capital are as follows:

1. In contrast to the physical capital, which through its application gradually deteriorates and exits the production process due to physical and moral wear and tear, the human capital, throughout a defined period of utilization (the individual's working lifetime), is enhanced, improving in quality and accumulating: the knowledge and skills of employees are developing and improving, experience is accumulating over time, the degree of specificity and cross-specialization is advancing. With the passage of time, human capital wears out both physically and morally: the rapid development of science

and technology leads to a fast pace of knowledge depreciation, which imposes increased demands on employees and requires additional investments in human capital for the duration of an active working lifetime. And, consequently, this requires investments in human capital across the entire active working life of an individual. Here, it is vital to underline that investments aimed at improving or developing new knowledge and skills in individuals with prior training are more effective and require fewer financial and time resources. Skilled individuals find it easier to acquire new knowledge and improve previously acquired knowledge and skills. Specifically, the rate of return on investment in this case is higher in contrast to untrained individuals (*Mayilyan F. N., 2021*).

2. Physical capital is depleted entirely after the completion of its effective lifecycle. Unlike physical capital, human capital, after the expiration of its productive use, is not fully depleted, as the key element of human capital, knowledge, is accumulated in some form or another, can be transferred to next generations, is persistently used as well as contributes to the generation of new knowledge, skills and experience. It is crucial to underline that considerable importance is attached to the system of science and education in the process of transferring explicit knowledge, whereas social capital is significant in the transfer of tacit knowledge (*Mayilyan F. N., 2021*). Social capital serves as the crucial mechanism that ensures the effective transfer of tacit knowledge in a distinct system. Social capital refers to a set of norms, standards, and institutional relationships between members of society and government authorities, as well as interpersonal relations among members of society, established on trust and contributing to the increase of labor productivity. From the perspective of tacit knowledge transfer, the proportional allocation of social capital within society is equally significant (this issue is explored more comprehensively by the author in the paper "The Role of Social Capital in the Process of Formation and Realization of Human Capital") (*Mayilyan F.N., 2012*).

3. Human capital in the process of development and usage, frequently, depending on the scope of utilization of human capital and the peculiarities of the profession, contributes to the growth of the human capital of other individuals (exchange of experience, professional development, etc.). To be more specific, in the process of employing human capital, a synergistic effect is realized, which consequently provides considerable positive externalities from investments in human capital. Nevertheless, it should be highlighted that positive externalities emerging in the process of accumulation and utilization of human capital cannot be precisely measured, since the scope of externalities spans across all types of human activities and has a multiplicative effect. In this context, the inclusion of the value of positive externalities in the models of economic growth is bound by certain limitations (*Mayilyan F. N., 2021*).

4. Investments in human capital generate positive externalities demonstrated by the decline in disease rates, rise in average life expectancy, improvement of life quality, education quality, decline in unemployment rates, decrease in crime rates, enhancement of the environment within the country etc.

5. Contrary to conventional resources, the fundamental aspect of human capital, the knowledge base and resource, is inexhaustible and indicates a pattern of exponential growth: the higher the value it assumes, the faster it increases. The demonstrations of this pattern are intensifying and becoming more evident in recent decades, due to the rapid pace of digitalization of the economy. If land and physical capital, considered as factors of production, demonstrate the tendency of diminishing returns, then human

capital prevents the demonstration of the tendency of diminishing returns of these factors, thereby assuring economic growth and development. N.D. Kondratyev, in his distinguished work "Problems of Economic Dynamics," underlined that growth and development are irreversible processes, since they are grounded on the process of ongoing accumulation of knowledge, which is not considerably affected by economic conditions. On the contrary, the intensity of knowledge accumulation defines the economic landscape, solving the issue of the phases of economic development and helping ensure that the economy is not situated at the same level or stage of development on more than one occasion (*Kondratiev N.D., 1989*).

6. If the investment in physical capital is determined only by economic incentives and generates a private return on investment, then the process of investing in human capital is strongly affected by national, historical, psychological and socio-cultural factors. Consequently, investments in human capital, in addition to private returns, also provide social returns. And frequently, social returns outweigh the level of private returns from investments in human capital, thereby reinforcing the trend of increasing returns on human capital (*Mayilyan F. N., 2021*).

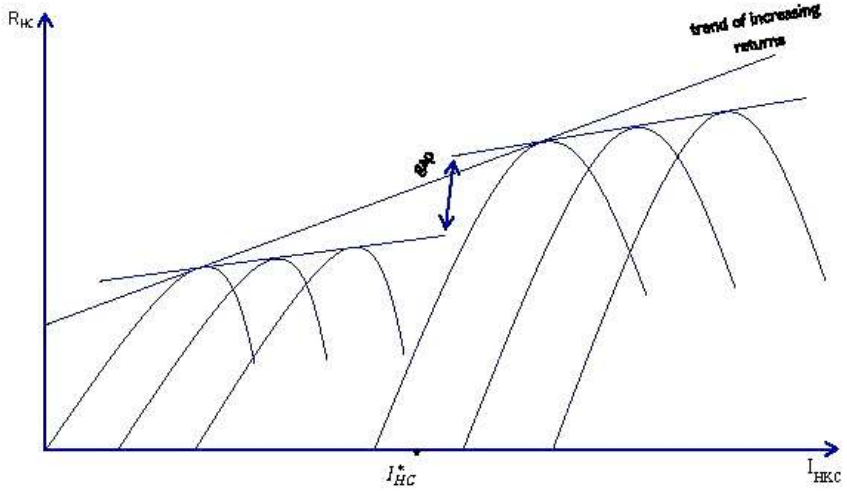
7. Investments in human capital usually generate a higher return rate when compared to physical capital both on the level of individuals and society as a whole. Although it should be highlighted that this pattern has some features that are indicated in the economies of developing countries, where the private return on human capital is often considerably lower than the level of social return. This is not attributed to the efficiency of the institutional setting for the realization of human capital as in developed countries, but to the high level of exploitation of human capital (*Mayilyan F.N.*, 2019).

Conclusion

If we analyze the return on investment in human capital at the macro level and in the long run (in the scope of large economic cycles) we can argue that investments in human capital are not constrained to the principle of diminishing returns. The process of renewal of human capital is ongoing; specifically, in the scope of economic cycles, human capital is constantly renewed. If in terms of quantitative analysis, the renewal of human capital within the scope of individual countries and regions can be simple, extended or narrowed, then in terms of qualitative analysis, due to the exponential pace in the accumulation of knowledge, the extended renewal is ensured in qualitative terms. If we aggregate the total investment in human capital of individuals, and the amount of private and social returns from investments in human capital, we can assume that at the macro level and in the long run a trend of increasing returns is expected. Namely, a function reflecting the relationship between investments in human capital and income will be obtained. It is important to highlight this principle in the scope of long-wave economic cycles. Consequently, the increasing trend of the economic cycle is due to the increasing returns on human capital. At a pivotal stage of knowledge accumulation (followed by a scientific and technological breakthrough) the return on investment in human capital increases dramatically. An illustration of the theoretical hypothesis of the principle of increasing returns on investment in human capital at the macro level can be introduced as follows (graph 1).

Graph1

Dynamics of return on investment in human capital



Source: *The schedule was compiled by the author.*

Where

$\boldsymbol{I_{HC}}$ *– investment in human capital*

$\boldsymbol{R_{HC}}$ *– return on investment in human capital*

$\boldsymbol{I^*_{HC}}$ *- the level of investment that aligns with the pivotal level of knowledge accumulation.*

As we see in graph 1, total investments in total human capital generate increasing returns over a specified period; subsequent to reaching a particular point, a trend of diminishing returns becomes evident (this trend appears until the point I^*_{HC}). But this trend emerges within the short-term period of the economic cycle and at the micro level. As investments in human capital continuously rise, the cumulative knowledge accumulation is ensured, and the "critical" level of knowledge accumulation is attained (the level that ensures a scientific breakthrough) a dramatic increase in the level of return from investments in human capital is demonstrated (indicated by an arrow on the graph). Specifically, in the long run and at the macro level, when investments in human capital are examined from the perspective of society as a whole and not of individuals, there is a tendency toward increasing returns on investments in total human capital. Investments in human capital are key factors that ensure the continuous development of science and economics. Essentially, investments in human capital should be regarded as the most profitable type of investment that provides high returns.

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INTERNATIONAL INDICES AS TOOLS OF MANIPULATION: A CRITICAL EXAMINATION

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Abstract: International indices, such as the Human Development Index (HDI), Corruption Perceptions Index (CPI), Doing Business Index, Safety Index, Happiness Index, and others, are pivotal in assessing national performance across economic, social, and political domains, influencing investment, policy, and global perceptions. However, their methodologies are vulnerable to manipulation through subjective criteria, selective data sources, and external political or economic pressures, raising questions about their objectivity and reliability. This article examines the mechanisms enabling such manipulation, including biased weighting, qualitative assessments, and geopolitical influences, using case studies from Georgia's CPI improvements, the World Bank's Doing Business scandal involving China and others, and Turkey's Democracy Index rankings. A regression analysis of the Happiness Index reveals that higher crime rates and antidepressant consumption paradoxically correlate with elevated happiness scores, suggesting methodological inconsistencies. Focusing on Armenia, the study presents original survey research involving 250 respondents (urban and rural, balanced by age and gender) to compare public safety perceptions with Armenia's high Safety Index ranking (8th globally, score 77.9, Numbeo 2024). The survey reveals significant discrepancies with the country's high Safety Index ranking, such as 50% reporting frequent theft and 30% of women feeling unsafe, highlighting methodological flaws in crowd-sourced indices. These findings underscore economic and political implications for small economies like Armenia, where idiocies drive tourism but misalign with realities. Recommendations include enhancing transparency and reforming safety policies. By integrating case studies, survey data, and regression analysis, this study contributes to discourse on index reliability and informs policy for small states.

Key words: *International indices, manipulation, public perception, Safety Index, Doing Business Index, Happiness Index*

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Introduction

International indices, such as the Human Development Index (HDI), Corruption Perceptions Index (CPI), Doing Business Index, Safety Index, Happiness Index, and others, serve as standardized tools to evaluate countries' performance in economic, social, and political domains. Compiled by organizations like Transparency International, the World Bank, the United Nations Organization, and recently popular Numbeo, these indices shape global perceptions, guide investment decisions, and influence policy reforms in countries worldwide. However, their methodologies – often reliant on subjective criteria, selective data sources, and vulnerable to external pressures – raise concerns about objectivity and potential manipulation. Such vulnerabilities necessitate a critical examination of index construction.

The study employs a mixed-methods approach to investigate index manipulation. Three case studies – Georgia's CPI gains post 2003 Rose Revolution, the 2021 Doing Business scandal, and Turkey's Democracy Index rankings – use historical data and secondary sources to uncover manipulation mechanisms, including biased data selection and geopolitical influences. The Happiness Index regression analysis conducted for this study, using World Happiness Report data with Numbeo-sourced variables, reveals that higher crime rates and antidepressant consumption paradoxically correlate with elevated happiness scores, highlighting methodological flaws in well-being metrics. Such contradictions question index validity and necessitate a critical examination of index construction. A survey of 250 Armenian residents (urban and rural, balanced by age and gender) uses Likert-scale questionnaires (e.g., "never" to "very often") to assess perceptions of safety issues like theft, assaults, and nighttime security, compared to Armenia's high Safety Index ranking (8^{th} globally, score 77.9, Numbeo 2024). This article presents survey findings that expose discrepancies, such as 50% reporting frequent theft, underscoring flaws in crowd-sourced indices. The conclusion synthesizes findings and suggests future research directions.

Methodology of Index Formation

The construction of international indices involves standardized methodologies that ensure cross-country comparability. Each index relies on selected indicators, normalization techniques, and data sources that reflect the underlying concept being measured. The reliability and transparency of these indices depend heavily on how data are collected and processed.

Table 1

Classification of Major International Indices

Category	Index Name	Institution / Source	Main Indicators	Type of Data	Potential Manipulation Vulnerability
Economic	Doing Business Index	World Bank	Business regulation indicators (permits, taxes, credit, etc.)	Quantitative + expert survey	Data adjustments and political pressure
Economic	Global Competitiveness Index	World Economic Forum	Infrastructure, innovation, labor market, institutions	Mixed (survey + statistics)	Corporate bias in survey data

Social	Human Development Index	UNDP	Life expectancy, education, GNI per capita	Quantitative statistics	Limited context sensitivity
Political	Corruption Perceptions Index	Transparency International	Perceived public sector corruption	Expert and business surveys	Perception bias, selective sources
Political	Democracy Index	Economist Intelligence Unit	Electoral process, civil liberties, political culture	Expert assessment	Ideological bias, geopolitical influence
Safety / Well-being	Safety Index	Numbeo	Crowd-sourced crime and safety perceptions	Subjective survey data	Non-representative sample
Safety / Well-being	Happiness Index	World Happiness Report (Gallup)	Life satisfaction, GDP, social support, freedom	Survey + statistical inputs	Overreliance on subjective responses

Source: *Authors' compilation based on World Bank, UNDP, Transparency International, Numbeo.*

- **Human Development Index (HDI)** [1]

The HDI is a composite index measuring life expectancy at birth, education, and gross national income (GNI) per capita. Minimum and maximum thresholds are defined for each component to standardize them into indices ranging from 0 to 1. Education is represented by the arithmetic mean of expected and mean years of schooling. Income is transformed using the natural logarithm to reflect diminishing returns. The overall HDI is the geometric mean of the three-dimension indices (Human Development Report 2024).

Data Sources – Life expectancy: UN Department of Economic and Social Affairs; Schooling: UNESCO Institute for Statistics, World Bank, CEDLAS, UNICEF, ICF Macro Surveys, Barro-Lee dataset; GNI per capita: IMF, UN Statistics Division, World Bank.

- **Corruption Perceptions Index (CPI)**[2]

The CPI aggregates assessments from 13 sources measuring expert and business perceptions of public sector corruption, including bribery, misappropriation of public funds, and abuse of office for personal gain. Each source is standardized via Z-scores, then transformed to a 0–100 scale using the formula: $CPI\ score = Z \times 20 + 45$. The final score is the average of available transformed values, requiring at least three sources per country for inclusion. Standard errors and confidence intervals are calculated to account for variability across sources. Prior to 2012, differing methodologies and scaling methods prevented comparability over time. In 2012, Transparency International introduced a new methodology with a fixed mean (45) and standard deviation (20) based on that year's data. This change allows for direct comparison of CPI scores across years from 2012 onward. The final CPI score is the average of all available standardized values for a country. Inclusion requires at least three independent sources. A standard error is

[1] https://hdr.undp.org/data-center/human-development-index#/indicies/HDI
[2] https://www.transparency.org/en/cpi/2024

also reported to reflect variability among sources and to construct a 90% confidence interval, indicating the precision of the score (Transparency International, The ABC of the CPI, 2025).

Data Sources: African Development Bank, Bertelsmann Stiftung, Economist Intelligence Unit, Freedom House, Global Insight, IMD World Competitiveness Center, PERC, PRS Group, World Bank, World Economic Forum, World Justice Project, Varieties of Democracy (V-Dem).

- **World Happiness Report (Happiness Index)**[3]

Based on the Gallup World Poll, the index uses the Cantril Ladder method, asking individuals to rate their life satisfaction on a 0–10 scale. Regression analysis is used to quantify the contribution of six explanatory factors: GDP per capita (log-transformed), social support, healthy life expectancy, freedom to make life choices, generosity, and perceptions of corruption (Helliwell J. et al., 2024).

Data Sources – Survey data: Gallup World Poll; GDP: World Bank, IMF; Life expectancy: World Health Organization; Other variables: Gallup survey questions.

- **Doing Business Index**[4]

This index evaluates business regulations across ten areas: starting a business, dealing with construction permits, getting electricity, registering property, getting credit, protecting minority investors, paying taxes, trading across borders, enforcing contracts, and resolving insolvency. Each component is assessed using objective indicators and converted into a "Distance to Frontier" score (0–100). The final index is the average of the ten indicators (World Bank 2020).

Data Sources: legislative analysis, standardized questionnaires, expert surveys (lawyers, accountants, public officials).

- **Safety Index**[5]

The Safety Index is calculated as the inverse of the Crime Index, which is based on users' subjective perceptions of safety and crime. Survey participants rate aspects like fear of being robbed, perceived effectiveness of law enforcement, and safety when walking alone. Scores are scaled to a 0–100 range (Numbeo, 2024).

Data Sources: crowd-sourced user responses collected via Numbeo's online platform.

- **Global Peace Index (GPI)**[6]

The GPI measures internal peace (60%) and external peace (40%), using weighted indicators such as political instability, violent crime, militarization, weapons imports, and international conflicts. Each indicator is scored and aggregated using a weighted average formula: $GPI = 0.6 \times Internal\ Peace + 0.4 \times External\ Peace$ (Institute for Economics & Peace, 2024).

Data Sources: United Nations, World Bank, Stockholm International Peace Research Institute (SIPRI), Economist Intelligence Unit, Governmental and NGO reports.

In the digital era, international indices and statistical indicators are key tools for shaping political and economic strategies. They help states track trends, attract investment, and guide reforms. Strong performance enhances evidence-based

[3] https://www.worldhappiness.report/ed/2024/
[4] https://archive.doingbusiness.org/en/reports/global-reports/doing-business-reports
[5] https://www.numbeo.com/crime/indices_explained.jsp
[6] https://www.economicsandpeace.org/wp-content/uploads/2024/06/GPI-2024-web.pdf

policymaking and bolsters a country's international reputation. Conversely, low scores can undermine credibility and limit opportunities in tourism, investment, and international cooperation.

Mechanisms of Manipulation in International Indices

International indices have become powerful benchmarks for evaluating governance, economic development, democracy, and social well-being. They serve not only as analytical tools for policymakers but also as instruments of influence for international organizations. However, their objectivity is not guaranteed. Many indices are susceptible to manipulation through selective criteria, biased data sourcing, subjective evaluations, and non-transparent methodological adjustments. These mechanisms can be deliberately employed to favor or discredit certain countries, often in line with broader economic, political, or ideological interests.

Subjectivity of Criteria and Methodology

At the core of each international index lies a set of selected indicators – either quantitative or qualitative – used to measure performance in areas such as the economy, society, politics, environment, or technology. While these criteria are designed to offer standardized assessments, their selection and implementation are often subjective and open to manipulation.

Economic Criteria – Economic indicators commonly include GDP per capita, inflation rates, unemployment, debt-to-GDP ratios, and trade balances. These form the basis for rankings such as the Global Competitiveness Index or Economic Freedom Index. Although generally seen as objective, their influence depends heavily on data quality, sources, and the weight assigned to each variable. Investors and entrepreneurs often rely on such indices when evaluating business environments, making these criteria a target for selective emphasis or omission.

Social Criteria – Social indicators include education levels, healthcare access, life expectancy, poverty rates, and human rights protections. These metrics are typically developed by organizations such as the UN, WHO, or ILO. Despite their relevance, social indicators are particularly prone to subjective interpretation – especially when reliant on survey data or expert assessments. Methodological inconsistencies can arise across countries due to different data collection practices or selective inclusion of social issues.

Political Criteria – Political indices – such as the Democracy Index, Rule of Law Index, and Corruption Perceptions Index (CPI) – are frequently used to assess a country's governance and legal environment. These are often shaped by value-laden frameworks and funded or influenced by political actors. Many incorporate qualitative judgments or expert opinions, introducing a degree of bias. Moreover, the weight assigned to specific political dimensions (e.g., electoral process vs. civil liberties) can tilt rankings in a way that supports particular narratives or ideologies.

Environmental and Climate Criteria – These criteria track ecological performance through indicators like air pollution, CO_2 emissions, renewable energy use, and forest conservation. While mostly data-driven, these indices can still be influenced by the availability and reliability of national statistics or by focusing on selected environmental priorities that may disadvantage certain countries.

Technological and Innovation Criteria – Measured through outputs such as patent filings, R&D investment, digital infrastructure, and publication volume, these indicators reflect a country's innovation capacity. However, methodological bias can enter through unequal data reporting, selective timeframes, or differing definitions of what constitutes innovation.

While each index appears to follow a scientific and neutral framework, their construction often involves subjective methodological choices:

- **Indicator Selection**: Emphasizing or excluding certain indicators can favor a particular political or economic profile.
- **Source Bias**: Indices may draw on government reports, international databases, or NGO surveys – each carrying different assumptions and reliability levels.
- **Qualitative Assessments**: Many indices rely heavily on expert surveys, which are vulnerable to perception bias, ideological leanings, or limited geographical understanding.
- **Weighting Systems**: The relative weight assigned to different criteria can significantly alter outcomes. These weights are often chosen without full transparency and may reflect institutional preferences.
- **Inconsistent Data Processing**: Applying different data collection or transformation methods across countries (e.g., using hard statistics for some and perception-based surveys for others) compromises comparability and fairness.

Political interests can further exacerbate these distortions. Indices are sometimes funded, developed, or promoted by actors with strategic agendas. In such cases, index design may serve geopolitical purposes – rewarding allies, penalizing rivals, or legitimizing preferred governance models.

Therefore, while international indices are widely regarded as tools of evidence-based governance and global benchmarking, they often embody subjective choices that can be strategically manipulated. To interpret them responsibly, one must critically assess their methodological transparency, data integrity, and underlying institutional motivations.

Case Studies of Index Manipulation

While international indices are often presented as objective tools for evaluating the progress and condition of states, their methodologies – frequently reliant on subjective expert assessments or limited surveys – open the door to manipulation and bias. Below are selected case studies that illustrate how indices have been used not only to reflect but to shape political and economic realities.

- **Corruption Perceptions Index: Selective Narratives and Political Legitimacy**

Following the 2003 Rose Revolution, Georgia implemented ambitious reforms aimed at combating corruption and modernizing the state. The country's position in Transparency International's Corruption Perceptions Index (CPI) improved dramatically – from 124th place with a score of 1.8 in 2003 to 64th with 4.1 in 2011 – signaling international approval and attracting praise from Western donors like USAID and Freedom House. However, deeper scrutiny revealed that these improvements were largely focused on low-level corruption and public service transparency, while high-level corruption and political favoritism persisted.

By the 2010s, evidence of systemic corruption within the ruling elite surfaced. Business dealings connected to Bidzina Ivanishvili, the billionaire founder of the

Georgian Dream coalition, raised serious concerns. His companies and those linked to his relatives allegedly received preferential treatment, questionable public contracts, and favorable legal outcomes[7]. Yet during this same period, the CPI continued to register improvements. For instance, in 2018 Georgia ranked 41st with 56 points. Experts argue that such perception-based indices are particularly vulnerable to elite lobbying and donor-driven narratives, which can mask deeper governance issues and legitimize power structures rather than challenge them[8]. Georgia's case reveals how the CPI can also become a tool for sustaining favorable international images that obscure state capture and elite corruption.

- **Doing Business Index: Geopolitical Pressures and Data Manipulation**

A striking example of methodological vulnerability and political pressure is the World Bank's Doing Business index, which was discontinued in 2021 after revelations of data manipulation. In the 2018 edition, China's ranking was initially projected to fall from 78th to 85th, a politically inconvenient development as the World Bank sought increased funding from its major shareholders – China included. An independent investigation by WilmerHale revealed that senior officials pressured staff to alter China's data, ultimately maintaining its position at 78th[9].

This manipulation was not isolated. Saudi Arabia, Azerbaijan, and the UAE were also found to have benefited from selective adjustments, with methodological changes aimed at artificially inflating their rankings. The case exposed a broader systemic flaw: the susceptibility of global indices to political influence, especially when compiled by institutions reliant on the financial contributions of powerful states[10].

Critics emphasized that the problem extended beyond individual rankings to the structural design of the index itself. Its reliance on self-reported data, elite surveys, and overly simplified benchmarks made it ripe for exploitation. WB created an external advisory group led by professor Cárdenas, which called for governance reforms within the World Bank to prevent conflicts of interest, especially within the framework of Reimbursable Advisory Services, which allowed countries to pay for technical assistance that conveniently aligned with improved rankings. Analysts warned that the Doing Business index had become a tool for geopolitical image management rather than an objective measure of investment environments.

- **Democracy Index: Strategic Labeling and Diplomatic Double Standards**

The Democracy Index produced by the Economist Intelligence Unit (EIU) also illustrates how indices can reflect political alignments more than democratic realities. Turkey, a NATO member and strategic partner to the West, has undergone significant democratic backsliding, especially since the failed 2016 coup attempt. The government responded with mass arrests, civil service purges, and an unprecedented crackdown on media freedom. In the 2024 *Democracy Index*, Turkey ranks 102nd out of 167 countries, scoring 4.4 out of 10, placing it in the "hybrid regime" category, which indicates a mix of democratic and authoritarian traits. For comparison, in 2006, Turkey was considered

[7] https://transparency.ge/en/post/russian-businesses-bidzina-ivanishvili-and-his-relatives
[8] Corruption and Anti-Corruption Policy in Georgia: 2016-2020. Transparency International. https://transparency.ge/en/post/corruption-and-anti-corruption-policy-georgia-2016-2020
[9] Sandefur J. "The Data Manipulation Scandal That Could Topple the Heads of the World Bank and IMF". https://www.cgdev.org/blog/data-manipulation-scandal-could-topple-heads-world-bank-and-imf-explained
[10] Broome, Andre. 2022. "Doing Business: How Countries Gamed the World Bank's Business Rankings." https://eprints.lse.ac.uk/114220/1/politicsandpolicy_world_bank_business.pdf

a "flawed democracy," holding a higher position[11]. Nevertheless, critics argue that this categorization softens the extent of Turkey's authoritarian drift.

As Human Rights Watch has documented, Turkey's democratic institutions have been systematically eroded. The judiciary lacks independence, civil liberties are restricted, and over 85% of the media is controlled by pro-government conglomerates. Opposition voices are silenced through arrests, internet censorship, and regulatory pressure[12]. Yet Turkey's international image remains buffered by its geopolitical importance. This results in muted criticism and comparatively moderate ratings in global indices, raising concerns about whether the Democracy Index and others are influenced by diplomatic alliances rather than objective analysis.

These cases reveal that international indices, while framed as neutral benchmarks, can serve as instruments of soft power, strategic influence, or even manipulation. Whether through elite lobbying, political pressure, financial interests, or methodological loopholes, indices such as the CPI, Doing Business, and Democracy Index can be shaped to advance particular narratives and obscure inconvenient truths.

- **Happiness Index: Unpacking Empirical Contradictions**

This study conducted an econometric analysis to examine the Happiness Index's methodological vulnerabilities, aligning with concerns about index manipulation. While the Happiness Index may seem less critical than economic or governance metrics, its growing relevance is evident in Bhutan's pioneering adoption of Gross National Happiness (GNH) as its primary development indicator, prioritizing well-being over GDP. Other nations, such as the UAE with its Ministry of Happiness, increasingly focus on subjective well-being to shape policy.

Using the Happiness Index as the dependent variable, the regression model incorporated explanatory variables such as crime rate, antidepressant consumption and internet access. We used cross-sectional data from 46 countries for the year 2021. Surprisingly, the results indicate that higher crime rates and increased antidepressant consumption positively correlate with elevated happiness scores (see Table 2).

Table 2

Regression Analysis of Happiness Index

Dependent Variable: HAPPINESS_INDEX				
Method: Least Squares				
Included observations: 45 after adjustments				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
ANTIDEPRES-SANT	0.012010	0.003864	3.108487	0.0034
CRIME_RATE	0.000257	8.62E-05	2.981271	0.0048
INTERNET_ ACCESS	0.043106	0.012344	3.492015	0.0012
C	1.173383	1.182314	0.992447	0.3268
R-squared	0.619243	Mean dependent var		6.458000
Adjusted R-squared	0.591383	S.D. dependent var		0.900453

[11] https://www.hrw.org/world-report/2016/country-chapters/turkey
[12] https://www.hrw.org/world-report/2023/country-chapters/turkey

S.E. of regression	0.575599	Akaike info criterion	1.817875
Sum squared resid	13.58386	Schwarz criterion	1.978467
Log likelihood	-36.90218	Hannan-Quinn criter.	1.877742
F-statistic	22.22673		
Prob (F-statistic)	0.000000	Durbin-Watson stat	2.150333

These counterintuitive findings suggest flaws in the Happiness Index's construction, such as overreliance on subjective surveys or inconsistent weighting, which may misrepresent societal well-being and align with manipulative practices seen in other indices. These issues, mirrored in the Happiness Index regression, highlight the risk of misaligned policy priorities in small economies like Armenia, where global rankings influence perceptions and investment, underscoring the need for rigorous, context-sensitive methodologies.

Armenia and the Safety Index: Perception vs. Reality

Armenia's geopolitical and economic context makes it highly sensitive to international indices. In 2022, its HDI was **0.786** (76th globally), reflecting gains in life expectancy, education, and per capita GDP (UNDP, 2022). Its 2023 GDP per capita was **$8,053,** placing it mid-tier among regional peers (World Bank, 2023). The CPI improved from 35 in 2018 (105th) to 47 in 2024 (63rd) (Transparency International, 2024).

Despite these improvements, the **Safety Index** ranked Armenia **8th out of 147 countries** in 2024, with a score of 77.9 (Numbeo, 2024), highlighting potential discrepancies between global rankings and local perceptions.

To investigate the alignment between Armenia's Safety Index ranking and public perceptions, a survey was conducted among 250 Armenian residents, comparing internationally published data with subjective experiences on crime, safety, police effectiveness, and external threats. The survey replicated the structure and logic of Numbeo's data collection method, relying on voluntary self-reporting and perception-based questions. This approach was intentionally adopted to reveal the inherent methodological weaknesses of such surveys, particularly their vulnerability to sampling bias and territorial imbalance. Although this design illustrates the problem of subjectivity in safety perception measurement, it also carries the same limitation: it may flatten regional differences, overrepresent urban respondents, and underrepresent rural or border communities.

Questions addressed perceptions of theft, physical assaults, violent incidents, criminal groups, nighttime safety, safety of women and children, public transport safety, police effectiveness, weapon accessibility, and external threats (see Table 3).

Table 3

Sample Survey Questions

Question	Response Options
How often do thefts occur in Armenia (home, car, or parts theft)?	1 – Very Rarely … 5 – Very Often
How often do physical assaults occur (street fights, robbery-related violence, etc.)?	1 – Very Rarely … 5 – Very Often

How visible are criminal groups in Armenia?	1 – Not visible at all … 5 – Very visible
How safe do you feel walking alone at night in your city?	1 – Not safe at all … 5 – Completely safe
How effective is the police in preventing and controlling crime?	Yes / Partly / No
How strong are external threats to Armenia from neighboring countries?	1 – Not strong … 5 – Very strong

Source: *Authors' compilation based on survey (YSU, 2025), replicating Numbeo methodology.*

Responses were collected using structured questionnaires with a Likert scale (e.g., "rarely," "sometimes," "often") to assess perceptions. The data were analyzed descriptively to identify patterns across region, gender, and age. The survey tested the following hypotheses:

- **H1:** Public perceptions of safety in Armenia differ significantly from the Safety Index ranking.
- **H2:** Urban residents perceive higher crime rates than rural residents, reflecting population density and socio-economic factors.
- **H3:** Women and younger respondents report lower safety perceptions due to gender-based vulnerabilities and media exposure.

Survey Findings

The survey revealed significant discrepancies between Armenia's Safety Index ranking and public perceptions. Key findings are presented below (see Table 4):

Table 4

Survey main findings

Category	Indicator	Key Findings	Demographic/Regional Patterns
Perception of Crime	Theft	50% reported theft occurs "often" or "very often"	Yerevan: 60%, Rural: 40%
	Physical Assaults	40% report "sometimes," 25% "often/very often"	Women: 35%, Men: 15%
	Violent Incidents	40% report "often/very often"	Age 18–24: 50%
	Criminal Groups	60% "mostly invisible/sometimes visible"	Yerevan: 30% "visible"
Perception of Safety	Nighttime Safety	40% feel "mostly safe"	Women: 30% "mostly/completely unsafe"
	Women & Children Safety	50% believe "mostly unsafe"	Rural: 60%

	Public Transport Safety	50% feel "yes/partly safe"	Women: 40% feel unsafe
Police Effectiveness	Overall Rating	60% "partly effective," 20% "not effective," 10% "effective"	Young (18–24) more critical
Weapon Accessibility and Use	Ease of Obtaining Weapons	40% report "partly/mostly easy"	Especially in Yerevan
	Weapon-Related Incidents	40% report "sometimes/often"	Negative impact on safety perceptions
External Threats and Immigration	Threats from Neighboring Countries	60% "very strong/quite strong"	Reflects tensions with Azerbaijan/Turkey
	Refugees & Immigrants	40% "neither low nor high," 20% "high"	—

Source: *Survey conducted by the authors among 250 Armenian residents in 2025, replicating Numbeo methodology.*

Overall, regional and demographic differences show that:

- Residents of Yerevan more frequently reported high rates of theft, violent incidents, and use of weapons compared to those in the regions. Meanwhile, regional residents more often emphasized that women and children feel unsafe at night.
- Women more often gave negative assessments of safety, especially at night and on public transport. Men, by contrast, were more likely to report feeling safe.
- Young people (18–24) reported higher exposure to violence and weapons, yet paradoxically felt safer overall. Older adults (45–64) were more critical of external threats.

Analysis

The survey confirms H1, showing a significant gap between Armenia's high Safety Index ranking and public perceptions. Urban-rural differences (H2) are evident, with Yerevan residents perceiving higher crime rates, likely due to density and economic inequality. Gender and age disparities (H3) highlight women's and young people's heightened concerns, driven by vulnerabilities and media exposure. The Safety Index's reliance on crowd-sourced data from Numbeo may overstate Armenia's safety by prioritizing quantitative metrics over subjective experiences, underscoring methodological flaws.

The misalignment between the Safety Index and public perceptions has economic and political implications. Economically, a high Safety Index ranking attracts tourists and investors, but persistent public concerns could deter visitors if not addressed. Politically, low trust in police and high external threat perceptions fuel public discontent, potentially leading to protests or demands for reform. Findings highlight the need for targeted safety policies, despite Armenia's post-2018 transparency reforms.

Discussion

The case studies and Armenia's survey highlight how international indices can be shaped by subjective criteria, selective data, and external pressures. In Georgia, the CPI masked high-level corruption; the Doing Business scandal revealed rankings adjusted to favor powerful states; in Turkey, geopolitical importance softened Democracy Index evaluations; and the Happiness Index shows paradoxical correlations between crime rates, antidepressant use, and happiness scores. Armenia's high Safety Index ranking, while seemingly positive, does not fully reflect public perceptions, revealing methodological limitations.

These discrepancies carry tangible economic and political consequences. High index rankings may attract investment, yet misaligned perceptions can undermine trust and policy effectiveness. The Armenia survey demonstrates the value of local data in challenging global indices and informing more accurate, context-sensitive policies. Small economies are particularly vulnerable, as indices heavily influence investment and governance decisions.

This study does not aim to design a new universal methodology for global indices but rather to expose the weaknesses within existing ones. By identifying how subjective weighting, selective sourcing, and perception-based surveys distort outcomes, it highlights the need for greater transparency and methodological accountability rather than entirely new measurement systems.

Recommendations

To reduce manipulation risks and enhance index reliability:

1. Enhance Methodological Transparency: Index compilers should standardize data sources and reduce reliance on subjective surveys, using independent audits to ensure accuracy.
2. Incorporate Local Perspectives: Indices like the Safety Index should integrate local surveys, as demonstrated by Armenia's case, to reflect subjective experiences.

Conclusion

International indices shape perceptions of national performance but are often biased by subjective methods, selective data, and political influence. Case studies from Georgia, the Doing Business scandal, and Turkey illustrate this, while Armenia's Safety Index contrasts sharply with local perceptions. Our survey highlights the value of local data in questioning global rankings and guiding reforms. Ensuring transparency, inclusivity, and methodological rigor is crucial for indices to reflect reality, especially in small economies. Future research should expand local surveys to validate global indices and better understand their economic and social impacts.

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THE RECONFIGURATION OF INTRA-REGIONAL TRADE IN THE EAEU UNDER SANCTIONS AGAINST RUSSIA[1]

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Abstract: The 2022 sanctions on Russia created a natural experiment testing the resilience of the Eurasian Economic Union. This paper investigates the transformative impact of these sanctions on the structure, volume, and logistics of intra-regional trade within the EAEU. It aims to identify the key adaptation mechanisms that ensured the bloc's resilience and to analyze the reconfiguration of its internal economic landscape. Using 2021–2024 trade and logistics data, we document a stark divergence: while Russia's and Belarus's 2024 exports contracted to 80.2% and 20.0% of their 2021 levels, respectively, Armenia's exports surged to 439.4%, with Kyrgyzstan and Kazakhstan also more than doubling. A granular analysis reveals profound structural shifts beneath these aggregates: EAEU imports consolidated around critical machinery and consumer goods, while exports underwent a pronounced shift towards a commodity-based economy, with the share of mineral fuels soaring from 44% to 62% of the total. This reorientation was enabled by a logistical pivot to road transport, which saw a 28% increase in freight turnover, and the emergence of vital hubs like Armenia. We argue that the EAEU's pre-existing institutional architecture was critical for this adaptation, transforming into a vital buffer. While the sanctions were a primary catalyst, other global economic factors concurrently shaped these outcomes. The study offers global lessons on the diminishing returns of sanctions against integrated blocs and the newfound strategic agency of small economies in a fragmenting world.

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Introduction

The contemporary geo-economic reality is characterized by the increasing use of sanctions as a tool of foreign policy (Morgan et al., 2023). However, their effects often prove to be more complex and contradictory than intended (Felbermayr et al., 2025). The sanctions against Russia, being among the most extensive in recent history, have had not only direct but also profound indirect consequences, radically transforming the economic landscape of the Eurasian Economic Union (EAEU). Rather than triggering the anticipated disintegration, this external pressure has catalyzed a deep internal restructuring of the bloc, constituting the central paradox examined in this article.

Our analysis focuses on the transformative impact of sanctions on the EAEU's intra-regional trade. We argue that the sanctions shock served as a catalyst for reconfiguring trade and logistics flows within the Union; second, it exacerbated the bloc's internal asymmetries, leading to a sharp divergence in the economic trajectories of its member states; and third, it activated previously latent integrative potentials, transforming the EAEU from a largely declaratory project into a practical mechanism for collective adaptation. To verify these theses, the article employs a multi-level analysis, assessing the dynamics of mutual trade, examining profound shifts in the commodity structure of imports and exports, in the structure of freight transport, and synthesizing the adaptation strategies of individual member states. The empirical foundation of the research is comprised of official EAEU and national government statistics for the period 2021–2024.

Literature Review

A significant portion of the academic literature on the EAEU has traditionally focused on analyzing its institutional design, the political-economic motives of its member states, and assessing its effectiveness under "normal" conditions. Research by scholars such as Tarr (Tarr, 2016), Vinokurov (Vinokurov, 2017) has concentrated on the establishment of common markets, customs regulation, and potential effects of trade creation and diversion. While these works have laid a crucial foundation for understanding the Union's structure, they have typically treated it as a static model, paying insufficient attention to the bloc's potential and mechanisms for adapting to high-intensity exogenous shocks.

A separate strand of scholarship, actively developed after 2014 and especially after 2022, examines the economic consequences of sanctions for Russia. These works (Sedrakyan, 2022; Bali et al., 2024) provide detailed analyses of aspects such as import substitution, trade reorientation to the East, and the resilience of the macroeconomic system. However, this body of literature is predominantly confined to the national framework of the Russian Federation, treating it as an isolated object of pressure (Loginova et al., 2015; Belozyorov, Sokolovska, 2020). Consequently, the systemic impact of sanctions on the configuration of the entire regional integration bloc to which Russia belongs often remains on the periphery of scholarly attention.

In a broader context, there is a theory concerning the resilience of regional groupings to external shocks. Studies focused, for instance, on the European Union and its crises

(Sensier, 2016; Giannakis, Bruggeman, 2017; Di Pietro et al., 2020), emphasize the role of supranational institutions and solidarity in overcoming difficulties. Nevertheless, this theoretical framework has been applied only sparingly to the EAEU. A gap exists in empirical research that would demonstrate with concrete data how exactly the EAEU's pre-established rules (e.g., unified technical regulations, the free trade regime) were operationalized for adaptation, and how a shock targeted at one economy transformed the interactions between all members of the bloc.

Thus, at the intersection of these research fields, a clear scientific gap emerges. The following aspects remain understudied: 1) the differential impact of the sanctions shock on the economies of all EAEU member states and the consequent divergence of their roles within the Union; 2) the specific mechanisms of logistical and trade adaptation (such as the modal shift in freight transport and the emergence of new hubs) that enabled the redistribution of flows; and 3) the testing of the thesis on the paradoxical strengthening of an integration grouping under destabilizing external pressure. This article aims to fill this gap by offering a comprehensive analysis of the transformation of the EAEU's intra-regional trade as a holistic system, demonstrating that the sanctions acted not as a factor of disintegration, but as a catalyst for its new, qualitatively deeper, yet more asymmetric configuration.

Methodology

The research methodology is based on an integrated approach, combining quantitative and qualitative analysis. The empirical foundation was comprised of official EAEU and national statistics for the period 2021–2024, supplemented by data from the international Trademap database (Trademap, 2025) for verifying trade flows and operational information from key logistics operators reflecting real-time dynamics in freight traffic and tariffs on specific corridors. Qualitative analysis involved a review of the Union's regulatory framework and case studies of member states' adaptation strategies. This comprehensive approach allowed not only for the identification of macroeconomic trends but also for the uncovering of the underlying microeconomic mechanisms and logistical practices of adaptation.

Results

The Sanctions Shock as a Catalyst for the Reconfiguration of Intra-Regional Trade

The unprecedented sanctions pressure served as a powerful stress test for the EAEU, creating a unique natural experiment for assessing the resilience of regional integration.

The EAEU's position in the global economy was characterized by a limited scale, accounting for only 1.7% of world trade (Diagrams 1, 2), which underscored its marginal influence and heightened susceptibility to external economic shocks.

Diagram 1

The EAEU in world trade

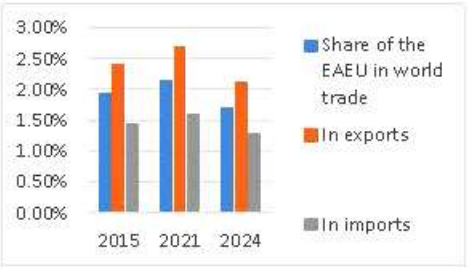
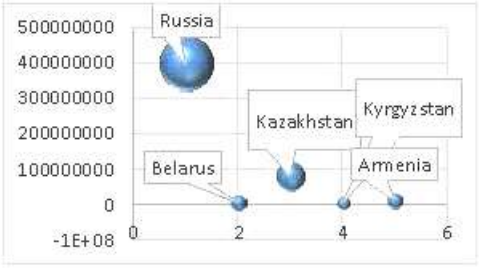


Diagram 2

EAEU's trade turnover in 2024



Source: *Developed by the authors based on Trademap's data (Trademap, 2025)* URL: https://www.trademap.org/Index.aspx (accessed October 1, 2025)

Internally, the Union exhibited a pronounced asymmetry, with Russia's economy constituting the overwhelming share of the bloc's GDP and trade turnover. This fundamental imbalance meant that any major external shock targeting the Russian economy, such as the unprecedented sanctions pressure, would inevitably create systemic consequences and transmit vulnerabilities across all member states within the integrated bloc. However, contrary to expectations of disintegration, the EAEU's internal market demonstrated remarkable resilience, acting as a critical stabilizing mechanism.

Despite the initial shock in 2022, the level of mutual trade not only recovered but also showed significant growth. According to official data (Izvestiya, 2025), mutual trade within the EAEU grew by 6.8% in 2024, reaching 9 trillion rubles (approximately 113 billion US dollars). This overall growth, however, masks a profound internal transformation.

The most direct evidence of this is the stark divergence in trade performance across member states (Table 1).

Table 1

Changes in Exports and Imports by EAEU Country, 2024/2021, %

Country	Export			Import		
	2019/2015, %	2024, bn USD	2024/2021, %	2019/2015, %	2024, bn USD	2024/2021, %
World	114.3	23900.0	107.9	115.2	24090.4	107.3
Russia	127.2	398.1	80.2	128.9	206.0	77.3
Belarus	137.6	6.7	20.0	138.3	16.8	44.0
Kazakhstan	125.6	81.6	135.3	125.5	59.8	144.4
Kyrgyzstan	119.4	3.7	225.5	124.5	11.9	213.8
Armenia	176.6	13.0	439.4	155.4	16.8	315.7
EAEU	127.7	503.2	84.6	129.7	311.3	87.2

Source: *Calculated by the authors based on Trademap's data (Trademap, 2025)* URL: https://www.trademap.org/Index.aspx (accessed October 1, 2025)

As we can see, the Union effectively split into two groups. Russia and Belarus experienced a severe contraction, with their exports falling to 80.2% and a dramatic 20.0% of their 2021 levels, respectively. In stark contrast, the other three member states demonstrated remarkable resilience and explosive growth: Armenia's exports surged to

439.4% of the 2021 level, while Kyrgyzstan and Kazakhstan more than doubled their export volumes (to 255.4% and 210.3%, respectively). This divergence points to a key adaptation mechanism: the sanctions triggered a major reorientation of trade flows, with countries like Armenia and Kyrgyzstan amplifying their roles as vital trade and logistics hubs, facilitating both official and parallel imports into the larger EAEU market.

However, the nominal trade data presented in Table 1, while indicative of dramatic shifts, may be influenced by global inflationary pressures and currency fluctuations. To isolate the real changes in trade volumes and present a more objective picture, we adjusted the trade values using the global inflation rate from 2000 to 2024, with forecasts until 2030 (Statista, 2025) (Diagrams 3, 4). The data shows a dramatic contraction in real imports in 2022 (a drop of approximately 38%), reflecting the immediate disruptive impact of sanctions on supply chains and access to Western goods. Conversely, real exports surged in 2022, leading to a record trade surplus. This initial phase was likely driven by a combination of high global commodity prices and a rapid reorientation of Russian trade flows towards EAEU partners and other alternative markets. The subsequent sharp decline in both real exports and the trade surplus in 2023-2024 uncovers a more profound reality. The recovery in real imports suggests some success in establishing new supply routes and parallel imports. However, the simultaneous fall in real exports indicates the initial windfall was unsustainable and points to the mounting costs of adaptation. These costs include the higher expense of new logistics, the inefficiencies of reoriented supply chains, and a potential deterioration in the terms of trade for finished goods and technology.

Diagram 3

EAEU trade balance in real terms, USD bln

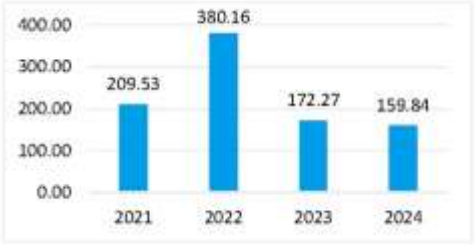
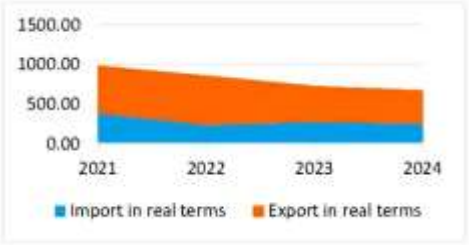


Diagram 4

EAEU imports and exports in real terms, USD bln



Source: *Calculated by the authors based on Trademap's data (Trademap, 2025)* URL: https://www.trademap.org/Index.aspx (accessed November 12, 2025)

This refined analysis demonstrates that while the EAEU demonstrated remarkable short-term resilience, the rapid erosion of the real trade balance highlights growing underlying vulnerabilities and signals that the long-term economic sustainability of the bloc has been significantly pressured.

Beyond the aggregate figures, a granular examination of shifts in the commodity structure of EAEU imports from 2021 to 2024 reveals the strategic reprioritization and specific vulnerabilities exposed by the sanctions.

The analysis of the EAEU's import structure (Table 2) reveals significant shifts in strategic priorities and adaptation patterns following the 2022 sanctions concerning the redistribution of import shares across commodity groups.

Table 2

Structural Shifts in EAEU Imports by Product Category (2021-2024, Nominal US Dollar in thousands)

HS Code	Product Group	Total EAEU Imports, bn USD		Share in Structure, %	
		2021	2024	2021	2024
01–15	Foodstuffs and Agricultural Raw Materials (excluding textiles)	27.12	16.20	7.00	6.32
16–24	Prepared Foodstuffs, Beverages, and Tobacco	17.40	12.77	4.49	4.98
25–27	Mineral Products and Fuel	10.25	6.89	2.65	2.69
28–40	Chemicals, Fertilizers, and Rubber	65.59	46.03	16.92	17.95
41–43	Raw Hides, Raw Fur Skins, and Articles Thereof	1.50	1.28	0.39	0.50
44–49	Wood, Pulp, and Paper Articles	6.58	3.12	1.70	1.22
50–67	Textiles, Textile Articles, and Footwear	22.30	20.49	5.75	7.99
71	Precious Stones, Precious Metals, and Articles Thereof	1.87	7.30	0.48	2.85
72–83	Base Metals and Articles Thereof	30.22	16.77	7.80	6.54
84–90	Machinery, Equipment (including electrical), and Vehicles	160.72	114.18	41.46	44.52
68–70, 91–99	Other Goods	44.05	11.418	11.36	4.45
Total		387,62	256.46	100	100

Source: *Calculated by the authors based on Trademap's data (Trademap, 2025)* URL: https://www.trademap.org/Index.aspx (accessed November 12, 2025)

The most dramatic transformation occurred in several key categories. Machinery and equipment (HS 84-90) consolidated their position as the dominant import category, increasing its share from 41.46% to 44.52% of total imports despite a substantial absolute decline. This underscores the critical, inelastic demand for technological imports that could not be readily substituted domestically, likely reflecting both continued needs for industrial equipment and consumer demand for electronics rerouted through alternative channels. Simultaneously, textiles and footwear (HS 50-67) demonstrated remarkable resilience, with their share growing from 5.75% to 7.99% – the second-largest percentage point increase among all categories. This suggests successful logistical adaptation for consumer goods, potentially facilitated by parallel imports and new supply routes through EAEU hub countries. Similarly, precious metals and stones (HS 71) experienced a spectacular six-fold increase in their relative share (0.48% to 2.85%), possibly indicating their role as alternative value storage adapting to financial restrictions.

Conversely, several categories experienced notable relative declines. Metals and articles thereof (HS 72-83) and wood and pulp products (HS 44-49) also saw significant relative declines, potentially indicating reduced demand from construction and manufacturing activities affected by the new economic conditions.

The relative stability in shares of chemical products (16.92% to 17.95%) and prepared foodstuffs (4.49% to 4.98%) suggests these essential industrial and consumer categories maintained their strategic importance, with supply chains successfully reconfigured to maintain access despite external pressures. This structural analysis reveals that the EAEU's import adaptation has followed a clear pattern of prioritizing essential technological inputs and certain consumer goods while sacrificing less critical manufacturing components and miscellaneous goods – a rational crisis response that has fundamentally reshaped the union's economic relationship with the global market.

A symmetrical analysis of the EAEU's export structure (Table 3) reveals an even more pronounced consolidation around primary commodities, highlighting a critical vulnerability despite the bloc's overall trade resilience.

Table 3

Structural Shifts in EAEU Exports by Product Category (2021-2024, Nominal US Dollar in thousands)

HS Code	Product Group	Total EAEU Exports, US Dollar Thousand		Share in Structure, %	
		2021	2024	2021	2024
01–15	Foodstuffs and Agricultural Raw Materials (excluding textiles)	33,80	28,54	5.66	6.85
16–24	Prepared Foodstuffs, Beverages, and Tobacco	10,55	8,15	1.77	1.96
25–27	Mineral Products and Fuel	262,18	257,83	43.91	61.93
28–40	Chemicals, Fertilizers, and Rubber	40,96	31,79	6.86	7.64
41–43	Raw Hides, Raw Fur Skins, and Articles Thereof	0,31	0,15	0.05	0.04
44–49	Wood, Pulp, and Paper Articles	19,67	8,92	3.29	2.14
50–67	Textiles, Textile Articles, and Footwear	3,93	2,28	0.66	0.55
71	Precious Stones, Precious Metals, and Articles Thereof	32,77	23,94	5.49	5.75
72–83	Base Metals and Articles Thereof	65,25	37,31	10.93	8.96
84–90	Machinery, Equipment (including electrical), and Vehicles	32,33	14,15	5.41	3.40
68–70, 91–99	Other Goods	95,38	3,22	15.97	0.77
Total		597,15	416,29	100.0	100.00

Source: *Calculated by the authors based on Trademap's data (Trademap, 2025)* URL: https://www.trademap.org/Index.aspx (accessed November 12, 2025)

The most significant change is the overwhelming consolidation of Mineral products and fuel (HS 25-27), whose share of total exports surged from 43.91% to 61.93%. This indicates that the union's role as a global supplier of energy and raw materials has intensified, making it more, not less, dependent on this volatile sector.

Conversely, several value-added sectors experienced a severe contraction in their relative importance. The most dramatic decline occurred in the "Other goods" category (HS 68-70, 91-99), which collapsed from 15.97% to a mere 0.77% of exports. Similarly, exports of Machinery and equipment (HS 84-90) and Metals and articles thereof (HS 72-83) saw their shares significantly reduced. This suggests a severe setback in industrial and technological exports, likely due to sanctions restricting access to key technologies and markets. Modest bright spots include a slight increase in the share of Food and agricultural products (HS 01-15) and Chemical products (HS 28-40), pointing to potential areas of sustained competitiveness. However, these gains are far outweighed by the dominant narrative of a retreat to a primary commodity-based export model, underscoring a significant challenge for the bloc's long-term economic development and resilience.

The Logistical Pivot: Enabling Trade Redistribution through Modal and Corridor Shifts

The profound reconfiguration of intra-Union trade would have been unattainable without a parallel and equally dramatic transformation of its logistical underpinnings. While the aggregate freight turnover for the EAEU demonstrated notable resilience, declining by a modest 2.2% from its 2021 peak to 6181.9 billion ton-kilometers in 2024 (Table 4), this macro-level stability belied a fundamental internal restructuring of supply chains.

Table 4

Cargo Turnover of EAEU Countries by Mode of Transport

Mode of Transport	billion ton-km		Share, %		Change 2024 vs 2021, %
	2021	2024	2021	2024	
All modes of transport	6,322.76	6,181.86	100.00	100.00	
Pipeline	2,808.15	2,685.16	44.41	43.44	-0.977069
Railway	2,938.66	2,858.69	46.48	46.24	-0.234207
Road (Motor)	332.78	426.93	5.26	6.91	1.6429547
Air	9.29	2.24	0.15	0.04	-0.110704

Source: *Calculated by the authors based on Eurasian Economic Commission's data* URL: https://eec.eaeunion.org/en/news/statistics/ (accessed September 15, 2025)

The sanctions precipitated a decisive modal shift, disrupting traditional transport hierarchies. Established, efficient modes were severely impacted: rail and pipeline transport, the historical backbone of Eurasian cargo, saw their shares erode, while the air freight segment, though small, collapsed by more than four times, becoming a direct casualty of the restrictions.

In this vacuum, road transport emerged as the paramount adaptation mechanism. It recorded a massive 28% increase in freight turnover, effectively becoming the primary artery for reconfigured import flows, particularly along nascent north-south and east-west corridors. This strategic pivot from globalized, speed-intensive supply chains (air) to flexible, regional, land-based alternatives (road) is starkly visible in the Russian data,

where road transport surged by over 30% even as air freight turnover contracted by almost 80% (Table 5). This shift underscores a market-driven reorientation towards flexibility and bypass routes, even at the cost of longer delivery times.

Table 5

Freight Turnover by Mode of Transport (billion ton-kilometers)

Country	Total Freight Turnover		Change, %	Road Transport		Railway Transport		Air Transport	
	2021	2024		2021	2024	2021	2024	2021	2024
EAEU	6322.76	6181.86	-2.23	362.37	…	2983.14	…	9.387	…
Armenia*	5.09	4.75	-6.66	1.05	1.26	0.81	0.38	0.002	0.012
Belarus	118.78	74.04	-37.66	29.59	...	44.48	...	0.093	…
Kazakhstan	483.49	520.92	7.74	33.72	36.77	297.41	332.06	0.077	0.065
Kyrgyzstan	2.62	3.18	21.36	1.35	1.53	1.00	1.08	0.021	0.253
Russia	5712.79	5578.96	-2.34	296.66	387.36	2639.43	2525.17	9.195	1.912

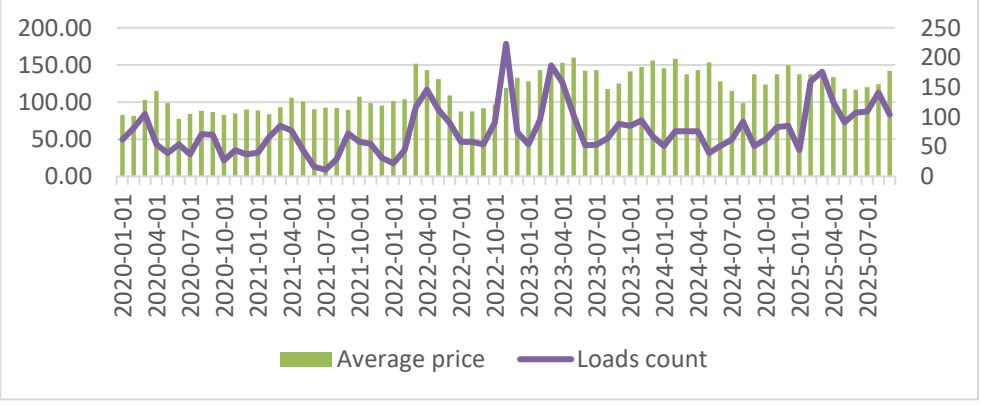
** Data for Armenia includes air freight turnover of other countries*

Source: *Calculated by the authors based on Eurasian Economic Commission's data URL: https://eec.eaeunion.org/en/news/statistics/ (accessed September 15, 2025)*

The real-world manifestation of this logistical pivot is captured by the evolution of key corridors, such as Moscow-Yerevan. An analysis of this route reveals a classic market response to a supply shock: following an initial period of disruption, a sharp recovery ensued within two months, characterized by a steep surge in both the volume of loads and the average tariff, which peaked by March 2024 (Diagram 5).

Diagram 5

Moscow–Yerevan Rates, RUB per km, VAT included



Source: *Developed by the authors based on ATI.SU Freight Exchange's data URL: https://ati.su/ (accessed October 1, 2025)*

This price spike signals the newfound strategic importance and initial congestion on this alternative pathway. The subsequent stabilization of rates indicates a market normalization as capacity adjusted, solidifying Armenia's role as a pivotal logistics hub. This "hub effect" is further corroborated by long-term data, which shows a sharp initial surge in Armenia's freight turnover in 2022 (109.6%), followed by a subsequent decline as markets optimized flows. Thus, the logistical landscape was not merely disrupted but

fundamentally reshaped, facilitating the trade redistribution by creating new, sanction-resistant supply chain pathways.

Divergent National Adaptation Strategies, Their Trade-Offs, and the Emerging Lessons

The dramatic reconfiguration of trade and logistics was facilitated by the distinct adaptation strategies employed by each EAEU member state. The sanctions shock forced a rapid re-evaluation of economic priorities, where each chosen path involved a calculated balance of short-term gains against long-term risks and vulnerabilities. The table (Table 6) below systematizes these divergent strategies and their inherent trade-offs.

Table 6

Key Adaptation Strategies of EAEU Countries (2021-2024)

Country	Armenia	Belarus	Kazakhstan	Kyrgyzstan	Russia
Core Strategy	Leverage EAEU status for trade with Russia, attract relocated companies, IT development	Maintain access to the Russian market, find alternative partners	Diversification, multi-vector policy, East-West balance	Re-export, regional hub between China-EAEU-South/Central Asia	Import substitution and pivot to the East
Trade Diversifi-cation	Russia (main), EAEU, US, EU	Russia (main), China, CIS, Asia	China, Russia, EU, Central Asia, Turkey, Persian Gulf	Russia (main), China, EAEU, Central Asia	China, India, Turkey, Middle East, Africa, Latin America
Domestic Production Support	IT sector support, FDI attraction, tourism development, export promotion	State industrial support, import substitution, SME assistance, export promotion	SME support, FDI attraction, manufacturing development, agriculture, IT sector	Industrialization, export agriculture, tourism	Subsidies, preferential loans, deregulation, innovation support, SEZs
Financial Measures	Liberalization, FDI attraction, financial sector development, exporter support	Russian ruble in mutual trade, currency restrictions, exporter support, financial market stabilization	Floating exchange rate, financial sector strengthening, cashless payments promotion	Migrant remittances, Russian ruble in mutual settlements	National currencies in settlements, alternative payment systems (SPFS), capital controls
EAEU Coopera-tion	Participation in EAEU infrastructure/ trade projects, leveraging membership benefits	Deeper integration with Russia, joint industrial/energ y projects, economic policy coordination	Transport corridor development, EAEU diversification projects, transit cargo attraction	Participation in EAEU infrastructure/tr ade projects, investment attraction	Deepening EAEU integration, developing transport corridors (North-South, East-West), industrial policy coordination

Risks and Challenges	Geopolitical risks, secondary sanctions risk	Dependence on the Russian economy, limited financial resources, technological backwardness, political risks, secondary sanctions	Secondary sanctions risk, raw material export dependence, infrastructure modernization needs	Dependence on the Russian economy and remittances, political instability risks	Technological dependence, logistics issues, inflation, skilled labor shortage, supply chain restructuring challenges

Source: *Developed by the authors*

This analysis of national strategies reveals that the process of choosing an adaptation path is inherently complex, involving significant trade-offs (the foregoing of one option to achieve the benefits of another) as well as synergies (the greater aggregate effect achieved by combining strategies). For instance, Russia's pivot and import substitution created synergies for the entire union by deepening industrial cooperation, but came with the trade-off of a persistent technological lag.

Furthermore, the EAEU's experience provides critical insights for understanding economic statecraft and regionalism in a fragmenting world. First, it underscores the immense value of pre-existing regional institutions, which do not merely facilitate trade during stable periods but can be activated as vital shock absorbers during crises. The EAEU's institutional framework, particularly its Common Economic Space with duty-free trade and unified regulations, provided a ready-made platform that allowed goods to be seamlessly rerouted between member states. This pre-established set of rules provided the necessary trust and operational mechanisms for a rapid, collective response, ultimately transforming the bloc from a trade agreement into a genuine economic buffer.

Second, the sanctions shock redefined the strategic role of smaller economies within the regional bloc. Countries such as Armenia and Kyrgyzstan were swiftly transformed from peripheral players into crucial logistical hubs and trade conduits. This demonstrates that in an era of reconfiguring supply chains, connectivity and strategic location can surpass raw economic mass in importance, granting smaller states significant leverage and newfound agency within their regional groups.

Finally, the case of the EAEU strongly suggests that comprehensive sanctions used as a blunt instrument of foreign policy can yield diminishing and even counterproductive returns. Instead of achieving the intended isolation of the target economy, the pressure stimulated the creation of alternative, sanction-resistant ecosystems within the union. This included the rapid development of alternative financial systems using national currencies and the forging of new internal trade routes. Consequently, such measures are less likely to cripple a target that is embedded in a cohesive regional group and are more likely to catalyze the very thing they aim to prevent: the formation of a more self-reliant, albeit reconfigured, economic space.

Discussion

Thus, the empirical analysis provides robust evidence that directly corresponds to the three central theses advanced in the introduction, demonstrating how the sanctions shock has fundamentally transformed the EAEU.

1. Confirmation of trade and logistics reconfiguration. The documented, stark divergence in trade performance – where Russia and Belarus contracted while Armenia, Kyrgyzstan, and Kazakhstan experienced explosive export growth – is the primary evidence supporting the first thesis. This was not a uniform decline but a fundamental reconfiguration of trade flows, with smaller member states becoming crucial conduits. This shift was physically enabled by a parallel logistical pivot, evidenced by the 28% surge in road freight turnover and the emergence of new strategic corridors like Moscow-Yerevan. The sanctions shock clearly served as the catalyst for this dual restructuring of commercial and supply chain pathways within the Union.

2. Validation of deepened internal asymmetries. The findings conclusively demonstrate that the reconfiguration process was inherently unequal, thereby confirming the second thesis on increased asymmetry. The EAEU effectively bifurcated into a core of directly sanctioned economies (Russia, Belarus) and a periphery of adaptive hubs (Armenia, Kyrgyzstan, Kazakhstan). This divergence in economic trajectories, quantified in Table 1, reveals how an external shock targeted at one member state systematically amplified pre-existing structural disparities, creating a new, more complex internal hierarchy within the bloc.

3. Demonstration of activated integrative potentials. Finally, the analysis confirms that the crisis activated latent integrative potentials, transforming the EAEU from a declaratory project into a practical buffer. The pre-existing institutional architecture – specifically the Common Economic Space with its duty-free trade and unified regulations – provided the essential platform for seamless trade rerouting. Furthermore, the operationalization of mechanisms for parallel imports and the accelerated shift to national currency settlements show how previously underutilized integrative tools were activated for collective adaptation. This demonstrates the Union's evolution into a functional mechanism for crisis management.

Thus, the cumulative evidence from trade, logistics, and institutional analysis consistently and powerfully affirms the article's three foundational arguments.

However, while this study establishes a strong associative relationship between the imposition of sanctions and the subsequent reconfiguration of EAEU trade and logistics, it is crucial to note that these observed changes cannot be attributed to sanctions as a sole cause. The period 2021-2024 was also marked by ongoing post-pandemic supply chain adjustments and global inflationary trends, which may have concurrently influenced economic outcomes within the bloc. The sanctions are thus best interpreted as a powerful catalyst that accelerated pre-existing trends and triggered specific adaptation mechanisms within the EAEU's institutional framework.

Conclusion

Summary of Key Findings

This study demonstrates that the unprecedented sanctions pressure on Russia, rather than triggering the disintegration of the Eurasian Economic Union, acted as a powerful catalyst for its profound and paradoxical transformation. The empirical evidence reveals a clear narrative: the initial shock was rapidly absorbed by the bloc's internal market, leading not to collapse but to a significant reconfiguration of intra-regional trade and logistics. The resilience of the EAEU was evidenced by the robust recovery and growth of mutual trade, which served as a critical stabilizing mechanism, offsetting the negative external shock.

However, this aggregate stability masked a fundamental internal shift, characterized by a stark divergence in the economic trajectories of member states and a strategic pivot in supply chains, primarily enabled by the flexibility of road transport and the emergence of new logistical hubs like Armenia and Kyrgyzstan. Crucially, this adaptation had a profound structural dimension: the bloc's import basket consolidated around critical machinery and consumer goods, while its export profile underwent a marked shift towards a commodity-based economy, with mineral fuels expanding to over 60% of total exports, revealing a growing long-term vulnerability despite short-term resilience.

The capacity for such a rapid adaptation was not spontaneous but was fundamentally underpinned by the EAEU's pre-existing institutional architecture. The Common Economic Space, with its duty-free trade and unified regulations, provided a ready-made platform for the seamless rerouting of goods and intra-union import substitution. Furthermore, the institutional legitimization of parallel imports and the accelerated shift to alternative financial systems and national currencies formed a vital financial buffer. This experience underscores a critical lesson: regional institutions are not merely fair-weather frameworks but can become indispensable tools for crisis management, providing the trust, rules, and mechanisms for a collective response under extreme duress.

Ultimately, the EAEU's experience offers broader implications for the global community. It challenges the efficacy of comprehensive sanctions as a blunt instrument of foreign policy, demonstrating that their primary effect may be not to cripple but to stimulate the creation of alternative, more self-reliant economic ecosystems within regional blocs. Concurrently, it redefines the geopolitical agency of small economies, which can leverage their connectivity to become pivotal hubs in reconfigured supply chains. Looking forward, the Union's main challenge lies in navigating the vulnerabilities unveiled by this new phase of integration – such as technological lag, logistical bottlenecks, structural dependence on raw material exports, and collective dependence on China. The future stability of the EAEU will, therefore, hinge on its ability to transition from reactive adaptation to a proactive strategy for sustainable and balanced development.

Policy Implications

The EAEU's experience offers several critical lessons for policymakers. For regional blocs, the primary implication is the necessity of proactive institutional deepening; investing in robust common markets, unified technical regulations, and integrated payment systems before a crisis strikes transforms a trade agreement into a vital economic buffer, enhancing collective resilience. For smaller economies within such unions, the lesson is to strategically leverage connectivity by investing in logistics infrastructure and streamlining customs to position themselves as indispensable hubs, thereby converting geographic location into economic and political agency. Finally, for sanctioning bodies, the key takeaway is the law of diminishing returns; comprehensive sanctions against a large economy embedded in a regional bloc are more likely to catalyze the creation of alternative, sanction-resistant ecosystems within the bloc than to achieve strategic isolation, a calculation that must be factored into policy design.

Limitations and Future Research Directions

This study has certain limitations, primarily the challenge of definitively isolating the impact of sanctions from other concurrent global factors, such as post-pandemic supply

chain adjustments and global inflationary trends, which also influenced trade patterns during the 2021-2024 period. Furthermore, the reliance on national and EAEU-level trade data, while official, may not fully capture the granularity of firm-level adaptation and shadow economic activities. These limitations point toward promising avenues for future research. Subsequent studies could employ firm-level surveys and customs record analysis to uncover the microeconomic mechanisms of supply chain reorientation. A comparative analysis with other regional organizations facing external shocks could help distinguish the EAEU's unique adaptive features from general patterns of integration resilience. Finally, longitudinal research is crucial to assess the long-term sustainability of the new trade patterns and the Union's ability to manage its growing collective dependencies, particularly on China.

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ANALYSIS OF THE ORGANIZATION'S ACTIVITY ON THE EXAMPLE OF THE MCKINSEY MATRIX. THEORETICAL-EXPERIMENTAL APPROACH

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Abstract: Due to resource constraints, a company cannot cater to all potential markets worldwide in a manner that satisfies all clients and achieves business goals. Therefore, it becomes important for the company to carefully select the most appropriate markets. Given the plethora and diversity of available markets, analyzing market attractiveness and selecting the most promising ones becomes a complex process. The General Electric Matrix, also known as the McKinsey Matrix, employs two dimensions-market attractiveness and competitive strength of the firm-to analyze a company's strengths and weaknesses across various areas. The matrix aims to help the company identify the most appealing markets, guiding managers in resource allocation and enabling them to enhance the firm's weaker competitive positions in emerging markets or withdraw from less attractive markets. This tool proves highly effective for international market specialists, aiding in the selection of foreign markets for the company and determining the internationalization strategy to be employed in those markets. This paper concludes with a segment of a broader study showcasing how the General Electric Matrix/McKinsey is specifically utilized in the process of selecting markets. The author used a matrix as an example of a case study, as a result of which the position of a separate portfolio in the market was analyzed and the necessary strategy was proposed for each portfolio. An example analysis is conducted based on a hypothetical company producing four product lines. Data from 2024 are used to calculate business strength and market attractiveness, positioning each product within the McKinsey Matrix. Results indicate that the company's laptops are in the field of selective development, requiring continued investment to raise the scores and transform laptops into a leading business. Mobiles are leading products for the company; accordingly, the company must keep investing in the portfolio in order to maintain the position. As for TVs and headphones, they are in the field of selectivity.

Key words: *Route attractiveness, General Electric Matrix/McKinsey, market assessment, resource allocation, competitive strength.*

Introduction

For firms aiming to expand the market, it is necessary to precisely identify the markets they intend to enter and determine the most suitable entry strategies. Nearly all companies that operate internationally or plan to do so base their marketing strategies on identifying and selecting the best markets or market segments. They structure their

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offerings based on the specific conditions of these markets. Recognizing the limitations of their resources, companies understand that serving all potential markets worldwide to satisfy all clients and achieve business goals is unfeasible. Therefore, it becomes imperative for a company to carefully choose the most appropriate markets for its international endeavors. The objective of this study is to demonstrate how the McKinsey Matrix can be applied to assess market attractiveness and business strength, using a case example to illustrate its role in guiding resource allocation and strategic decision-making. Companies may opt for a focused approach, concentrating on a single product market and serving numerous geographical areas. Alternatively, they may choose to serve different product markets in a selected group of geographical areas. Given the vast number and diversity of potential markets, the analysis of market attractiveness and the selection of the most promising one become intricate processes. This careful evaluation is necessary to ensure that a company's expansion efforts are strategically aligned with the unique characteristics and demands of the chosen markets.

Results and Findings

In the late sixties and early seventies, as the Boston Consulting Group was formulating the BCG or Growth Share matrix, General Electric (GE), a prominent corporation in the United States, was also exploring concepts and techniques for strategic planning. Seeking a portfolio approach with broader dimensions than the BCG matrix, GE enlisted the services of McKinsey and Company, a leading consulting firm in the USA. In 1971, McKinsey and Co. developed the business screen for General Electric, aiming to assess the potential for future profit in each of the 43 strategic business units. This matrix is alternatively known as the industry attractiveness–business strength matrix and the nine-box matrix (Boyd W. Harper, Walker C. Orville, Larreche Jean-Claude, 1995, pp. 3-5).

The matrix requires the identification and assessment of both external and internal factors, followed by positioning each by unit in terms of overall industry attractiveness and business strength on a nine-cell grid. Three categories are used to classify both attractiveness and strength: to grow, to hold, or to harvest. This involves making moves in each controllable factor to result in a desirable competitive position. Strategies must be formulated aimed at securing long-term sustainable competitive advantage. The global strategy chosen has to be fitted to the actual internal capabilities of the firm (McKinsey, 14.01.2025). The GE-McKinsey model bears resemblance to the more widely known SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis, as it accommodates both internal and external factors in the matrix construction. The competitive position or business strength component reflects internal capabilities that are within the company's control. In contrast, external factors, which are not directly controlled by the company, including opportunities and threats, constitute the industry attractiveness aspect.

This matrix-based approach provides a comprehensive view, allowing for the simultaneous consideration of both internal and external factors. It serves as a strategic tool for businesses to assess and prioritize their business units, facilitating decision-making related to resource allocation, strategic planning, and overall portfolio management (Grant R. M., 2000, pp. 36-37).

The matrix, featuring two dimensions-market attractiveness and competitive strength of the firm-aims to analyze the strengths and weaknesses of the company across various areas. The analysis of market attractiveness in the General Electric Matrix/McKinsey involves considering various factors that offer information about the characteristics and dynamics of the market (Business tools, McKinsey matrix, 12.01.2025). These factors fall into several categories (Cascade, 15.01.2025):

- Market Factors:

Customer Characteristics: Examining the benefits customers seek, their satisfaction with existing products, and their bargaining power with suppliers.

Market Volume Factors: Assessing overall market size, growth rate, and the life cycle stage of the market.

- Economic and Technological Factors:

Capital and Technology Requirements: Evaluating the financial and technological resources needed for the company to compete effectively in the market.

Structural Variables: Considering entry and exit barriers that shape long-term competitiveness and potential profitability.

- Competitive Factors:

Number and Strength of Competitors: Analyzing the existing competition in the market in terms of quantity and strength.

Potential for Changes: Assessing the likelihood of future competitive changes, including the emergence of replacement products.

- Macro Factors:

Social and Political Constraints: Reflecting on broader societal and political influences that may impact the company's ability to compete profitably.

Government Regulations and Interest Groups: Considering external factors such as regulatory policies and the influence of interest groups on market dynamics.

This comprehensive analysis allows managers to understand the various dimensions and complexities of a market. By systematically evaluating these factors, companies can make informed decisions about market selection, resource allocation, and strategic planning, aligning their efforts with the most promising opportunities and minimizing risks associated with market entry.

Indeed, assessing industry attractiveness is subjective, but certain factors can provide a framework to help determine the attractiveness of an industry. Here are some key factors to consider:

- Industry size,
- Industry growth,
- Market profitability,
- Pricing trend,
- Competition intensity,
- Overall risk and returns in the industry,
- Opportunity to differentiate products and services,
- Distribution structure.

When evaluating the company's competitive position, market position factors are particularly relevant for assessing markets where the company is already established. These factors provide insights into the current strength of the company's position and product offerings in comparison to existing competitors. This includes considerations

such as market share, brand strength, and customer loyalty (ResearchGate, Răzvan Decuseara, 15.01.2025). On the other hand, economic and technological factors can reveal the actual or potential competitive advantages of the firm. This process involves assessing the efficiency of production processes, technological capabilities, and the potential for sustainable product differentiation.

For instance, a company with advanced technology or strong patent protection may have a competitive advantage. Business skills, another aspect, shed light on the company's strengths and weaknesses relative to competitors. This could involve having a broader distribution channel, superior marketing strategies, or financial constraints that may affect future growth. Interactions between markets are also key considerations. Positive interactions can arise from shared activities or resources across markets. For example, sharing a sales force to cover multiple markets can be a cost-effective strategy (Fleisher S. Craig, Bensonssan E. Babette, 2003, pp. 97-101). Conversely, negative interactions may occur if activities in one market adversely affect performance in another.

By examining these factors, companies can gain a comprehensive understanding of their competitive position, enabling them to make informed decisions about resource allocation, strategic planning, and market prioritization. This holistic assessment takes into account both the internal capabilities and external market dynamics that shape the company's competitiveness. Factors that affect Business Strength are:

- Strength of assets and competencies,
- Relative brand strength,
- Market share,
- Customer loyalty,
- Relative cost position,
- Distribution strength,
- Record of technological or other innovation,
- Access to finance and other investment resources.

In the original GE McKinsey matrix, business strength is positioned on the vertical axis, industry attractiveness on the horizontal axis, and the size of the circle corresponds to the size of the industry. Additionally, a shaded wedge within the circle represents the firm's current share of the industry. The matrix is organized into nine boxes, allowing for a detailed classification of business units (graph 1).

The GE McKinsey or Attractiveness-Strength matrix provides a framework for analyzing businesses or products based on dimensions of value to both the organization and the customer. The two key dimensions are Industry Attractiveness (value to the organization) and Relative Business Strength (value to the customer). This matrix is particularly significant for assigning priorities in terms of investment across different businesses within a firm. It serves as a guide for resource allocation, helping the organization make informed decisions about where to invest resources based on the attractiveness of the industry and the relative strength of its business in that industry.

Unlike the BCG matrix, which also deals with portfolio analysis but emphasizes cash flow balance and categorizes businesses into "cash cows," "stars," "question marks," and "dogs," the GE McKinsey matrix focuses more on the strategic aspects of resource allocation. It provides a nuanced view of businesses, considering both internal and

external factors, to guide decision-makers in strategically managing their portfolio (Hollensen S., 2004, p. 38).

Graph 1

McKinsey matrix

BUSINESS STRENGTH	High	Medium	Low
High	**1. Invest and Grow** Seek dominance Maximize investment (Leader)	**4. Selective Growth** Identify growth area Invest in growth (Try harder)	**7. Selective Growth** Maintain position Seek cash position (Cash generation)
Medium	**2. Selective Growth** Identify weaknesses Build on strengths	**5. Selectivity** Specialize Invest selectively (Proceed with care)	**8. Harvest /Divert** Pure lines Minimize investment (Phased withdrawal)
Low	**3. Selectivity** Specialize niche Seek acquisition (Improve or quit)	**6. Harvest /Divert** Specialize niche Consider exit (Phased withdrawal)	**9. Harvest /Divert** Attack rivals Time to exit (Withdrawal)
	High	**Medium**	**Low**

INDUSTRY/MARKET ATTRACTIVENESS

1.Invest and Grow – Businesses falling into the category of strong business strengths and operating in attractive markets, as identified in the GE McKinsey or Attractiveness-Strength matrix, are considered prime targets for investment. These businesses possess the potential for high returns on investment and a competitive advantage. As such, they warrant strategic attention and should be supported financially and managerially to maintain and enhance their strong positions. The objectives for such businesses typically include seeking dominance, growing, and maximizing investment.

1. **Selective Growth** – Businesses categorized in very attractive industries but with average business strength, according to the GE McKinsey or Attractiveness-Strength matrix, present opportunities for improvement in their long-term competitive position. For such businesses, the strategic focus should include evaluating the potential for leadership via segmentation, identifying weaknesses, and building strengths.

2. **Selectivity** – For businesses situated in very attractive markets but exhibiting weak business strength, strategic investment becomes imperative to enhance their long-term viability and competitiveness. The focus should be on initiatives aimed at improving their internal capabilities. Key considerations and actions for businesses in this category are supposed to be to specialize, seek niches, consider acquisitions.

3. **Selective Growth** – For businesses positioned in the category of good business strength within an industry experiencing declining attractiveness, strategic decisions should aim to navigate the challenges of the changing market dynamics. The approach for businesses in this scenario includes identifying growth segments, investing strongly, and maintaining position elsewhere.

4. **Selectivity** – For businesses positioned with average business strengths in industries of average attractiveness, a strategic approach involves creative segmentation and selective investment to enhance their competitive positions. The key components of

this strategy comprise identifying growth segments, specializing, and investing electively.

5. **Harvest /Divert** – For businesses with weak business strengths in moderately attractive industries, the strategic consideration involves evaluating the feasibility of a controlled exit or divestment. The approach for businesses in this category includes specializing, seeking niches, and considering exit.

6. **Selective Growth** – For strong businesses operating in unattractive markets, the strategic focus should be on their role as net cash generators within the overall portfolio. Absolutely, the statement emphasizes the delicate balance that companies with strong businesses in unattractive or mature markets must strike. While it's important to strategically invest in maintaining a dominant position, there are risks associated with overinvestment, particularly in mature markets. Here's a breakdown of the key considerations: maintain overall position, seek cash flow, invest at maintenance level.

7. **Harvest /Divert** – For businesses with average business strengths in an unattractive market, the strategic consideration involves a controlled harvesting approach. The strategy should be carefully crafted to either extract value from the business in a controlled manner or potentially disrupt a competitor. Here's a breakdown of the key elements: minimize investment, position to divest.

8. **Harvest /Divert** – For businesses with neither strengths nor an attractive industry, the strategic imperative is clear: exit. The strategy involves making prudent investments solely to facilitate a smooth and strategic exit.

The practical use of the McKinsey matrix can be shown in the example represented below. In the market there are 4 products produced by “AI” Company (Table 1.).

Table 1

Sales by products, 2024

	Products	**Total Sales in 2024 (mln USD)**
1	Mobiles	5
2	Laptop	7
3	TV	2
4	Headphones	4

***Source*:** Developed by author.

In the example provided, an analysis was conducted using the General Electric/ McKinsey Matrix to assess the market potential. The analysis was performed for the year 2024, considering 6 indicators for each of the two dimensions: market attractiveness and business or competitive strength of the company. The methodology involved assigning a weighting coefficient to each indicator, reflecting its significance for the company. These coefficients were subjectively determined based on the importance of each activity. The sum of all indicators within each dimension equaled '1'. Expert judgment was used to determine weights, which represent each factor's relative strategic importance to the company's goals. For example, factors like custom duties were given lower weights (0.10) because they represent short-term constraints rather than sustainable advantages, while market growth and industry size were given higher

weights (0.15–0.20) because they directly affect long-term profitability. The current position of each potential target market was then assessed for each indicator, assigning a score between 1 and 5. Performance levels are represented by scores ranging from 1 to 5, where 1 denotes extremely poor positioning and 5 denotes a strong, advantageous situation. For instance, a brand image score of four indicates high recognition in comparison to rivals, whereas a profitability score of two denotes market margins that are below average. The score awarded to each indicator was multiplied by its respective weight, and the products obtained were summed together to generate a total for each column (market) (Table 2).

Table 2

McKinsey table for the products

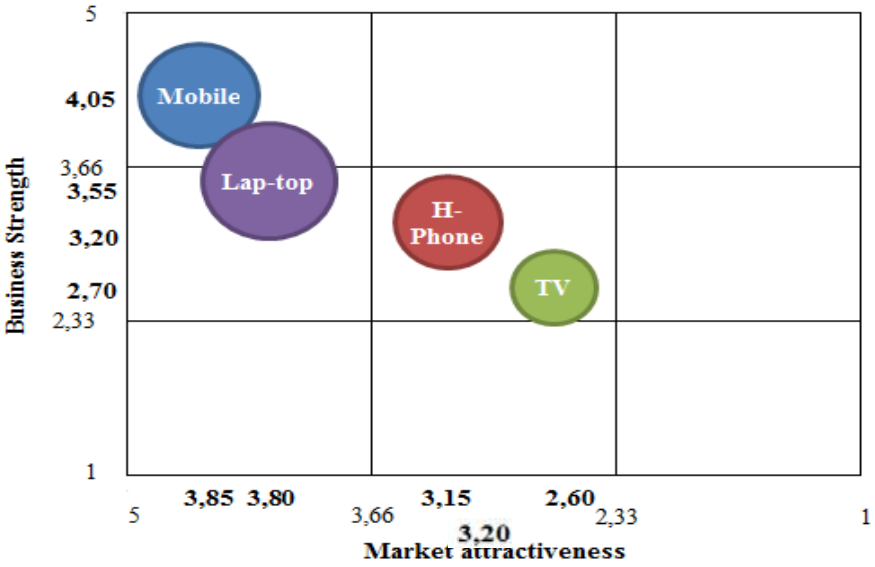
			Mobiles		**Laptop**		**TV**		**Headphones**	
Market attractiveness	**Indicators**	**Weight of factors**	**Grade**	**Weighting value**	**Grade**	**Weighting value**	**Grade**	**Weighting value**	**Grade**	**Weighting value**
	Competition	0,2	3	0,6	3	0,6	2	0,4	3	0,6
	Market growth	0,15	5	0,75	3	0,45	3	0,45	4	0,6
	Industry size	0,2	4	0,8	3	0,6	3	0,6	4	0,8
	Custom duties	0,1	3	0,3	3	0,3	3	0,3	3	0,3
	Pricing trends	0,15	4	0,6	3	0,45	3	0,45	3	0,45
	Profitability	0,2	4	0,8	4	0,8	2	0,4	2	0,4
	Score	**1**	**-**	**3,85**	**-**	**3,2**	**-**	**2,6**	**-**	**3,15**
			Mobiles		**Laptop**		**TV**		**Headphones**	
Business strength	**Indicators**	**Weight of factors**	**Grade**	**Weighting value**	**Grade**	**Weighting value**	**Grade**	**Weighting value**	**Grade**	**Weighting value**
	Quality	0,2	5	1	4	0,8	3	0,6	4	0,8
	Technologies	0,15	4	0,6	4	0,6	3	0,45	3	0,45
	Brand image	0,2	4	0,8	4	0,8	3	0,6	3	0,6
	Design	0,15	4	0,6	3	0,45	3	0,45	3	0,45
	Market share	0,15	4	0,6	3	0,45	2	0,3	3	0,45
	Investments	0,15	3	0,45	3	0,45	2	0,3	3	0,45
	Score	**1**	**-**	**4,05**	**-**	**3,55**	**-**	**2,7**	**-**	**3,2**

***Source*:** Developed by author.

This approach allowed for a comprehensive evaluation of market attractiveness and competitive strength, considering both subjective judgments and quantitative assessments. The resulting matrix provides a strategic overview of potential target markets, guiding the company's initiatives based on the combined analysis of various indicators (Graph 2).

Graph 2

McKinsey matrix of "AI" company



***Source*:** Developed by author.

As revealed by the study, mobiles are leading products for the company (high business strength and high market attractiveness), accordingly the company must keep investing in the portfolio in order to maintain the position. This is the second profitable business for the company with 5 mln USD in sales (Table 1).

Laptops are in the field of selective development with high market attractiveness and medium business strengths. This product is the most profitable portfolio with 7 million USD in sales. Besides this, the business strength score is 3.55, which is close to 3.66, above which it will be considered a leading business. Therefore, the company can actively invest in the product in order to develop it and make a leading project. Based on the scores of Table 2, "Design," "Market share," and "Investments" of laptop were assessed as "3"; consequently, the company can develop the design, do better marketing in order to increase the market share, and invest more in R&D to raise the scores and transform Lap-tops into a leading business.

As for TVs and headphones, they are in the field of selectivity with medium market attractiveness and medium business strengths. The key components of this strategy comprise identifying growth segments, specializing, and investing electively considering the figures of table 2.

Conclusion

The study concludes that the McKinsey Matrix is versatile and applicable across various industries for assessing industry attractiveness and business strength, serving as a foundation for resource allocation decisions. The matrix's adaptability extends to companies with diverse product lines competing in different markets. It is especially

recommended for organizations with multiple business units or business units comprising various product lines. General Electric's use of the GE McKinsey matrix across different organizational levels demonstrates its flexibility. The matrix can be applied at five levels within an organization: product, product line, market segment, strategic business unit (SBU), and business sector. This broad applicability allows for a comprehensive analysis and strategic planning process.

Key points highlighted in the study:

- Multi-Level Application: The GE McKinsey matrix is applicable at various organizational levels, enabling analysis of the entire corporate portfolio, as well as individual business units and product lines.
- Strategic Planning Tool: The matrix serves as a strategic planning tool, aiding in the identification of strengths and weaknesses within the business units or products. This analysis helps set future strategies based on the current portfolio and forecasts future positions by assessing factors contributing to business strengths.
- Forecasting Future Positions: Through mapping the present portfolio and forecasting future positions, the matrix assists organizations in anticipating market dynamics and making informed decisions about resource allocation.
- Focus on Strengths and Weaknesses: By emphasizing the strengths and weaknesses of business units or products, the matrix guides organizations in refining their strategic focus and making targeted improvements where necessary.

In conclusion, the GE McKinsey matrix is a powerful and adaptable tool that goes beyond a singular application. Its multi-level use enables organizations to gain insights into their overall portfolio, individual business units, and product lines, facilitating strategic decision-making and resource allocation across diverse business environments.

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ENERGY SECURITY AND ECONOMIC RESILIENCE OF RA IN THE CONTEXT OF CURRENT GEOPOLITICAL DEVELOPMENTS

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Abstract: This article analyzes the current manifestations of Armenia's energy security and economic resilience in the context of recent geopolitical changes. It assesses the current state of Armenia's energy security and economic resilience based on key indicators used in international policy and well-supported in the academic literature. The analysis shows that the adopted indicators - such as energy intensity, external energy dependence, and measures of supplier concentration - have methodological limitations and do not fully reflect the country's structural and geopolitical specificities. The main goal of this study is to examine the limitations and gaps of commonly used energy security indicators in the context of Armenia's green transition policies and current geopolitical developments. By analyzing various indicators of energy security and economic resilience and contextualizing them for the Armenian economy, a multi-component qualitative assessment has been investigated, showing that these indicators alone do not provide a comprehensive picture and do not fully reflect the country's structural and geopolitical characteristics. Energy policy can be more effective and targeted when informed by clear and integrated assessments of these factors. Such an approach is essential to support Armenia's long-term energy security and economic resilience.

Key words: Energy security; Economic resilience; Geopolitical risks; Energy intensity, Primary energy supply; Energy market.

Introduction

Modern energy systems are shaped by geopolitical uncontrollable risks, global energy transitions, and structural vulnerabilities, which most acutely affect small and import-dependent states. Armenia's energy profile is particularly risky: energy security and economic resilience are jointly determined by limited domestic resources, high import dependence, geopolitical shocks, and dependence on infrastructure pathways. As defined in the Energy Security Concept of the Republic of Armenia (2007), energy security is understood as a set of measures ensuring reliable, high-quality, and affordable energy supply under normal, emergency, and wartime conditions. Despite the increasing use of quantitative indicators such as energy intensity, diversification indices, external dependency ratios, and supplier concentration metrics, these tools often fail to capture the multidimensional risks that characterize Armenia's position in the regional energy profile. In this context, Armenia's strategic energy priority is to ensure that energy is affordable,

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reliable, and clean—a triad that is easy to achieve individually but extremely difficult to balance simultaneously in practice. Recent geopolitical shifts, including disruptions to traditional trade routes, instability in the broader post-Soviet energy space, and the acceleration of the global transition to low-carbon systems, have further exacerbated the need for an integrated assessment of Armenia's energy vulnerabilities. At the same time, existing policy analyses rely heavily on standardized international indicators, which, while methodologically sound, only partially capture the real picture on the ground.

Following Lefevre (2010), the distinction between reliability (a physical criterion) and affordability (an economic criterion) is crucial for understanding Armenia's constraints, as the interaction of these two pillars is particularly visible in small, import-dependent energy systems. In this context, the current study addresses three interrelated questions:

- ✓ To what extent do traditional energy security indicators reflect Armenia's real structural and geopolitical vulnerabilities?
- ✓ How are energy security constraints reflected in broader outcomes of economic resilience for a small, landlocked, and import-dependent state?
- ✓ What analytical framework can best capture the multifaceted risks facing Armenia's energy system in a rapidly changing regional environment?

To answer these questions, the article combines approaches from the energy security literature, economic vulnerability analysis, and regional geopolitical studies, allowing for a more holistic assessment that goes beyond the limitations of indicator-based assessments. As a result, the study places Armenia's energy security challenges in a broader strategic context, emphasizing the need to understand not only quantitative criteria but also the structural, institutional, and geopolitical development dynamics that shape long-term resilience.

Research methodology and information bases

In this study, a qualitative and analytical approach is employed to examine Armenia's energy security and resilience. The methodology focuses on conceptual analysis of the trade-offs between energy affordability, reliability, and sustainability, considering geopolitical and structural shocks. The analysis focuses on identifying limitations and gaps in widely used energy security indicators in the context of green transition policies and current geopolitical developments. Combining a wide range of academic literature and scientific research on energy security, as well as insights gained from economic vulnerability studies and regional geopolitical assessments, it presents which aspects of Armenia's energy system are not sufficiently reflected by standard quantitative criteria. The information base includes both quantitative and qualitative sources, including: (i) International organizations: World Bank, IEA, EBRD; (ii) National sources: Statistical Committee of the Republic of Armenia, Public Services Regulatory Commission, Ministry of Territorial Administration and Infrastructure; (iii) Academic and professional literature on energy security and economic resilience. This approach allows for a systematic identification of the gaps and methodological limitations of conventional indicators, forming the basis for a more comprehensive understanding of Armenia's real energy security and economic resilience profile.

1. Foundations of Energy Security: Armenia

Armenia's current strategic priority is to ensure that its energy system is affordable, reliable, and clean. While separate mechanisms can and are being developed to address each of these pillars separately, implementing all three simultaneously is a complex challenge in all economies, and is particularly sensitive and problematic in a small, open, and geopolitically vulnerable country like Armenia. Reliability refers to the physical availability of energy that ensures the smooth and consistent operation of supply systems. Availability takes into account economic factors, making energy affordable for both businesses and households.

Reliability: electricity is not reliable if the mechanisms for delivering it to the consumer are not functioning smoothly. Reliable electricity is not always available to householders.

Availability: availability is an economic concept. Energy can be available, but so expensive that the business refuses or limits its use. From the perspective of the end consumer, it does not matter whether the energy is unavailable or not affordable, since in both cases it is not used by the latter.

In Armenia, the two aforementioned issues are often interrelated, especially in rural or border communities, where electricity supply may be interrupted due to wear and tear on distribution networks (a reliability issue), and in some remote areas, it may not be available due to low-income levels (an accessibility issue). Of course, reliability can be improved by adding new transmission lines, reserve capacity, or new fossil/hydro power plants, but these are additional costs, which, if not implemented under direct state control, can make energy more expensive and, therefore, further reduce affordability.

Clean energy: clean energy emphasizes environmental sustainability and the long-term economic resilience of the system. Together, these three pillars form the foundation of Armenia's energy security, guiding both policy and investment decisions in the context of regional and global challenges. The World Bank highlights that without prioritizing climate action, Armenia's energy security and economic resilience could face significant long-term risks, emphasizing the need for investments in sustainable energy infrastructure and adaptive policies (World Bank, 2024).

These three pillars of energy security - affordability, reliability, and clean energy - characterize Armenia's energy profile, the system of internationally acceptable indicators of which and their limitations will be discussed below. According to the government of the Republic of Armenia (2021), the Strategic Program for the Development of the Energy Sector up to 2040, Armenia seeks to develop "a free, competitive, non-discriminatory, inclusive, and diversified energy system with a high level of energy independence" (Government of RA, 2021).

2. Economic Resilience: Concept

Economic resilience is the ability of an economy to absorb, recover from, and adapt to external shocks, such as geopolitical tensions or market volatility (Tsiotas, 2022; Mirjalili, 2025). In small, open and import-dependent economies like Armenia, resilience is deeply intertwined with energy security. Energy supply disruptions disproportionately and tangibly damage economic performance, affecting economic stability and social well-being. The scientific literature distinguishes three main types of economic resilience, including absorptive capacity (the ability to withstand shocks),

adaptive capacity (to adapt to systemic changes), and transformative capacity (the ability to structurally transform the economy) (OECD, 2020; Mirjalili, 2025; World Bank, 2023, 2024). There are many indices assessing economic resilience, but perhaps the most comprehensive is the FM Global Resilience Index, which combines economic, infrastructure, and risk management metrics to form a comprehensive picture of the comparative resilience of countries. Specifically, the index, which presents a score for 130 countries/territories, is based on 8 global "resilience factors" with both macro and physical risks, including energy intensity, political risk, climate risk, infrastructure risk, etc., which are the most important indicators of energy security. As a result, the index provides a comprehensive picture of a country's overall "resilience" that you can use as a sub-section of a comprehensive assessment of economic resilience and energy security. *The FM Global Resilience Index* assesses a country's overall resilience through three main pillars: Economic, Risk Quality, and Supply Chain. From the perspective of this research, the current scores in these pillars provide an important picture of how a country's economy and energy system respond to shocks and geopolitical risks. The FM Global Resilience Index (2025) is constructed from 18 factors (6 physical, 12 macro), standardized using z-scores and summed into a score of 0-100. All factors included in the index are directly or indirectly related to the energy system. Some of these factors (notably energy intensity, logistics, water stress, greenhouse gas emissions, and physical risk metrics such as climate impact and seismic risk) directly reflect different aspects of a country's energy system, but they do so at a level of aggregation that misses important structural details specific to Armenia (FM Global, 2025).

Table 1

Groups of Resilience Factors (FM Global Resilience Index)

Group	Factor	Energy Sector Linkage	Linkage
Physical (6)	Climate change impact	Energy production & consumption affected by climate events	Indirect
	Climate risk exposure	Extreme weather events can disrupt energy infrastructure	Direct
	Climate risk quality	Quality of adaptation measures for energy systems	Direct
	Cybersecurity	Protection of energy grids and critical infrastructure	Direct
	Fire risk quality	Wildfires affecting energy infrastructure	Direct
	Seismic risk exposure	Earthquakes damaging energy facilities	Direct
Macro (12)	Corruption control	Governance affects energy sector investments and reliability	Indirect
	Education	Skilled workforce for energy sector and efficiency improvements	Indirect
	Energy intensity	Direct measure of energy efficiency	Direct
	GHG emissions	Reflects energy mix and fossil fuel dependence	Direct
	Health expenditure	Energy access impacts public health (heating, cooling, hospitals)	Indirect

	Inflation	Energy price shocks contribute to inflation	Indirect
	Internet usage	Digitalization supports smart grids and energy management	Indirect
	Logistics	Energy supply chains depend on transport infrastructure	Direct
	Political risk	Geopolitical instability affects energy imports and security	Direct
	Productivity	Energy disruptions reduce economic output	Indirect
	Urbanization	Higher urban energy demand and infrastructure needs	Indirect
	Water stress	Hydropower generation and cooling of thermal plants	Direct

Source: *Compiled by the author based on the study's analysis.*

According to the data, over the past four years, significant shifts have been observed in several countries, including Armenia, which has declined by nine positions (Composite Rank (Score) - 85 (51)). According to the FM Global Resilience Index (2025), Armenia's energy intensity score is 65.4, placing the country 95th globally. This reflects structural challenges in energy efficiency and the need for policies enhancing energy use and economic resilience (FM Global, 2025). For understanding the mechanisms of influence of these pillars of economic resilience, the next section examines the main indicators, which used to assess energy security, highlighting both their observations and limitations.

3. Indicators of energy security: limitations of indicators

Energy security has traditionally been defined in terms of ensuring uninterrupted supply, accessibility, and infrastructure reliability (Yergin, 2006). However, recent developments have changed the criteria for security. Not only security of supply, but also diversification, sustainability, governance, and geopolitical resilience are considered important (Cherp & Jewell, 2014; Sovacool, 2013).

The system of energy security indicators commonly used in policymaking has serious limitations (Bohringer and Bortolamedi, 2015). These indicators focus primarily on supply-side factors, neglecting the demand side (Jansen and Siebregts, 2010; Gracceva and Zeniewski, 2014). Most importantly, these indicators are only indirect quantitative assessments and do not qualitatively and fully assess the vulnerability of the energy system to potential shocks (Cherp and Jewell, 2011).

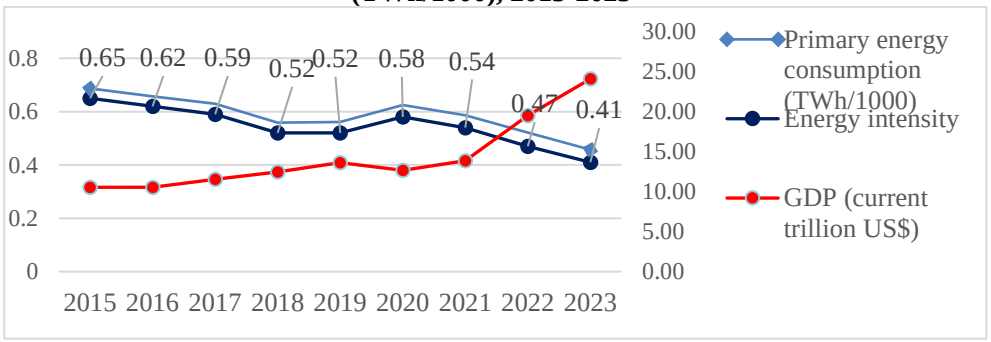
Four widely used indicators of energy security are the following (Bohringer and Bortolamedi, 2015):

1. ***Primary energy intensity*** - indicator is calculated as the ratio of a country's total primary energy consumption to its gross domestic product (GDP). Since primary energy use is a physical measure, this indicator only indicates reliability and does not reflect availability. So, the indicator has many limitations and in the context of Armenia, these limitations become especially visible:

1.1. It does not differentiate between more reliable and less reliable energy supplies. The indicator only assesses the reliable use of energy. But it does not distinguish whether energy is reliably available (available for use) or not: when the country consumes a lot of energy due to the development of energy-intensive sectors of the economy, but most of the energy used is imported, and energy access is vulnerable.

Figure 1

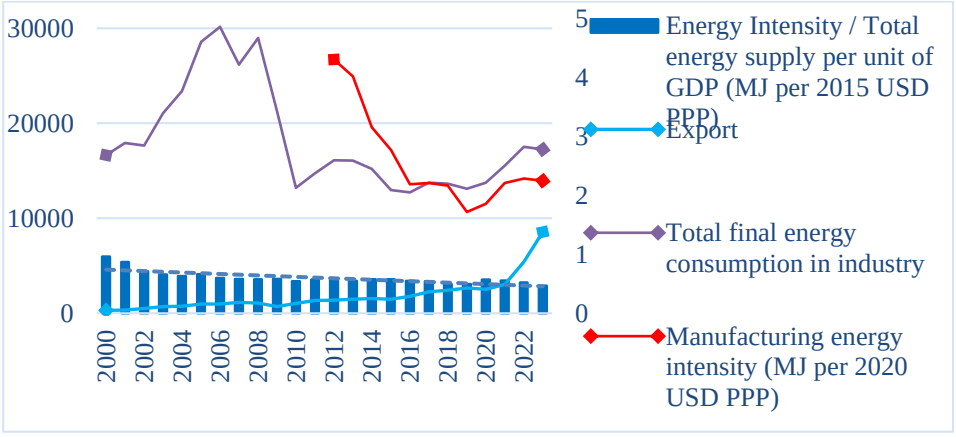
(i) Energy Intensity; (ii) Primary energy consumption; (iii) GDP (cur. trln USD) (TWh/1000), 2015-2023[1]



Source: *(ArmStat, SDG data, 2025;* Ritchie, Rosado, and Roser 2023*).*

Figure 2

(i) Trends in Armenia's energy indicators; (ii) Total energy intensity (MJ per 2015 USD PPP); (iii) Manufacturing energy intensity (MJ per 2020 USD PPP); (iv) Total final energy consumption in industry; (v) Export of goods, Armenia, 2000-2023[2;3]



Source:*https://www.iea.org/countries/armenia/efficiency-demand;*
https://armstat.am/en/?nid=12&id=10003;
ArmStat SDG data; https://sdg.armstat.am/7-3-1/. Seen 05.12.2025

[1] The Figure was compiled by the author based on ArmStat reports (SDG data; https://sdg.armstat.am/7-3-1/); Hannah Ritchie, Pablo Rosado, and Max Roser. 2023. "Energy." *Our World in Data*. Seen 05.12.2025. https://ourworldindata.org/energy.

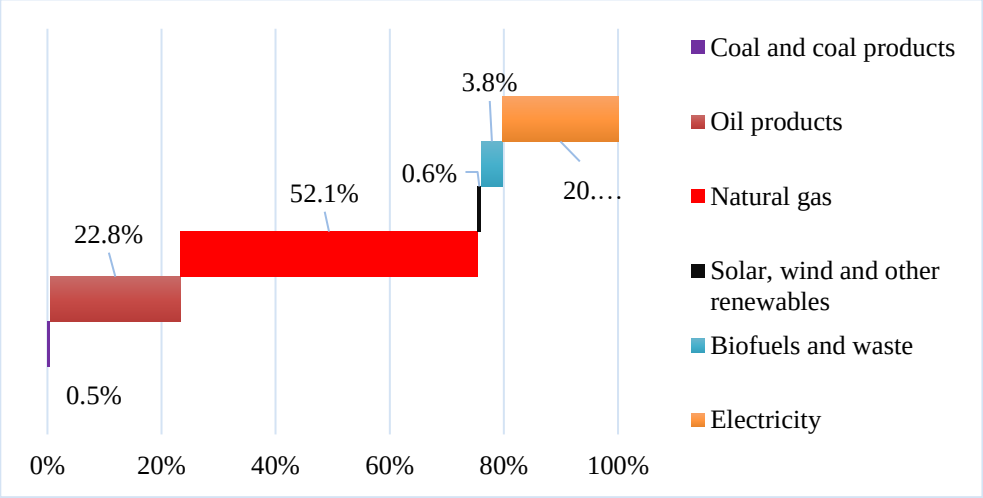
[2] Note: Although the GDP base years differ (2015 USD PPP for total energy supply per unit of GDP and 2020 USD PPP for manufacturing energy intensity), Figure 2 illustrates the comparative trends of overall and industrial energy intensity in Armenia, highlighting the role of the manufacturing sector in shaping the country's energy profile.

[3] All figures in this paper were created by the author using "IEA statistics".

Case of Armenia: Although Armenia uses significant amounts of primary energy relative to the size of its economy, and particularly in urban heating, transport and energy-intensive manufacturing, a significant portion of this energy is imported. In 2023, Armenia used about 2,889 MJ of energy per 1 USD (PPP) of GDP, showing a 51% decrease since 2000 (IEA, 2024). As a result, the indicator classifies Armenia as a country with high and stable energy use, implying a certain level of "reliability", even though the main supply is structurally vulnerable (we will address the issue of diversification in our further discussions). Since the indicator only reflects the volume of energy used, and not the terms on which it is supplied, it does not reflect the risks associated with Armenia's geographical and geopolitical location. In the case of dependence on a single import route and a dominant external supplier, energy may be widely used, but not necessarily reliably available. Thus, while improvements and high levels of the indicator may indicate high energy consumption (which could be mistakenly interpreted as sustainability), it does not reveal issues such as the fact that Armenia's energy access is subject to transit vulnerabilities, infrastructure constraints, and external political risks. This discrepancy highlights why using the primary energy use indicator alone is not sufficient to characterize the true energy security situation in Armenia.

Figure 3

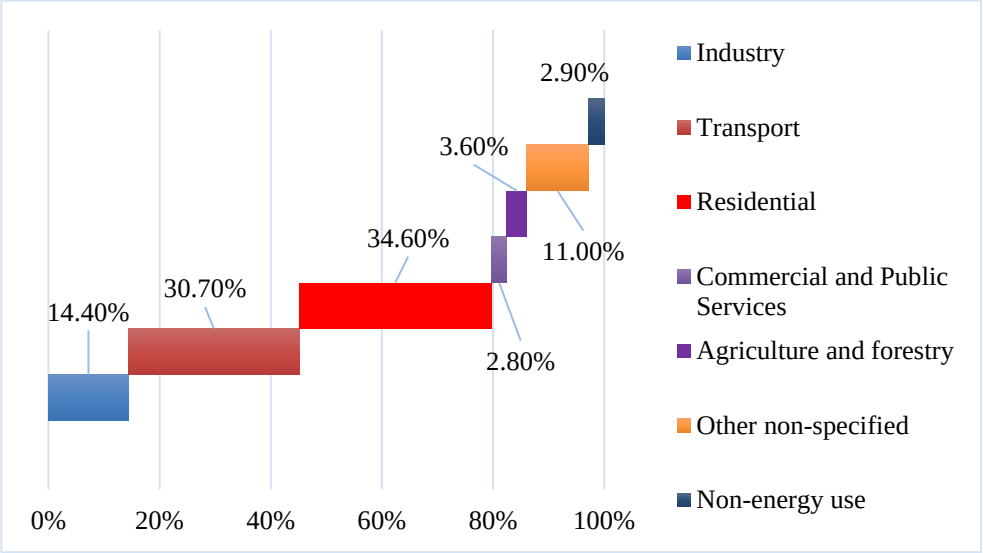
Total final consumption structure, Armenia, 2023



Source: *https://www.iea.org/countries/armenia/efficiency-demand. Seen 05.12.2025*

Figure 4

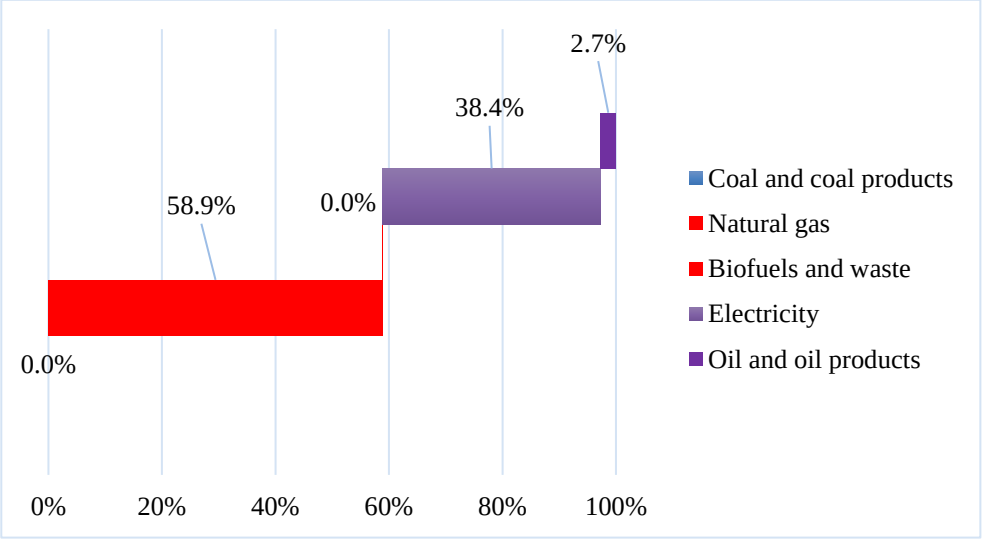
Total final energy consumption structure by sectors, Armenia, 2023.



Source: *https://www.iea.org/countries/armenia/efficiency-demand. Seen 05.12.2025*

Figure 5

Industry total final consumption by source, Armenia, 2023



Source: *https://www.iea.org/countries/armenia/efficiency-demand. Seen 05.12.2025*

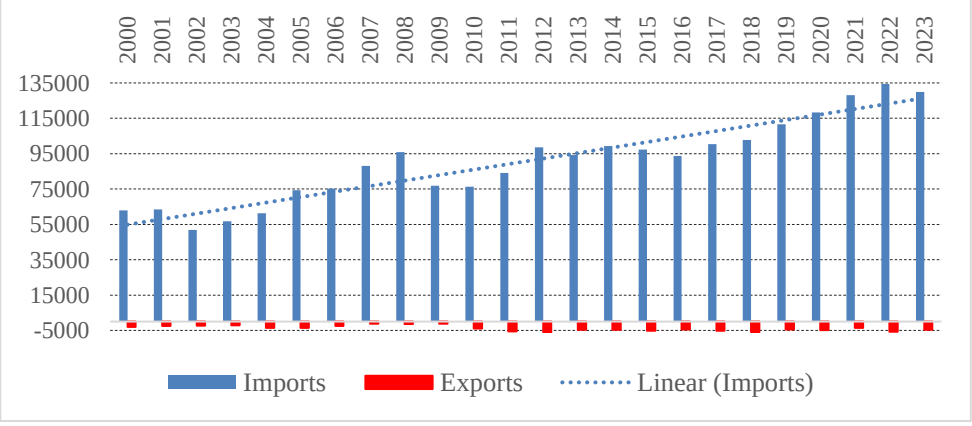
1.2. International energy trade is ignored. For example, exporting energy-intensive goods may appear to improve energy security, even if the imported goods come from countries with higher energy intensity. This means that if a country exports energy-

intensive products, it may appear to be more energy secure because it is "exporting" energy in exchange for GDP, but in reality, this energy is imported.

Case of Armenia: Armenia imports the majority of its primary energy, but some of this imported energy is later incorporated into exported goods and services. In such cases, the standard indicator may suggest that Armenia is creating economic value from domestic energy use, while in reality the energy underlying these exports is largely of foreign origin. In Armenia, heavy industry, mining, and some sectors of light industry consume significant amounts of imported fuel or electricity. When Armenia exports these products, the indicator may interpret this as an improvement in energy security, as the country's GDP grows, seemingly at the expense of the efficient use of its own energy resources. In reality, however, most of the energy used is imported, and exporting these products does not mean that energy security has been strengthened. However, the primary energy used in production is not produced domestically; it is imported, often from a single supplier or via a transit route. Of course, the indicator has improved significantly in recent years: between 2012 and 2023, an improvement of about 48% was recorded, but not because the country is purposefully implementing a targeted policy to increase energy efficiency in the sector, and the recorded reduction /see Figure 2/ was recorded only with the latest production technologies (IEA, 2022). This means that Armenia is essentially re-exporting the value of imported energy, without demonstrating independence or resilience in its own energy system. Moreover, since the indicator does not reflect the energy contained in imported intermediate goods, it ignores the fact that Armenia's export competitiveness in certain sectors may depend on external energy conditions. Any disruption in energy imports, whether due to geopolitical tensions, supply disruptions, or price volatility, would immediately lead to a reduction in export capacity, revealing a fragility that the indicator does not capture. Thus, ignoring international energy trade in the case of Armenia leads to a distorted perception: the country may appear to benefit from energy-based economic activity, but this activity is built on external energy dependence, not on domestic energy security.

Figure 6

Trade in energy, Armenia, 2000-2023



Source: *https://www.iea.org/countries/armenia/energy-mix. Seen 05.12.2025*

1.3. GDP is one of the first indicators of economic performance and is highly sensitive to external shocks. The use of GDP as a denominator in energy efficiency indicators necessitates additional interpretation of the estimates, which are particularly relevant in the case of Armenia. In small open economies. The Armenian economy is highly affected by developments occurring outside its borders, such as fluctuations in world prices, changes in trade corridors, and changes in regional geopolitical conditions. As a result, GDP has increased or decreased sharply even when domestic energy consumption has remained relatively stable. Conversely, GDP has decreased in response to geopolitical tensions, war situations, and global economic shocks, even when the energy needed to maintain essential services has remained unchanged. As a result of these independent developments, Armenia's energy intensity may appear to have improved or deteriorated purely due to macroeconomic fluctuations, rather than changes in energy efficiency or security.

Case of Armenia: Armenia's GDP is highly sensitive to external factors, including global prices (oil, gas, metals), regional logistical constraints, import/export structure, as well as war or geopolitical changes. We have contradictory developments; for example, in 2020, due to the war and COVID, the country's energy consumption almost did not decrease in the face of a sharp decline in GDP. But in 2022–23 the sharp growth in GDP was due especially to emigration flows from Russia, the expansion of the IT sector, and the export of services—not energy-related changes, but in 2023 a decline in electricity consumption was recorded, which distorts the real change in the indicator, especially if it coincides with high GDP growth.

1.4. Exchange rate - Artificial exchange rate fluctuations, which are largely underived and unrelated to structural economic indicators, change the value of the energy efficiency indicator. It is clear that a stronger dram artificially increases GDP (in US dollars), which "makes Armenia more energy efficient." A weaker dram has the opposite effect, although actual energy consumption trends may not change. Thus, international comparisons of Armenia's energy efficiency can be misleading when they are based on GDP at market exchange rates.

Case of Armenia: In Armenia, fluctuations in the national currency, the Armenian dram (AMD), significantly distort energy efficiency indicators when GDP is expressed in US dollars. Exchange rates of small economies are extremely sensitive to external factors. This was the case both during the war months of 2020 and in 2022, when the dram temporarily depreciated against the dollar due to macroeconomic factors occurring against the backdrop of the Russia-Ukraine conflict. As a result, the energy efficiency indicator calculated in US dollars decreased, creating the illusion that Armenia has become more energy efficient, while the structure of energy consumption and import dependence have not changed significantly.

1.5. Informal economic activity - Another important issue not fully captured by this indicator is that although ArmStat estimates non-observed (informal) economic activity following the UN SNA methodology, GDP still does not fully reflect informal economic activity, which remains significant in Armenia despite government efforts to reduce it (ArmStat, Non-observed economy methodology). ***Case of Armenia:*** some sectors, notably agriculture, construction, and small-scale manufacturing, include informal components that consume energy but are not fully reflected in GDP. Informal economic activity in Armenia, estimated at 22% of official GDP (in 2022). This means that

Armenia's actual energy intensity is underestimated, as the numerator (energy consumption) is fully visible, while the denominator (real economic output) is partially missing.

Thus, GDP constraints in Armenia significantly distort the true picture of the primary energy intensity indicator. International energy trade, artificial exchange rate fluctuations, GDP sensitivity to external shocks, and the presence of informal economic activity affect the accuracy of this indicator. As a result, changes in Armenia's energy intensity indicator are often driven by macroeconomic factors rather than by real improvements in energy efficiency or security.

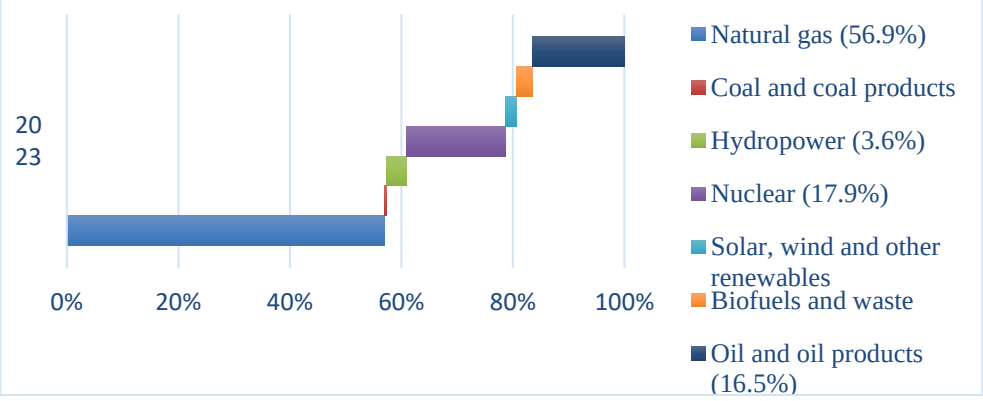
2. ***Dependence on foreign primary energy supply,*** defined as the ratio between the sum of net imports (or zero for net exporters) (for all fuels) and total primary energy use (Le Coq and Paltseva, 2009). The external energy dependence indicator is also not free from limitations in its use. In particular, it does not distinguish between more and less reliable suppliers.

2.1. All foreign suppliers are considered equally risky, while all domestic suppliers are considered non-risky.

Case of Armenia: In Armenia, only 23 % of primary energy demand was met with domestic production. Between 2000 and 2023, the share of natural gas in the total energy supply increased reaching 56.9%, while the share of supply from nuclear energy decreased reaching 17.9% in 2023 (IEA, 2024). The indicator considers all imports to be equally risky. In reality, Russian gas imports are regulated by long-term contracts and are relatively reliable. Oil imports from Iran are more sensitive to geopolitical risks and sanctions. The indicator does not reflect these differences in reliability. Thus, although this is considered "external dependence", the reliability of this supply depends on long-term contracts, transit stability, and regional geopolitics, which the indicator does not capture.

Figure 7

Total energy supply, Armenia, 2023



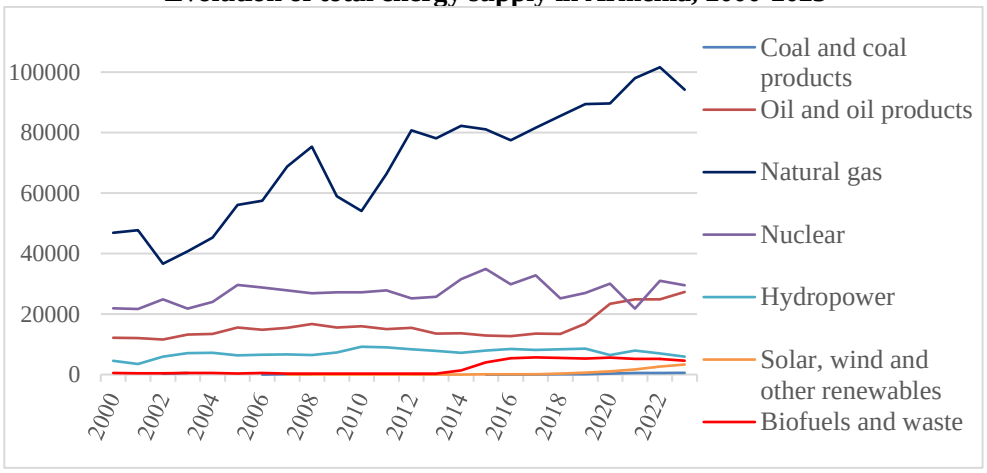
Source: *https://www.iea.org/countries/armenia/energy-mix. Seen 05.12.2025*

2.2. There is also no distinction between fuel types. Different fuels serve different purposes in the economy (electricity generation, heating, transport), and disruptions in one may be more important than in another.

Case of Armenia: The vast majority of energy used in Armenia is gas consumption. The country's economy is heavily dependent on imported natural gas for heating residential buildings and domestic services. In contrast, imports of liquid fuels (diesel/petrol) are less important from the perspective of immediate energy security. The indicator thus does not allow for the assessment of these differences.

Figure 8

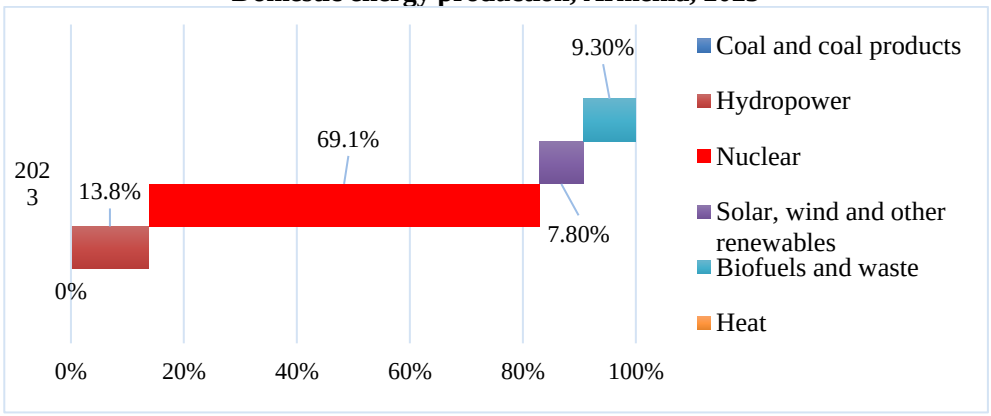
Evolution of total energy supply in Armenia, 2000-2023



Source: *https://www.iea.org/countries/armenia/energy-mix. Seen 05.12.2025*

Figure 9

Domestic energy production, Armenia, 2023



Source: *https://www.iea.org/countries/armenia/energy-mix. Seen 05.12.2025*

2.3. ***Domestic diversification*** and strategic reserve issues are also ignored. Even if a country imports most of its energy, it may have diversified sources or strategic storage that reduce external risks.

Case of Armenia: In Armenia's case, the nuclear power plant and the increasing volume of renewable energy have partially mitigated the risks of external dependence, but this is also beyond the scope of the indicator. Armenia's Metsamor Nuclear Power

Plant generates approximately 35% of the country's electricity. Armenia also has significant hydroelectric capacity (18-20% of electricity in 2023-2024), and solar and wind power are also expanding year by year. The RA State Strategy aims to increase the share of solar energy generation in the total to at least 15% or 1.8 billion kWh by 2030. These developments provide a buffer against external shocks, reducing dependence on imported fuel.

3. An indicator of primary energy supply concentration, also known as the Herfindahl-Hirschman index, is the sum of the squares of fuel market shares (Bhattacharyya, 2011).

3.1. The indicator does not reflect the true reliability of energy supply, nor does it take into account the strategic importance of different fuels.

Case of Armenia: In Armenia, both in the case of natural gas, gasoline and oil products, we have a problem of supplier concentration and fuel concentration. This situation means that the HHI of energy supply is very high, since the market is physically concentrated on a few fuels and a few suppliers. However, the problem here depends not only on the type of fuel, but also on the reliability of supply. In Armenia, the concentration of energy supply is high, mainly from a few external sources, which indicates high concentration according to the HHI calculation. However, the real danger is also due to the fact that these fuels are not easily interchangeable, and the reliability of supply is not always reflected in the concentration indicator.

4. An indicator of concentration of foreign primary energy supply, known as ***the Herfindahl-Hirschmann index***, for net energy imports, where concentration is measured either based on the number of foreign suppliers or on the number of foreign suppliers and fuels (Frondel and Schmidt, 2014).

4.1. Once again, the indicator does not reflect the reliability of imports. It is also important whether another third country is involved in the purchase process, which solves the transit logistics problem. A country can buy oil from multiple suppliers, but if it is imported through the same third-party country, this will not protect the importer from a possible shock.

Case of Armenia: In the case of Armenia, the concentration of foreign energy supply is high not only due to reliance on a few suppliers, but also because imports pass through a limited number of transit countries (via Georgia). Armenia has a very high HHI because the vast majority of its imported energy comes from a single source (Russia), and even the energy it produces itself (e.g., nuclear) depends on imported fuel. Even if multiple suppliers exist, dependence on the same transit routes creates significant risk, which is not captured by conventional concentration indices.

In the academic literature on energy security, one can find more than 80 different definitions and numerous indicators, none of which fully characterize the situation in the country (Ang et al., 2015). Energy is not reliable if the energy supply source is temporarily or permanently (i) unavailable or (ii) unavailable and cannot be replaced in a short time. Energy reliability is difficult to measure precisely, as it is a probability assessment process. In turn, energy availability is predictable to the extent of incomes and energy prices. Is the price acceptable to the end user?

The fact that the unreliability of electricity negatively affects both companies (Elliott et al., 2021; Chen et al., 2022), households (Meles, 2020; Bajo-Buenestado, 2021; Aweke and Navrud, 2022), as well as the entire economy (Carranza and Meeks, 2021)

has been presented in numerous studies. Moreover, the negative impact generates new impacts in a chain. Unreliable electricity leads to the interruption of production and daily life, which in turn increases other costs, leading to an increase in the price of goods, in turn giving a new negative impulse to the economy. Thus, an unreliable energy supply has a negative impact on the economy in the short term and on economic development in the long term. High energy access, in turn, has a largely positive impact on economic, social and environmental outcomes for all levels of development, both in the short and long term (Ayana and Degaga, 2022; Bo et al., 2022).

All of the above mechanisms, the purpose of which is to improve the level of energy security, in particular increasing reliability, require large-scale and carefully calculated investments.

Energy access, which is the next important pillar of energy security, is closely linked to social problems, uneven territorial development, and income inequality in Armenia. A state support program can temporarily improve energy access, especially in poor and border communities.

4. Green Economy Transition Challenges and Energy Security Risks

The issue of energy security has long ceased to be a two-dimensional one. It is a three-dimensional one, requiring the provision of reliable, affordable and "clean" energy. Reliability and affordability together constitute energy security in the short term. The pursuit of cleaner energy affects long-term reliability and affordability. In Armenia, the energy sector is the primary source of greenhouse gas (GHG) emissions, accounting for 70% of total emissions (EBRD, 2024). Of course, replacing fossil fuels with renewable energy will provide a more "reliable energy supply" in the long term. Here, reliability takes a different form. In addition to affecting the reliability of energy supply, green transition policies affect energy affordability. Estimates show that green energy is more expensive. And if a large-scale transition to green energy production occurs, energy, which is considered a primary consumption resource, could experience a price shock that could reduce the resilience of the economy in the short term. The burden of high energy prices will be felt particularly by businesses in the lower deciles. (Vandyck et al., 2021; Garaffa et al., 2021; Chepeliev et al., 2021). Climate policies directly affect energy access. In 2023, about 22.4% of Armenia's CO_2 emissions will be from electricity generation, 34.6% from transport, 9% from industry, and 24.3% from household consumption (IEA, 2023). This structure shows that building a green economy for the country is extremely challenging, as economic and energy policies must simultaneously strengthen energy security, reduce external energy dependence, and increase economic resilience (IEA, 2024).

Conclusion

This study aimed to reassess Armenia's energy security and economic resilience in light of recent geopolitical, structural, and systemic developments. Energy security is almost impossible to measure precisely, due to the limitations of the main indicators that we have addressed in our discussions. It is also difficult because it consists of two contradictory vectors: energy reliability and energy affordability. Green energy is a global public good, and its production can strengthen Armenia's energy independence and increase economic resilience. The results show that while internationally accepted

indicators such as energy intensity, external dependence, and supply concentration metrics offer useful starting points for comparative assessment, they capture only a fraction of the multifaceted vulnerabilities that shape Armenia's real energy profile. In line with the concerns raised in the introduction, the analysis shows that these indicators systematically ignore important qualitative metrics such as asymmetric interdependence with dominant suppliers, transit and infrastructure constraints, exchange rate distortions, informal economic activity, and global geopolitical pressures. As a result, the traditional analytical toolkit, when applied mechanically, provides an incomplete and sometimes misleading picture of the country's energy security (Keohane & Nye, 2011).

Armenia's economic resilience is deeply linked to its energy vulnerabilities. Energy supply disruptions, whether physical, geopolitical, or price-related, exacerbate macroeconomic instability in a small, import-dependent, and landlocked country. The FM Global Resilience Index and related literature further demonstrate that energy-related risks are reflected in economic, infrastructural, and supply chain sectors, shaping a country's absorptive, adaptive, and transformative capacities.

But analyses show that the FM Global Resilience Index 2025 estimates for Armenia do not (a) separate the share of imported primary fuels used in electricity and heating, (b) reflect the concentration of transit routes (in the case of Armenia, the only transit corridor through Georgia), or (c) reflect asymmetric relationships with suppliers and contractual stability (e.g., long-term Russian gas contracts compared to more volatile regional supplies). This rather complex energy profile from an assessment perspective creates a situation where: (i) the FM "Energy Intensity" factor may overestimate the country's economic resilience, especially if GDP growth masks the dependence on energy imports. and (ii) the FM system's logistical and physical risk factors hardly reflect the impact of transit transport and hazards, as the vulnerability of transit transport depends on the small number of corridor barriers, rather than the average logistic performance used in the indices between countries. In summary, Armenia's composite PF score can be viewed as a comparative tool, rather than a definitive measure of energy security or economic resilience. Therefore, the PF score serves as another assessment in characterizing a country's energy security profile, but it necessarily needs to be complemented by Armenia-specific energy balance criteria (ArmStat / RA MTAD / IEA) and a qualitative assessment of the country's structural features and risks. Thus, resilience cannot be meaningfully assessed without placing a comprehensive assessment of energy security at its core.

Addressing the third guiding question of the study, the analysis highlights the need for an integrated, multi-component framework to understand Armenia's energy system. A purely quantitative approach is not sufficient. A comprehensive assessment should include structural constraints, institutional arrangements, geopolitical dynamics, and physical and economic dimensions of reliability, affordability, and clean energy. Only such an approach can fully reflect the risks Armenia faces in a rapidly evolving regional and global environment.

Ultimately, the findings highlight that Armenia's long-term energy security requires a strategic synthesis of diversification, infrastructure modernization, improved domestic production (including low-carbon options), improved regulatory capacity, and targeted social and regional policies that ensure equitable access and affordability. Strengthening economic resilience, in turn, depends on the country's ability to manage asymmetric

dependencies, reduce exposure to external shocks, and implement energy and economic reforms that are consistent with global shifts toward cleaner and more resilient energy systems. By moving beyond superficial indicators and adopting a holistic analytical approach, this study provides a deeper and more accurate understanding of Armenia's vulnerabilities and opportunities. Such an approach is important not only for diagnosing current challenges but also for developing long-term, evidence-based policies that can improve both energy security and economic resilience in an increasingly uncertain geopolitical landscape.

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APPROACHES TO THE DEVELOPMENT OF A WATER RESOURCE SAFETY SYSTEM IN THE REPUBLIC OF ARMENIA

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Abstract: The objective of this study is to implement functions—specifically investment measures and legal mechanisms - targeted at reducing Non-Revenue Water (NRW) in the Republic of Armenia (RoA), to address the challenges and issues of enhancing the efficiency of water-resource supply and consumption, including both drinking and irrigation water. The object of the research is the water resources system of RoA and its components. The subject of the research is the principles of water resources supply/management, economic-mathematical methods and models, which are aimed at assessing the increase of the efficiency of water resources supply and consumption with the help of system-wide improvement.

Key words: *water resources management, non-revenue water. water losses, cost-benefit analysis, security of water resources, geographic information systems, Internet of Things (IoT) sensors.*

Introduction

What approaches should be undertaken for developing a comprehensive system for ensuring the Security of the Water Resource Reserves of the RoA, since the safeguarding of water resources is also a key component of the national security of this country.

The purpose of this work is to analyse Armenia's current water reserves, identify the main threats and vulnerabilities, and propose systematic approaches aimed at the sustainable and secure management of water resources. It presents a framework of recommended reforms in the legal, governance, technological, and international cooperation sectors.

Water is one of the fundamental resources of life, and the availability of necessary reserves is of strategic importance both for the livelihood of the population and from the standpoint of state security. In the Republic of Armenia, the uneven territorial distribution of water resources, the reduction of water flows caused by climate change, and the inefficient mechanisms of water use increase the risks of resource depletion and misuse (UNECE, 2022).

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The main purpose of this work is to present a vision for a comprehensive system to ensure the security of Armenia's water resources, based on an analysis of current challenges and opportunities.

Characteristics of Water Resources in Armenia

Armenia is rich in rivers and groundwater resources. Within the territory of the Republic, around 9,480 streams, rivers, and rivulets are registered, with a total length of more than 23,000 km. The most water-abundant rivers include the Debed, Hrazdan, Vorotan, and Arpa. Groundwater reserves are mainly concentrated in the Ararat Valley, which is of strategic importance for both drinking water supply and agricultural irrigation (Ministry of Environment RA, 2023).

According to studies, the annual water formation in Armenia amounts to approximately 6.7 billion m^3, of which about 4.2 billion m^3 is ecologically available for use (FAO, 2020).

The Impact of Water Resources Management on the Economy and Agriculture of RoA

Water resources management is considered one of the most important fields of the country's economy. The solution of problems related to water supply to the population and irrigation of irrigable lands is due to its flexible management. Water is one of the most valuable resources of our country, which should be treated with utmost care and precise targeting. In recent years, numerous projects have been undertaken to develop the irrigation system, with the most significant being those focused on constructing reservoirs. Despite all these, there are many other challenges in the field.

The primary objective in the water resources sector is to substantially enhance the efficiency of water resources management in order to effectively address challenges related to domestic water supply and agricultural development—especially the expansion of irrigated land—while also adapting to rising temperatures and decreasing precipitation caused by climate change.

What is non-revenue water?

Non-revenue water includes all water supplied by a utility that does not generate revenue. This consists of both actual losses, such as leaks and physical damage to the distribution system, and apparent losses resulting from theft, illegal connections, or inaccuracies in metering devices. The goal of water utilities is to minimize NRW to ensure that a greater percentage of supplied water reaches the paying customers. ([7], [8], [9])

The GoA strategy for improving the financial sustainability of the irrigation sector states:

- increase in the efficiency of irrigation services, assurance in the continuity of service provision and the maintenance of accessibility;
- improvement of the financial viability and sustainability of irrigation water system companies (water user companies and water receiving companies) by strengthening the prerequisites for a transition to current cost recovery;
- maintaining and upgrading irrigation systems and infrastructure;

• increase in the effectiveness of the investment of state financial support provided to the irrigation system;

Threats and Vulnerabilities

The main factors threatening the security of the water resources of the Republic of Armenia are:

- **Climate Change**

Over the past decades, a decrease in precipitation, an increase in air temperature, and seasonal changes in water flows have been observed. Years of water scarcity are becoming more frequent, especially in the rivers of the Sevan Basin (UNDP, 2021).

- **Pollution and Inefficient Use**

Agricultural and industrial activities contribute to the pollution of aquatic environments. In the Ararat Valley, a decline in groundwater levels has been noted as a result of the operation of illegal wells (Sargsyan, 2021).

- **Shortcomings in the Management System**

Water resource management in Armenia is a multi-agency system, involving various governmental bodies, including the ministries of environment, territorial administration, emergencies, and others. Fragmented regulations and limited monitoring data hinder the implementation of a unified policy (UNECE, 2022).

Approaches to Developing a Water Security Assurance System

- **Institutional Reforms**

A National Water Security Council should be established to oversee strategic planning, risk assessment, and coordinated intersectoral activities. The distribution of powers among state institutions must also be clarified.

- **Monitoring and Data Management**

The creation of a unified data platform with real-time monitoring systems will make it possible to forecast risks and manage water use more efficiently. These systems should be connected with regional centers.

- **Legal Reforms**

The Water Code must be revised, and the mechanisms of responsibility for illegal water use and pollution must be strengthened. In addition, it is necessary to clarify water-use quotas by sectors.

- **International Cooperation**

Armenia should intensify bilateral and regional cooperation within the framework of joint management of the Araks, Debed, and Akhuryan water flows. This will improve the processes of mutual use of water resources and data exchange (FAO, 2020).

Materials and Methods

The methodological basis for the research was the principles of water resources supply, the results of economic research, publications, and monographs related to commercial, investment, and financial optimal management and modelling, as well as RoA laws, government decisions, and RoA economic development trends and processes.

The Cost–Benefit Analysis (CBA) is a critical tool to evaluate the economic viability of the proposed water governance interventions in Armenia. This analysis helps policymakers understand the long-term economic returns of various strategies to address

water scarcity, climate change impacts, and regional water cooperation. The CBA uses the Net Present Value (NPV) approach and Benefit-Cost Ratio (BCR) to compare the costs of implementation with the expected benefits derived from each intervention.

Areas of application are irrigation, provision of drinking water and wastewater services, aiming at increasing the efficiency of operations and reducing losses.

Technologies like Internet of Things (IoT) enabled sensors, a Geographic Information Systems (GIS) based SCADA (Supervisory Control and Data Acquisition) systems can enhance the efficiency of the management of water systems by providing real-time monitoring and improving resource allocation.

Together, they allow operators to see **where** events are happening and **how** the system is performing in real time. Key functions are the following:

- Real-time visualization of water networks on maps
- Monitoring of reservoirs, canals, pumping stations, and irrigation systems
- Leak detection and pressure management
- Remote control of gates, valves, and pumps
- Alarm management with geographic context
- Historical data analysis and performance reporting

Predictive analytics can aid in anticipating system inefficiencies and enabling proactive maintenance, ensuring a reduction in NRW and improved service delivery.

During the research, several scientific results were obtained from which the following provisions will be distinguished as scientific innovations:

- New methods and models, and tools, and steps for their application;
- Implementation in educational processes;

A cost-benefit analysis of transitioning to smart water infrastructure will highlight the long-term savings achieved through reduced inefficiencies and better resource utilization.

Below is presented a comparison of water loss levels with electricity transmission & distribution and natural-gas sector losses' levels.

- **Water supply losses (NRW)** were by far the largest problem historically — extremely high in the 2000s (reports of **up to ~80–85%** NRW in some systems around 2007–2012), and have been a major focus of World Bank/donor projects since then. Overall, water losses dominate in percentage terms. ieg.worldbankgroup.org+1
- **Electricity transmission & distribution losses** have been **moderate** and **declined** over time: typical combined T&D loss rates in recent years are in the **~6–10%** range (World Bank / IEA series show values near **6–7%** by 2021–2022). World Bank Open Data+1
- **Natural-gas sector losses** (own use + distribution losses) have generally been **low-to-moderate** compared with water — often **~1–5%** as a share of gas throughput in recent years, though occasional spikes and reporting differences exist; 2019 press figures cited ~4.9% for a quarter, while IEA/energy reviews show distribution losses ~1–3% in recent years. In 2023 official energy-balance notes report some increase in gas distribution/transmission losses. Arka+2IEA+2

B — Compact comparison table (2005–2024 summary)

Numbers below show typical ranges or representative values across the period 2005–2024. Use these as comparative indicators rather than precise annual series (see sources & limitations).

Table 1

Compact comparison table (2005–2024 summary)

Sector	Typical range (2005–2024)	Representative recent value (c.2021–2023)	Notes
Water (NRW)	**~40% – 85%** (very high in mid-2000s for some systems; large variation by city/utility)	Still high in many systems; major reduction in some utilities but not uniformly resolved.	World Bank/donor reports document **NRW up to ~85%** in earlier years (Yerevan & other systems improved under projects). ieg.worldbankgroup.org+1
Electricity (T&D losses)	**~6% – 15%** (higher earlier, falling over time)	**~6–7%** combined T&D in 2021–2022 (IEA / World Bank series show ~6.5% by 2022). CEIC Data+1	Combined transmission+distribution loss percentage of output (World Bank indicator EG.ELC.LOSS.ZS). World Bank Open Data
Natural gas (transmission & distribution losses + own use)	**~1% – 6%** (some quarters or years reported near 4–5%)	**~1–3%** typical distribution losses in some official/IEA figures; 2023 energy balance noted increased losses in gas distribution. IEA Blob+1	Reporting differs whether "own use", technical leakage, unaccounted-for gas, or commercial losses are included. Energy Charter

Source: *https://ieg.worldbankgroup.org/sites/default/files/Data/reports/ppar_armeniawater.pdf, https://data.worldbank.org/indicator/EG.ELC.LOSS.ZS*
https://www.ceicdata.com/en/armenia/environmental-energy-production-and-consumption/am-electric-power-transmission-and-distribution-losses--of-output
https://www.energycharter.org/fileadmin/DocumentsMedia/EERR/ARMENIA_IDR_2017_Final_EN.pdf
https://iea.blob.core.windows.net/assets/55834e18-f66e-4642-aed2-7ebff9c54c2c/ArmeniaEnergyProfile.pdf

C — Short interpretation/trends (why these patterns)

1. **Water losses are very large historically** — caused by old/leaking networks, poor metering, weak revenue collection and commercial losses; donor projects and utility reforms (Yerevan and regional projects) reduced losses in some places, but coverage and outcomes vary. The World Bank IEG and project documents explicitly

note NRW as a major operational issue (reported peaks near 80–85% in earlier years). ieg.worldbankgroup.org+1

2. **Electricity losses improved** — investments in metering, network rehab and automation, and modern management reduced distribution losses; IEA notes transmission losses ~1.4% and distribution ~6.0% in 2021. The World Bank/World Development Indicators show an overall falling trend in T&D losses. IEA+1

3. **Gas losses are comparatively low** — the gas grid is metered and operated by a major operator (Gazprom Armenia), and losses are generally kept low; however, some years/quarters showed higher reported "losses & expenses" (e.g., ~4.9% in Q1 2019). Official energy-balance statements flag occasional increases (notably 2023). Differences in how "losses" are defined (own use, system recoveries, theft) complicate exact comparison. Arka+1

D — Key sources and limitations

Primary sources used (representative):

- World Bank / World Development Indicators — *Electric power transmission & distribution losses (% of output).* (time series, country-level). World Bank Open Data
- IEA / Armenia Energy Profile (Energy Policy Review/Armenia 2022) — detailed sector figures (electricity T&D split; gas transmission & distribution losses). IEA Blob+1
- Armenia national energy balance publications (Ministry / Energy Balance PDFs) — 2015–2023 energy balances showing gas loss volumes and notes about 2023 increases. api.mtad.am+1
- World Bank project evaluations and Independent Evaluation Group notes on municipal water projects — document very high NRW (reports citing up to ~85% in some systems around 2007–2012) and project outcomes. ieg.worldbankgroup.org+1
- Local press / Gazprom Armenia statements about quarterly/annual gas loss figures (e.g., 2019 press note about lowest recorded losses in Q1 2019). Arka

Limitations

- **Different definitions**: "Losses" for each sector may be reported differently (electricity: percentage of output; water: Non-Revenue Water as % of produced water; gas: % of imported volume or % of throughput including own use). That complicates direct apples-to-apples percentage comparisons. ONE MP
- **Data gaps & heterogeneity**: Water sector figures vary greatly across utilities (Yerevan vs regional systems) and by year; some mid-2000s values are extreme for some utilities but not nationwide averages.
- **Time coverage**: World Bank / WDI and IEA have consistent series for electricity and gas losses up to ~2021–2023; water NRW series are typically found in project reports and are less consistently published year-by-year nationally. World Bank Open Data+1

Armenian Water and Wastewater Supply Company "Veolia Jur" Closed Joint Stock Company (CJSC) mostly does not control the whole water supply network from water intake to end-user customers in the multi-apartment buildings. Inside the multi-apartment buildings, Condominiums are responsible for the maintenance and operation of the water and wastewater supply networks. Due to insufficient funding, Condominiums, in most cases, are not able to control technical and commercial losses

of water. In contrast to electricity transmission & and distribution, gas supply networks are fully controlled by those utilities. Therefore, the level of water losses is very high in comparison with electricity and gas supply losses.

How to reduce NRW in drinking and irrigation water supply systems?

Drinking water supply system

Calculation of the Reduction of Non-Revenue Water (NRW) in Water Supplies on the example of one multi-apartment building.

The average cost of internal network reconstruction of drinking water in one apartment is 30,000 AMD.

For 12 apartments in one entrance of a multi-apartment building, the cost is 360,000 AMD /12*30,000 AMD/.

For one entrance, the average cost of installation of the inter-floor water pipe and insulation and the connection to the main water pipe in front of the entrance is 300,000 AMD.

The total is 660,000 AMD or 55,000 AMD per customer.

Yearly Average Non-Collected Revenue Calculation from the population of all multi-apartment buildings

Actual yearly figures for 2023 (www.psrc.am)

- Water input to the centralized water supply system of Veolia Jur CJSC (utility) - 528.7 mln m^3.
- Sold water - 161.9 mln m^3.
- Water losses - 366.8 mln m^3 / 69.4%.
- Revenue & Collected amount - 31,334.1/29,907.1 mln. AMD.
- R&C amount (population)-20,924.9/20,114.5 mln. AMD.
- Actual Technical losses - 12.4 %.
- Non-Revenue water from population (multi app bld) - 57*0.67*20,924.9*0.6/(100-69.4)=15,670 mln. AMD.
- Average yearly non-collected revenue is 15,670*0.96 = 15,043 mln. AMD.

Cost-Benefit analysis

- 350,000 (domestic customers) *55,000 AMD = 19,250 mln. AMD;
- 19,250 mln AMD/15,043 mln. AMD = 1.3 years;
- Within 10 years, by investing yearly 1,925 mln. AMD: the utility can receive 1,504 mln AMD per year, plus the accumulated benefit.

Table 2

Cost-Benefit analysis of reconstruction of drinking water internal network

Name	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Total Benefits	0	3,008,600	4,512,900	6,017,200	7,521,500	9,025,800	10,530,100	12,034,400	13,538,700	15,043,000
Total Costs	19,250	19,250	19,250	19,250	19,250	19,250	19,250	19,250	19,250	19,250
Net Cash Flow	-19,250	2,989,350	4,493,650	5,997,950	7,502,250	9,006,550	10,510,850	12,015,150	13,519,450	15,023,750
R = 12%	1.0000	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606
NPV	-19,250	2,669,063	3,582,310	4,269,222	4,767,816	5,110,558	5,325,124	5,435,044	5,460,279	5,417,715

Source: *Calculated by authors.*

Irrigation water supply system

• Implementation of contemporary technologies to decrease the amount of non-revenue water in community distribution networks.

• Implementation of legal, financial, and commercial reforms to decrease NRW.

• Evaluation of necessary financial investments and redemption calculation.

• Financial calculations and comparisons between different service companies.

• Other steps.

Installation of a new internal network from PVC for an irrigation system for 1 hectare (ha):

• Pipes (with installation) for 1 ha – 500 meter*$10 = $5,000 or 2 mln. AMD. Plus, the cost of pumping is 10% and the water meter installation. In total 2.2 mln. AMD.

• Water supplied for l ha is10,000 m3/y, out of which only 4,000 m3/y reaches. The cost is 110,000-130,000 AMD. Water losses are 60%. There is no bookkeeping system. The collection rate is below 40%.

• After upgrading the new internal network water losses will be a maximum of 15%, which means 4,706 m3/y will be supplied, and 4,000 m3/y will reach the customers. Around 5,300 m3/y of water will be saved.

• The benefits are the introduction of a reliable bookkeeping system and a high collection rate. Water supply will be scheduled, which will ensure a high yield and extension of irrigable land areas.

• Cost-Benefit Analysis and NPV calculation are presented below:

Table 3

Cost-Benefit analysis *of the irrigation water supply new internal network construction*

Name	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Total Benefits	0	446,953	446,953	446,953	446,953	446,953	446,953	446,953	446,953	446,953
Total Costs	2,200,000	0	0	0	0	0	0	0	0	0
Net Cash Flow	-2,200,000	446,953	446,953	446,953	446,953	446,953	446,953	446,953	446,953	446,953
R = 12%	1.0000	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606
NPV	-2,200,000	399,065	356,308	318,132	284,047	253,613	226,440	202,179	180,517	161,176

Source: *Calculated by authors.*

Theoretical and applied significance of the research

• Creation of a complete system of RoA water resources management, which will be proposed to be implemented in the Water Committee of the Ministry of the Territorial Administration and Infrastructure of the Republic of Armenia (WC of MTAI of the RoA).

• Ensuring the full use of reliable data in the water supply system based on the use of modern information processing methods for operational, diagnostic, repair, and construction works.

• Representation of spatial data of the main pipelines of the Water and Wastewater (W&W) and Irrigation system by means of maps and technological schemes;

• Visualisation of the interrelationship of W&W and Irrigation system objects through maps and schemes;

• Obtaining information on the problem areas of the water supply system and irrigation system;

• Consumption distribution study and forecasting;

• Water system asset management

The integration of IoT sensors, GIS-based SCADA systems, and advanced data analytics will provide a robust framework for improving the management of water systems by providing real-time monitoring and improving resource allocation.

Benefits for water and irrigation management

- Improved operational efficiency and faster decision-making
- Reduced water losses and energy consumption
- Better response to failures and emergencies
- Optimized irrigation scheduling and water allocation
- Support for climate-change adaptation and drought management

Thus, integrating smart metering systems, combined with automated leak detection technologies, will provide effective tools for reducing non-revenue water in both urban and agricultural sectors.

Conclusion

The water resources security of the Republic of Armenia requires a comprehensive and institutional approach. It is clear that the existing threats—both ecological and governance-related—cannot be overcome through a single sector.

It is necessary to:

• Establish a water security strategy as a component of national security.

• Estimate necessary measurements (investments and legal) for reducing drinking and irrigation water losses.

• Cost-benefit analysis of measurements mentioned above.

• Suggested solutions for securing necessary water resources and reducing water losses to improve the quality of drinking and irrigation water supply systems and services.

• Introduce digital monitoring technologies.

• Build multifunctional reservoirs for water storage and distribution.

• Strengthen public–private cooperation in the water sector. A secure water future requires timely and well-grounded decisions.

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ASSESSMENT OF THE EFFICIENCY OF INVESTMENT ACTIVITY OF INSURANCE COMPANIES IN THE REPUBLIC OF ARMENIA

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Abstract: The article analyzes the structure and efficiency of investment activities of non-life insurance companies operating in the insurance market of the Republic of Armenia, based on which it is recorded that investment policy plays a key role in ensuring the financial stability, liquidity and profitability of companies. From the investment indicators of the six insurance companies studied for 2020–2024, including the investment activity ratio, profit sensitivity ratio, ROE and ROA, it becomes obvious that the efficiency of investments varies significantly between different companies and periods due to management approaches and the market situation. The recorded trends and asymmetries indicate the need to revise asset management strategies. This study is important from the point of view of the development of the insurance sector, since the investment policy of insurance companies significantly affects their financial stability and competitiveness.

Key words: *insurance market, insurance company, insurance activities, insurance premium, investment activities, investment performance indicators.*

Introduction

In the modern financial system, insurance companies play a key role, serving not only as a mechanism for protecting against risks, but also as financial institutions with significant investment potential in the long term. Given the nature of insurance activities, these companies, accumulating significant financial resources, in addition to the insurance purposes themselves, can use these financial resources as investment resources, creating an additional source of income. Effective investment management not only ensures the stability of insurance companies, but also contributes to increasing their competitiveness, stable replenishment of reserves and the development of the financial market.

The insurance market of the Republic of Armenia has undergone significant changes and development processes in the last decade. Although the investment tools here are relatively limited, due to the limited volumes of the securities market and the level of

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stability of the financial environment, insurance companies should strive to use their investment potential as efficiently as possible, taking into account market conditions, regulatory restrictions and risk factors. The requirements and investment restrictions set by the Central Bank of the Republic of Armenia form a very clear framework for insurance companies, within which the construction of an investment strategy requires a balanced approach between profitability, liquidity and risk reduction. The assessment of the effectiveness of investment activities becomes a matter of strategic importance as an indicator of the overall financial and economic health of the insurance company, the quality of asset management, the flexibility of internal financial policy and profitability. This analysis allows not only the identification of existing problems, but also the outlining of possible potential improvement directions, ensuring the strengthening of the company's competitiveness in the long term. Therefore, it is necessary to conduct a comprehensive analysis of the structure and effectiveness of investment activities, based on relevant financial indicators, portfolio approaches and sectoral comparisons.

Theoretical and methodical bases of the research and methods of analysis

Evaluating the effectiveness of investment activities of insurance companies is one of the fundamental directions for ensuring financial stability and profitability. Various studies indicate that the structure of investment assets, the level of investment diversification, and the effectiveness of risk management have a significant impact on the financial results of insurance companies (Arena, M., 2008).

Heyman (Heyman W.H., 2006), Pottier (Pottier S.W., 2007), Chen (Chen X., Yao T., Yu T., 2007), Babbel (Babbel D., 2001), Thomas (Thomas S., 2005) and other authors have made important contributions to the development of the theory and methodology for organizing the investment activities of insurance companies. However, despite the relevance and practical importance of the topic, a complete quantitative and qualitative assessment of the effectiveness of the investment activities of insurance companies has not yet been fully revealed, and individual authors offer their own analytical methods.

Among the researchers, in particular, Kraus and Litzenberger (Kraus A., Litzenberger R.H., 1973), as well as Eling and Schmeiser (Eling M., Schmeiser H., 2010) emphasize that the predominance of high-risk assets can lead to instability of profitability, while a balanced portfolio policy contributes not only to an increase in profitability, but also to strengthening the financial flexibility of the insurance company.

The relationship between investment activity and profitability is also emphasized in the analyses performed by combining ROA and ROE indicators, which are widely used in studies of the efficiency of the insurance sector. Some authors propose complex assessment methodologies, including the ratio of costs and income, the profit sensitivity factor and structural changes in the portfolio (Kozmenko O., Roienko V., 2013).

Zéghal and Maaloul propose a scientific and methodological approach to assessing the investment activity of insurance companies, based on the correlation of investment indicators. The authors emphasize the importance of defining clear criteria for choosing investment strategies, linking them to the relationship between risk, profitability and asset structure (Zéghal D., Maaloul A., 2010).

The Institute of Asset Management (IAM) initially introduced the 6-Box Model to provide a structured approach to asset management, focusing on core elements such as organisation and people, asset management strategy, decision-making, lifecycle

delivery, asset knowledge enablers, and risk & review. Over time, the model evolved into the 10-Box Model, which aligns more closely with ISO 55000 standards and incorporates additional aspects such as organisational context, leadership & governance, value and outcomes, risk management, and continual improvement. This evolution reflects international best practices and provides a more comprehensive framework for effective asset management. (Asset Management Academy, 2024).

The investment activity of insurance companies in Armenia is a limitedly studied area. For this reason, combining international experience with local data not only fills the scientific gap, but also allows identifying the specifics of the local market for the development of investment policy.

Methods

The methodological basis of the research is a combined approach of quantitative analysis, which is aimed at a comprehensive assessment of the effectiveness of the investment activities of insurance companies in the Republic of Armenia. The main research objective is to assess the investment policy of insurance companies through indicators of profitability, risk management and effective asset allocation. The analysis was based on data published by the Central Bank of the Republic of Armenia, annual reports of insurance companies, as well as additional open data sources, in particular, summary analyses of the insurance market. The research period covers the years 2019-2024. Within the framework of the study, six of the seven insurance companies operating in the RA insurance market were selected for analysis, since the seventh company (Efes) entered the market only in 2024 and did not have complete data for previous years. Several indicators were calculated to assess the effectiveness of investment activities. The analysis was carried out through a two-way, spatial comparison between companies to identify best practices and differences in investment efficiency. Based on the dynamics of the same company's data over time, to identify strategic stability and development trends. In addition to some performance indicators, asset structure, profitability levels, and sensitivity ratios were also analyzed for a more visible presentation of trends. Graphical data contributed to the intuitive perception of quantitative indicators. The analysis of investment activity efficiency was conducted not only based on the structure of assets and financial indicators, but also attempted to examine the asset management practices of insurance companies. Special attention was paid to whether the companies implement the requirements of ISO 55000 standards and at which level they are positioned within the 6-Box/10-Box Asset Management Maturity Scale, considering their placement to the left or right of the midpoint in accordance with ISO 55001 requirements. This approach ensures that the analysis encompasses not only quantitative but also strategic and process-oriented components, highlighting trends and asymmetries that necessitate a revision of investment and asset management strategies.

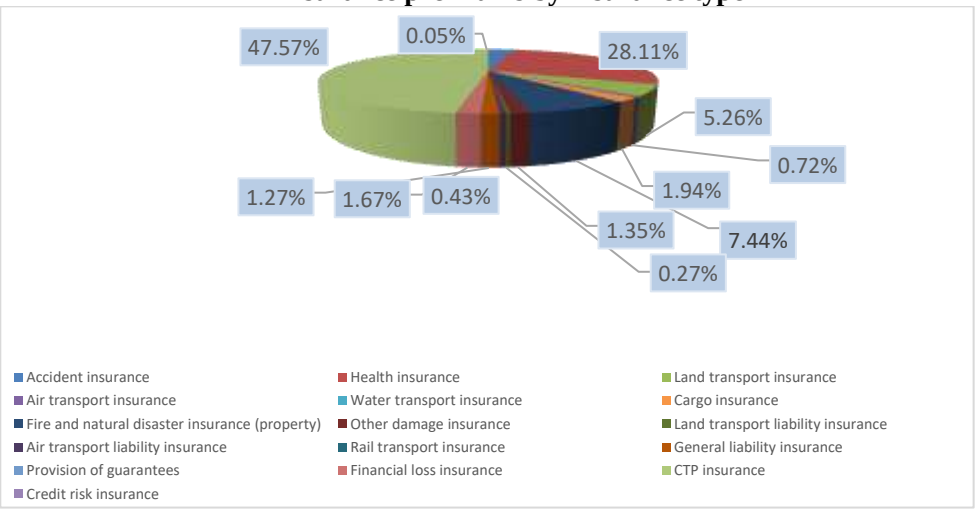
Analysis

Let's start the analysis of the investment efficiency of insurance companies in Armenia by studying the indicators of 6 companies operating in the market, based on their investment activities. The purpose of the analysis is to assess how effectively insurance companies manage their investment assets, what factors affect their profitability and what strategies are used in the investment management process. To

analyze the investment activities of insurance companies, it is necessary to first understand the main financial flows that form the basis of investment potential. Since a significant part of the income of insurance companies is formed at the expense of collected insurance premiums, the analysis of their structure and sources of origin is an important prerequisite for a substantiated assessment of investment policy. Within the framework of this study, the average insurance premiums of the last five years of the insurance market of the Republic of Armenia by types of insurance were analyzed.

Figure 1

Insurance premiums by insurance type



Source: *Prepared by the author based on publicly available reports of Ingo Armenia, Liga, Rego Insurance, Armenia Insurance, NAIRI, and SIL Insurance*.

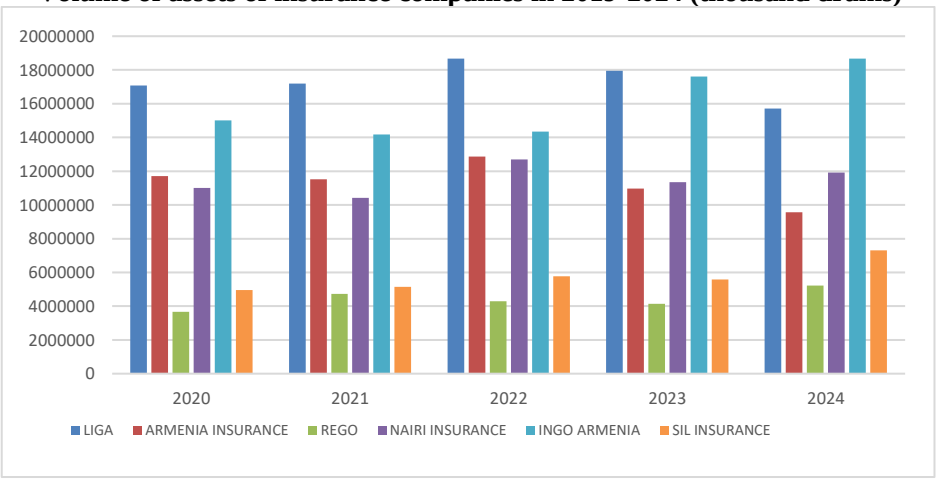
The results of the study show that the majority of total insurance premiums are provided by three main directions:

- Compulsory Motor Third Party Liability Insurance (MTPLI),
- Voluntary Medical Insurance,
- Property Insurance.

The stable financial flows formed by these directions are considered the main sources of investment asset formation of insurance companies. Therefore, this structural analysis not only records the dominant areas of insurance income, but also serves as a basis for assessing how these flows affect investment strategies and risk management. At the same time, such a concentration of insurance premiums in 1-2 directions increases the riskiness of the investment policy due to possible market fluctuations in a given sector. Therefore, the company should ensure a sufficient level of diversification in the investment portfolio, differentiating not only investment instruments, but also taking into account the distribution of sources of insurance premium income. One of the important prerequisites for assessing the effectiveness of investment activities of insurance companies is the analysis of the volume of total assets of the companies. Based on the data of the last five years, a study of the dynamics of the assets of the six leading companies operating in the insurance market of Armenia was conducted.

Figure 2

Volume of assets of insurance companies in 2019-2024 (thousand drams)



Source: *Prepared by the author based on publicly available reports of Ingo Armenia, Liga, Rego Insurance, Armenia Insurance, NAIRI, and SIL Insurance*.

In the Armenian insurance market, some companies show a steady growth in assets, while others show a decrease in assets, which indicates varying levels of adaptation to market changes. As of 2024, the leaders in terms of assets are INGO ARMENIA (18.7 billion drams), LIGA (15.7 billion drams) and NAIRI INSURANCE (11.9 billion drams), which have a larger asset base, providing broad investment opportunities. Despite a certain decrease, LIGA maintains its leading position, and NAIRI INSURANCE regained its position in the top three in 2024. ARMENIA INSURANCE, SIL INSURANCE and REGO have relatively small assets (9.6, 7.3 and 5.2 billion drams), but SIL INSURANCE has a steady trend of asset growth. Overall, large players continue to consolidate, while medium and small companies are trying to improve their asset structure.

Figure 3

Asset Structure 2020

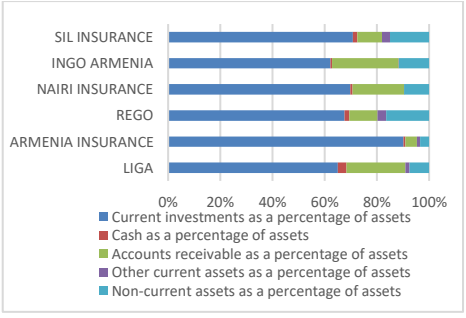


Figure 4

Asset Structure 2021

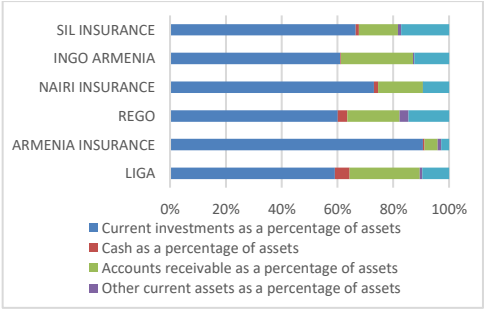


Figure 5

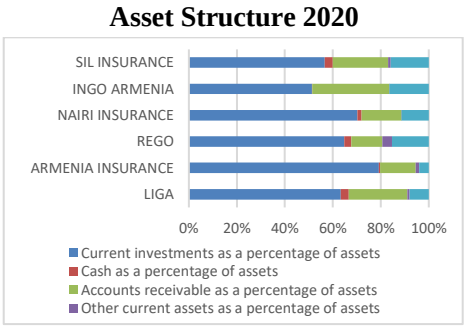


Figure 6

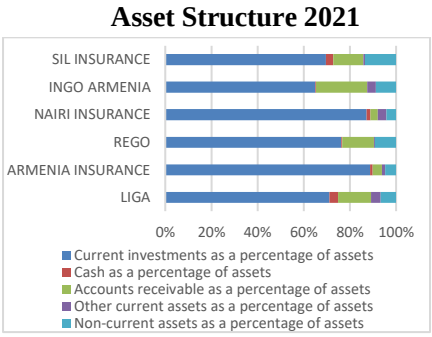
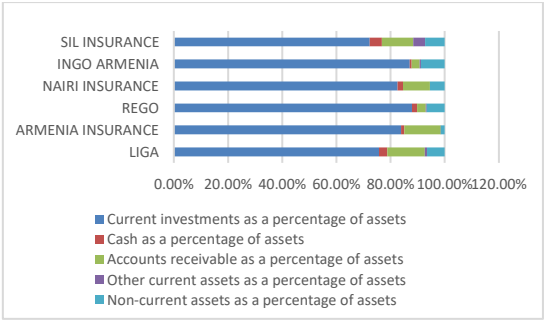


Figure 7



Source: *Prepared by the author based on publicly available reports of Ingo Armenia, Liga, Rego Insurance, Armenia Insurance, NAIRI, and SIL Insurance*.

Analyzing the asset structure of leading insurance companies during 2020-2024, several stable trends and shifts are observed, which affect both investment strategies and general market movements. Current investments have consistently dominated the composition of assets in all six companies, accounting for 50–90%.

Figure 8

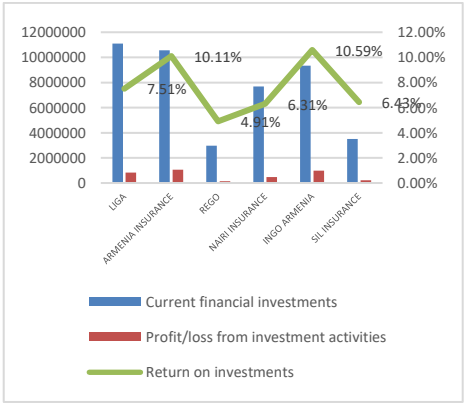


Figure 9

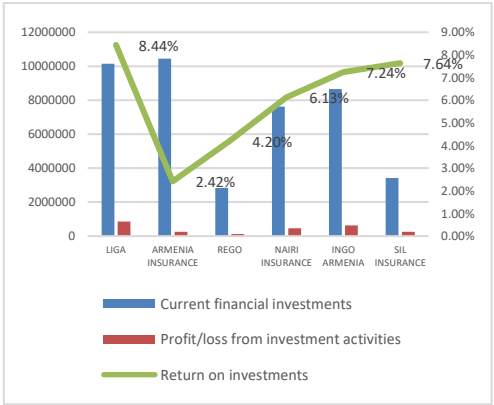


Figure 10

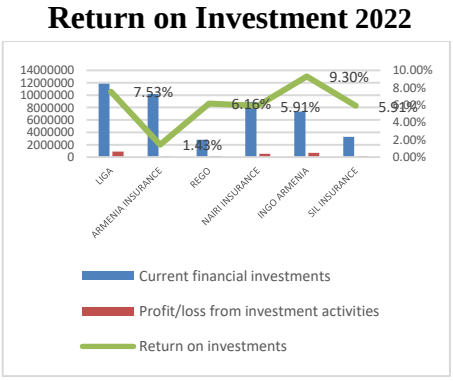


Figure 11

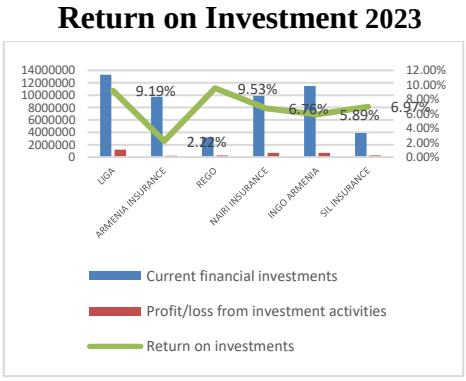
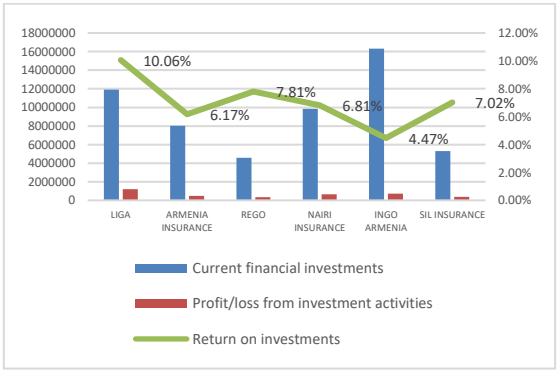


Figure 12



Source: *Prepared by the author based on publicly available reports of Ingo Armenia, Liga, Rego Insurance, Armenia Insurance, NAIRI, and SIL Insurance*.

In 2024, the share of current investments was highest in REGO (87.90%), INGO ARMENIA (87.10%) and ARMENIA INSURANCE (83.90%), which indicates the maintenance of a short-term, low-risk investment policy. In contrast, the share of cash increased only in a few companies. In 2024, the highest cash reserves were held by SIL INSURANCE (4.50%) and LIGA (3.09%). This may be due to the need to maintain high liquid reserves or the expectation of short-term liabilities. The share of other current assets remained insignificant, amounting to 0.1%-4.4%, with the highest figure again recorded by SIL INSURANCE (4.40%). The share of non-current assets has a general tendency to decrease for all companies. If in 2020 it reached 15-17% for some companies, then in 2024 it dropped to the range of 1.4%-8.8%. The lowest non-current assets were recorded by ARMENIA INSURANCE (1.4%), which indicates the use of a strategy based on a highly liquid portfolio.

By studying the investment activities of six insurance companies, it can be noted that both the volumes of current financial investments and the profits received from them have undergone changes over the years due to changes in investment strategies, as well

as macroeconomic and market developments. LIGA has provided stable and high profitability in all years, especially in 2023 (9.19%) and 2024 (10.06%). This indicates the application of a prudent and well-diversified investment strategy. INGO had the highest profitability level in 2020, 10.59%, but in 2024 it decreased significantly, amounting to only 4.47%, although the volume of investments increased significantly and reached about 16.3 billion drams. This may indicate that the increase in the volume of investment activity was not accompanied by adequate profitability, which may be due to both increased risks and low efficiency of the investment portfolio. It is also possible that there is a time lag here: that is, the results of investments will be reflected in profitability indicators in a longer-term perspective. ARMENIA INSURANCE's profitability has significantly declined. In 2020, it amounted to 10.11%, while in 2022–2023 it decreased to 1.43%-2.22%, and in 2024, with some growth, it reached 6.17%. This may be due to a more conservative investment approach or unfavorable external market conditions. REGO has been experiencing steady growth, from 4.91% in 2020 to 7.81% in 2024, which speaks of a gradual but effective strategy and management. NAIRI INSURANCE maintains an average level of profitability, in the range of about 6–6.8%, demonstrating stable investment behavior. SIL INSURANCE's indicators have also remained in the range of 6–7%, reaching 7.02% in 2024. Generalizing the results, the leader in terms of investment profitability for 2024 is LIGA - 10.06%, followed by REGO (7.81%), SIL INSURANCE (7.02%) and NAIRI INSURANCE (6.81%). These results confirm that high profitability is not always associated with a large volume of investments, but also depends on the structure of investments, the effectiveness of risk management and the tools used in the market. In general, changes in the investment profitability of insurance companies are determined by both the general financial environment and the investment policy of the companies, which requires in-depth study to assess the effectiveness of investment strategies.

For a comprehensive assessment of the effectiveness of investment activities, the following main indicators were studied:

• The ratio of the company's expenses and income (x1), which assesses the degree of effective cost management and allows analyzing the core components of the organization's profitability.

• The investment activity ratio (x2), which expresses the share of total assets that is directed to investment activities, that is, it shows the investment size of the company's assets.

• The coefficient of sensitivity of profit/loss to changes in the results of investment activities (x3): This indicator measures the degree to which the company's total profit responds to changes in investment income. It reflects the sensitivity of overall profitability to fluctuations in the results of investment activities. Unlike the classical market Beta coefficient, which compares an asset to overall market returns, this coefficient is internal to the company, focusing specifically on how variations in investment income impact the company's profit. High values indicate greater dependency on investment results and higher financial risk, while moderate values suggest a balanced and diversified investment portfolio.

• ROE (Return on Equity) and ROA (Return on Assets) profitability indicators, which measure the company's return on equity and total assets, indicating the level of operational efficiency.

The combination of these indicators provides a multifaceted and comprehensive assessment of investment activity, which is necessary for both financial stability and risk management and profitability analysis. Below are the five-year indicators.

Table 1

Financial Performance Trends of Armenian Insurance Companies (2020–2021), %

2020	X1	X2	X3	ROE	ROA	2021-X1	2021-X2	2021-X3	2021-ROE	2021-ROA
Liga	41.30	7.3	150.1	4.61	1.99	36.60	7.8	146.9	-8.86	-3.39
Armenia Insurance	43.2	31.7	75.6	45.51	9.85	37.2	7	64.4	14.27	2.8
Rego	43.50	3.9	66.2	11.17	4.11	41.00	3.3	75	-10.52	-3.36
Nairi Insurance	37.70	6.5	28.3	38.9	12.86	34.50	5.9	54.9	23.44	6.78
Ingo Armenia	34.60	13.2	60.3	25.36	8.72	29.20	7.9	82.8	13.7	4.35
Sil Insurance	36.50	4.9	551.2	11.17	4.11	39.20	6.1	477.9	-4	-1,06

Source: *Prepared by the author based on publicly available reports of Ingo Armenia, Liga, Rego Insurance, Armenia Insurance, NAIRI, and SIL Insurance*.

Table 2

Financial Performance Trends of Armenian Insurance Companies (2022–2023), %

2022	X1	X2	X3	ROE	ROA	2023-X1	2023-X2	2023-X3	2023-ROE	2023-ROA
Liga	36.30	7.1	92	11.02	4.2	39.00	9.4	235.8	5.12	2.11
Armenia Insurance	36.00	3.8	22.5	20.87	4.04	33.30	3.9	22.8	23.3	6.97
Rego	39.10	4.5	66	11.64	4.96	36.50	8.7	68.8	15.45	7.71
Nairi Insurance	31.40	5.1	30.7	33.13	10.51	34.30	5.2	83.7	14.73	5.75
Ingo Armenia	32.00	7	59.4	18.43	6.54	34.20	5.9	90	12.01	3.48
Sil Insurance	34.80	3.5	124.5	10.55	2.7	35.30	4.1	182.3	7.55	2.67

Source: *Prepared by the author based on publicly available reports of Ingo Armenia, Liga, Rego Insurance, Armenia Insurance, NAIRI, and SIL Insurance*.

Table 3

Financial Performance Trends of Armenian Insurance Companies (2024), %

2024	X1	X2	X3	ROE	ROA
Liga	36.60	9.1	323.6	-5.23	-2.35
Armenia Insurance	31.50	7.1	69.90	18.09	6.18
Rego	47.60	9.4	89.3	14.60	6.53
Nairi Insurance	37.80	5.6	185.6	6.18	2.36
Ingo Armenia	31.80	9.9	218.2	4.29	1.31
Sil Insurance	33.50	4.1	437.0	3.81	1.02

Source: *Prepared by the author based on publicly available reports of Ingo Armenia, Liga, Rego Insurance, Armenia Insurance, NAIRI, and SIL Insurance.*

The evaluation of investment activity efficiency was conducted not only based on financial indicators but also by considering asset management practices to the extent that data were publicly available. It should be noted that ISO 55000 standards are not fully implemented by insurance companies in Armenia, and firms rarely disclose detailed information about their asset management processes. Asset management maturity was assessed using the 6-Box Asset Management Model, as the 10-Box model would require more detailed information that is currently unavailable. Using the 6-Box Model, the assessment focused on six key dimensions: leadership and management commitment, policy and strategy, organizational structure and responsibilities, processes and procedures, information systems and data, and asset management outcomes. Asset Management Maturity is assessed in alignment with partial ISO 55000 principles. The position relative to the ISO 55001 midpoint indicates the level of competence and process maturity. Now let's compare the data from all the indices and evaluate the investment efficiency of the companies.

Table 4

Comparative Analysis of Investment Efficiency Indicators of Armenian Insurance Companies

Company	X1: Expense-to-Income Ratio	X2:Investment Activity Coefficient	X3: Sensitivity to Investment Results	ROE	ROA	Investment Volume–Profit Link	Assessment	Asset Management Maturity/ ISO55000 Compliance
ARMENIA INSURANCE	31%–43% (declining)	7%–31% (high)	22%–75% (moderate)	18%–45% (high)	4%–10% (high)	High volume, good profit	High efficiency	Developing (Basic processes exist; partial ISO 55000 implementation)
NAIRI INSURANCE	31%–38% (consistently low)	5%–6% (consistently moderate)	28%–185% (low–moderate)	33%–38% (high, stable)	5%–12% (high)	Moderate volume, stable profit	High efficiency	Developing (Partial risk management; some ISO-aligned processes)
REGGO	36%–47% (moderate)	3%–9% (moderate)	66%–89% (moderate)	-10%–15% (fluctuating)	4%–7% (moderate)	Growing volume, moderate outcome	Moderate efficiency	Basic (Processes not fully standardized; no ISO compliance)
INGO ARMENIA	29%–34% (low)	7%–13% (high)	60%–218% (high)	25%–4% (declining)	8%–1% (declining)	High volume, weak outcome	Moderate efficiency	Basic / Deve-loping (Partial risk mana-gement; no full ISO 55000)
SIL INSURANCE	33%–39% (moderate)	3%–4% (low)	124%–550% (very high)	10%–3% (low)	1%–4% (low)	Small volume, high dependency	Low efficiency	Basic (High dependency on ad hoc pro-cesses; no ISO)
LIGA	36%–41% (moderate)	7%–9% (moderate)	92%–323% (very high)	-8%–-5% (unstable, negative)	Negative or low	Moderate volume, unstable profit	Low efficiency	Basic / Low (Processes unstable; ISO not applied)

Conclusion

The analysis of the investment activity of the six leading insurance companies in the RA insurance market shows that there are significant differences between the companies not only in terms of investment volumes and structure, but also in terms of their efficiency, profitability, and risk management.

- ARMENIA INSURANCE and NAIRI INSURANCE are distinguished by relatively high and stable levels of investment activity and profitability. These companies have been able to maintain a significant share of investments in total assets, ensuring a stable relationship between investment volumes and the profit received. This indicates that the investment portfolio is managed comprehensively, taking into account both diversification and risk balancing. Based on publicly available information, these companies also demonstrate a higher level of asset management maturity, with structured processes, clear responsibilities, and partial alignment with ISO 55000 principles, as well as effective oversight from management.
- REGO and INGO ARMENIA have recorded a certain increase in investment activity, but the fluctuations in ROE and ROA indicators show that the volume of investments is not yet fully converted into stable profit. This indicates the need to improve the portfolio structure and implement more adequate risk management. These companies show moderate asset management maturity, with basic or partially developed processes, some management involvement, but limited formalization of practices.
- The examples of SIL INSURANCE and LIGA show that even with some investment activity, high sensitivity and low profit levels may indicate an ineffective investment policy. In particular, the high dependence of profit on investment income, as well as negative or low ROE indicators, suggest weak risk control and suboptimal investment strategy. These companies exhibit lower asset management maturity, with undeveloped processes, minimal standardization, and limited evidence of management engagement.

Thus, the effectiveness of investment activities of insurance companies is determined not only by the volume of investments, but also by the structure of these investments, diversification, risk management mechanisms, and the level of cost management. Moreover, the assessment highlights the need for greater transparency, more structured asset management practices, and the eventual adoption of ISO 55000 standards to enhance investment decision-making and overall efficiency.

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REMITTANCES IN POST-SOVIET COUNTRIES: ECONOMETRIC RESEARCH FOR ARMENIA

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Abstract: This study investigates the role of personal remittances in post-Soviet economies, with a particular focus on Armenia's economic development. In several post-Soviet countries, where remittances exceed 30% of GDP, they have become a crucial factor influencing economic stability, social welfare, and political security. The statistical analysis indicates significant heterogeneity across these economies: in Central Asian countries, remittances are an essential source of household income; in Russia, Kazakhstan, and the Baltic states, their role is relatively minor; while in the South Caucasus and Moldova, they represent a key driver of economic activity and investment.

For Armenia, the study estimates the impact of personal remittances, gross investment, and private consumption on economic growth using quarterly data for the period 1996–2024. Two multiple regression models were specified and estimated: the first using the Ordinary Least Squares (OLS) method, and the second addressing potential endogeneity issues through the Two-Stage Least Squares (TSLS) approach. The empirical findings suggest that personal remittances have no statistically significant short-run effect on economic growth in Armenia. In contrast, private consumption and gross investment make a positive and statistically significant contribution to economic growth. The results of this analysis may provide valuable insights for post-Soviet policymakers seeking to reduce reliance on external remittances and redirect these inflows toward productive investment.

Key words: *post-Soviet countries, Armenia, remittances, economic growth, regression analysis, endogeneity, OLS, TSLS.*

Introduction

Over the past two decades, personal remittances have evolved into one of the most significant components of international capital flows and an important source of external financing for developing economies. Globally, remittance inflows expanded from USD 1.93 billion in 1970 to USD 905.98 billion in 2024 (World Bank, 2025).

The post-Soviet region provides a particularly compelling empirical setting for examining the economic consequences of remittance flows. Following the dissolution of the Soviet Union, many of these countries experienced deep economic contractions due

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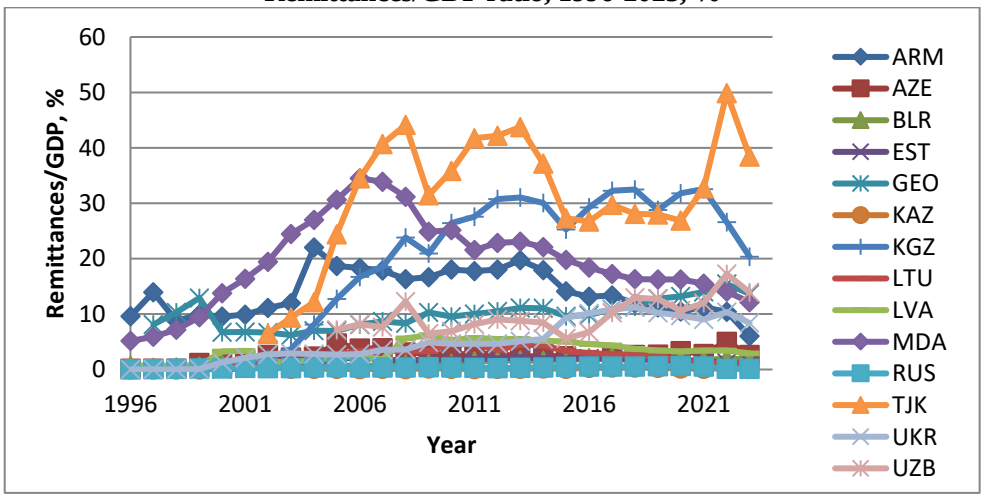
to the collapse of inter-republic trade and production networks. The resulting surge in poverty, and unemployment led to substantial outward labor migration.

In 2023, Tajikistan remained the most remittance-dependent economy in the post-Soviet space, with inflows equivalent to 38.4% of GDP, followed by Kyrgyzstan (20.4%) and Uzbekistan (13.9%). In these countries, between 70% and 80% of total remittance inflows originated from Russia, primarily serving as a lifeline for household consumption. Between 2005 and 2023, the share of remittances in GDP ranged from 12.7% to 32.5% in Kyrgyzstan, 24.4% to 49.9% in Tajikistan, and 5.6% to 13.9% in Uzbekistan (World Bank, 2025). In the aftermath of the Russia–Ukraine war, which began in February 2022, a one-time surge of savings transfers from Russia to Tajikistan led to an almost 80% increase in remittance inflows compared with 2021, pushing their share to 49.9% of GDP. However, in 2023, remittance inflows fell by USD 712 million, even as GDP expanded by USD 1.657 billion, reducing the remittance-to-GDP ratio by 11.5% year-on-year (IMF, Country Report No. 2025/169).

In Armenia, Georgia, and Moldova, a substantial share of remittances originates from Russia; however, the European Union countries (France, Italy, Germany, and Greece) and the United States also play a significant role. Moreover, remittances are partly directed toward investment purposes, including housing construction and small business development. In terms of their share in GDP, the highest inflow of remittances was recorded in Georgia at 15.42% (2022), in Armenia at 22.0% (2004), and in Moldova at 34.5% (2006). By contrast, in Russia, Kazakhstan, and the Baltic states, remittances represent only a marginal fraction of GDP, as these economies function primarily as migrant-destination countries. Between 1996 and 2023, remittances in Kazakhstan peaked at 0.45% of GDP (2002), in Estonia at 2.3% (2006), in Lithuania at 4.57% (2010), in Latvia at 6.18% (2009), and in Russia at 0.66% (2020). In Ukraine, the highest remittance inflow as a share of GDP was recorded in 2018 at 11.2%. In Azerbaijan and Belarus, remittances accounted for only 2–5% of GDP in 1996-2023 (Figure 1). Remittance data for Turkmenistan are not reported in the World Bank database.

Figure 1

Remittances/GDP ratio, 1996-2023, %

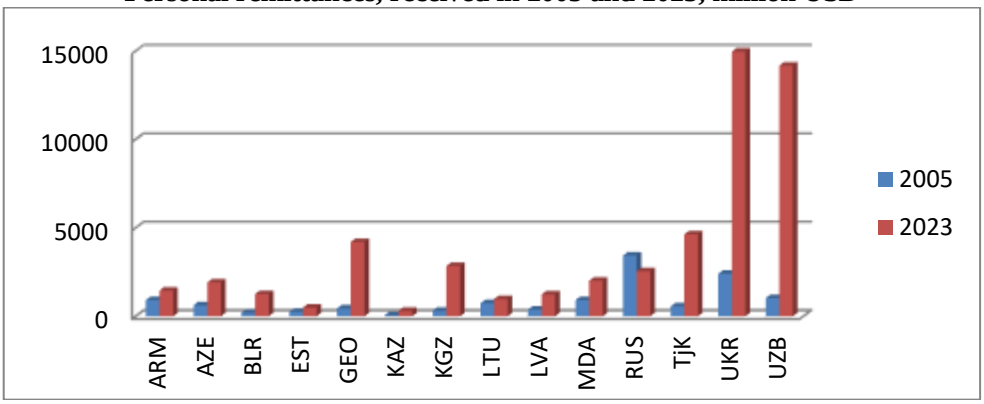


Source: World Bank, 2025.
https://data.worldbank.org/indicator/BX.TRF.PWKR.DT.GD.ZS seen 25.05.2025.

In terms of total remittance inflows, Ukraine ranked first among post-Soviet countries in 2023, receiving USD 14.97 billion in personal remittances, equivalent to 8.37% of its GDP. It was followed by Uzbekistan, with inflows amounting to USD 14.17 billion (13.95% of GDP), Tajikistan, with USD 4.63 billion (38.42% of GDP), and Georgia, with USD 4.20 billion (13.65% of GDP) (Figure 2).

Figure 2

Personal remittances, received in 2005 and 2023, million USD



Source: World Bank, 2025.
https://data.worldbank.org/indicator/BX.TRF.PWKR.CD.DT seen 25.05.2025.

Following the collapse of the Soviet Union, ***Armenia*** underwent a profound economic downturn. By 1998, the country's GDP had fallen to just 61% of its 1990 level. During this period, personal remittances became a critical source of household income, helping to alleviate poverty and improve living standards. Between 1995 and 2003, remittance inflows to Armenia rose steadily—from USD 71.35 million (4.86% of GDP) in 1995 to USD 335.86 million (11.96% of GDP) in 2003—providing vital financial support to many families (World Bank, 2025).

During the pre-crisis period of 2003–2008, Armenia experienced robust economic expansion, with an average annual growth rate of approximately 12%. This growth pattern was largely driven by external financing, particularly foreign direct investment and remittances, both of which increased substantially during this time. In 2004, remittances reached their peak share of GDP at 22.02%. Between 2004 and 2008, remittance inflows grew from USD 787.52 million to USD 1.904 billion (16.33% of GDP). Fueled by the rise in remittances and high household savings, the construction sector expanded significantly, accounting for 25.3% of GDP by 2008. However, the rapid increase in remittance inflows also contributed to symptoms of "Dutch disease," as the appreciation of the real effective exchange rate eroded export competitiveness.

The 2009 global financial crisis severely affected Armenia's economy, which contracted by 14.1%. Remittance inflows declined by USD 464 million compared with the previous year, and the construction sector shrank by 41.6%. The period 2010–2013 marked the post-crisis recovery phase, during which economic growth moderated to an average of 4.4%, reflecting reduced investment activity. A gradual shift toward a new

economic structure took place, with the services sector remaining the main growth driver. At the same time, industry and agriculture began to play increasingly important roles, enhancing the economy's export potential and fostering a more outward-oriented growth model (Strategic Program of the Republic of Armenia, 2014–2025). During this period, remittances continued to rise, reaching a historical high of USD 2.192 billion in 2013, equivalent to about 20% of GDP (Figure 1).

Between 2014 and 2016, remittance inflows declined sharply—from USD 2.079 billion to USD 1.382 billion—primarily due to the depreciation of the Russian ruble, which fell by 11.3% against the US dollar in the first half of 2014 (Armenpress, 2025). This depreciation had a direct negative impact on Armenia, given that a substantial portion of its remittance inflows originated from Russia. From 2017 to 2020, remittances stabilized within a range of USD 1.327–1.539 billion. According to the World Bank (2019), remittances accounted for over 40% of household income among both permanent and temporary migrant families (Armenia International Outmigration, 2019, p. 12).

Following the economic contraction in 2020—driven by the dual shocks of the COVID-19 pandemic and the Second Nagorno-Karabakh (Artsakh) war—the Armenian economy entered a recovery phase during 2021–2023, achieving an average annual growth rate of around 9%. In 2021, remittances from Russia rose notably, supported by the lifting of COVID-related restrictions, an increase in seasonal labor migration, and improved economic conditions in Russia. Total remittance inflows reached USD 1.557 billion in 2021. In 2022, inflows surged to USD 2.031 billion—the highest level since 2013—primarily as a result of the Russia–Ukraine war and the subsequent sanctions imposed on Russia by Western countries. That year, approximately 53% of remittances originated from Russia and 20% from the United States. However, remittance inflows decreased to $1.452 billion in 2023 and $1.278 billion in 2024 (World Bank, 2025).

Although the share of remittances in GDP declined from 22.02% to 4.96% between 2004 and 2024, they remain a significant source of external financing for the Armenian economy. Therefore, further empirical investigation into their role in Armenia's economic development remains both timely and policy-relevant.

Literature Review

A substantial body of empirical research has examined the relationship between remittances and economic growth. Many studies have identified a positive link between remittance inflows and national development, exploring this relationship from multiple perspectives. Calero (2008) and Barajas et al. (2009) argue that remittances stimulate investment and promote human development by financing better education and healthcare services. Similarly, Frankel (2011) and Chami et al. (2012) demonstrate that, unlike other forms of external financing, remittances constitute a more stable and counter-cyclical source of income for developing economies, contributing to macroeconomic stability. Poghosyan (2020) highlights their stabilizing role, emphasizing that remittance inflows often rise during periods of economic downturn, while Ratha (2019) stresses their importance for low-income countries, noting that remittances are more evenly distributed across developing economies than capital flows.

Grigorian and Kryshko (2017) find that in developing economies, remittances—particularly when transferred through formal financial channels—promote financial sector deepening. Islam and Lee (2023), using a time-series analysis, show that since the 1990s, the expansion of remittance flows has contributed significantly to democratic progress. Jansen and Vacaflores (2020) examine remittance inflows in small open economies and analyze their impact on output under different exchange rate regimes.

They conclude that the effects of remittances on labor dynamics, inflation, and output depend on both the structure of the utility function and the monetary policy rule governing interest rate adjustments, especially the responsiveness of interest rates to exchange rate movements. Lartey (2016), analyzing data for 135 developing and transition economies from 1970 to 2007, finds that the impact of remittances on economic growth depends on the degree of exchange rate flexibility. According to his results, more flexible exchange rate regimes are associated with stronger growth effects.

Kumar et al. (2018) investigate the short- and long-term effects of remittances and financial development in Kyrgyzstan and North Macedonia, finding that remittances positively influence long-term growth in both countries. Causality analysis reveals that remittances drive growth in Kyrgyzstan, whereas in North Macedonia, growth stimulates remittance inflows. Comes et al. (2018), examining seven Central and Eastern European economies with per capita GDP below USD 25,000 (Romania, Bulgaria, Croatia, the Czech Republic, Hungary, Slovakia, and Slovenia), find that both remittances and FDI significantly support economic growth, with Romania, Hungary, and the Czech Republic exhibiting the strongest effects. Dhungel (2023) confirms the vital role of remittances in Nepal's economy, finding that a 1% increase in remittances results in a 0.36% long-term rise in GDP. Olayungbo and Quadri (2019), analyzing 20 Sub-Saharan African countries, report that remittances and financial development both positively influence growth in the short and long run, although they find no causal link between remittances and financial development due to the prevalence of informal financial systems. Abdelhadi and Bashayreh (2019), using annual data from 1972–2016 for Jordan, also find a stable long-term relationship between remittances and per capita GDP.

Despite these generally positive findings, the literature also presents opposing evidence. Chami et al. (2003) argue that remittances can negatively affect growth by reducing labor force participation and creating moral hazard problems—recipients may rely on transfers instead of engaging in productive activities. Barajas et al. (2009) similarly find that over several decades, remittances have contributed little to growth and may even hinder it in certain contexts. Raimi and Ogunjirin (2012), analyzing data for Nigeria (1970–2006), find a negative association between GDP and remittance inflows, linking this outcome to migration-related distortions. Nwosa and Akinbobola (2016) show that foreign financial inflows, including aid, can impede growth in Nigeria. Abdelhadi and Bashayreh (2010), using an Error Correction Model for India, conclude that transaction costs are the dominant factor explaining remittance variation over the medium to long term.

Other studies report that remittances have no statistically significant impact on economic growth. Rao and Hassan (2011), examining 40 countries with high remittance inflows, find no robust evidence that remittances contribute to sustained growth. Senbeta (2013) demonstrates that while remittances foster capital accumulation, their effect on Total Factor Productivity is negligible. Konte (2014), using data for developing economies from 1970 to 2010, identifies two distinct regimes: in one, remittances exert a positive and significant marginal effect on growth; in the other, their influence is statistically insignificant. The likelihood of belonging to the growth-enhancing regime depends on geographical and institutional factors—Sub-Saharan African countries, for instance, are more likely to benefit from remittance-driven growth. Feeny (2014) also finds that remittances significantly support income growth in small island developing states, noting that in the absence of remittances, Pacific island economies experience notably lower growth rates.

Several Armenian economists have examined the role of remittances in Armenia's economy. Grigorian and Melkonyan (2011) argue that although remittances contribute to poverty reduction, they may simultaneously discourage labor force participation and reduce investment in human capital—such as children's education—as households either anticipate future migration or remain constrained by subsistence-level expenditures. Furthermore, households receiving remittances are less likely to engage in productive borrowing to finance entrepreneurial ventures, thereby limiting the developmental potential of remittance inflows at the microeconomic level.

According to the findings of Makaryan and Galstyan (2013), approximately 40% of Armenian households received remittances in 2013, positioning Armenia among the top 20 remittance-receiving countries globally. The World Bank reported that between 2010 and 2013, remittances in Armenia influenced poverty dynamics, benefiting primarily the upper 60% of the income distribution (Armenia International Outmigration, 2019, p. 6). More recent data from a 2023 study conducted by ARMSTAT and the International Organization for Migration indicate that 90.7% of remittances in Armenia were used for household consumption—including health and education—while 1.9% were directed toward real estate or construction and 7.4% toward other purposes. In terms of origin, 60.6% of transfers came from Russia, 4.3% from other CIS countries, 15.5% from European countries, 14.2% from the United States and Canada, and 5.4% from other countries (Migration Profile of the Republic of Armenia, 2025).

The results of the study conducted by Kharatyan and Buniatyan (2024) using a Vector Error Correction (VEC) model demonstrate the existence of long-run equilibrium relationships between remittance inflows and real GDP in Armenia. Specifically, the long-run elasticity estimates suggest that a 1% increase in personal remittances is associated with a 0.42% expansion in Armenia's real GDP. This finding underscores the significant and positive contribution of remittances to the country's long-term economic growth trajectory.

The present study aims to assess the impact of remittances on Armenia's economic growth in the short run. The following hypothesis is proposed: **H_0: In the short term, remittances have a positive impact on economic growth in Armenia.**

Model and Data

For the econometric study, we used quarterly data for the following variables for Armenia from 1996 to 2024: real GDP, million US$ (GDPR), gross investments, million US$ (INV), households' final consumption expenditure, million US$ (CONS), personal remittances, Balance of payments, million US$ (REM), exchange rate, USD/AMD (EXR), consumer price index (CPI), imports of goods and services, million US$ (IM) and GDP of the Russian Federation, million US$ (GDP_RUSS).

The data sources are the databases of the World Bank, the Central Bank of the Republic of Armenia, and the Statistical Committee of the Republic of Armenia. Russia's GDP, originally expressed in rubles, was converted to US dollars using the dollar/ruble exchange rate. Armenia's real GDP, gross investments, and private consumption, originally expressed in the national currency (dram), were converted to US dollars using the dollar/dram exchange rate.

We constructed the following multiple regression model:

$$\Delta(\ln(GDPR))_t = \beta_0 + \beta_1\Delta(\ln(REM))_t + \beta_2\Delta(\ln(CONS)_t + \beta_3\Delta(INV)_t + \varepsilon_t \quad (1)$$

To address the endogeneity problem (explanatory variables are correlated with the error terms), an extensive search for good instruments was conducted. The literature typically uses variables that are not subject to reverse causality, such as the origin of a country's legal systems and creditor rights (La Porta et al., 1997). These variables change little over time, so we cannot use them. The endogeneity problem was addressed by applying the TSLS method, using the following instrumental variables: (1) Russia's GDP, which reflects the economic conditions of the main remittance-sending country and influences the supply of remittances from abroad; (2) the USD/AMD exchange rate, capturing global economic trends; (3) the inflation rate, representing a macroeconomic stability variable; (4) the lagged value of gross investment (t–1), which reflects domestic capital accumulation trends; and (5) the lagged value of import of goods and services (t–1), indicating the structural orientation of the economy. These variables are theoretically and empirically appropriate as instruments, as they are unlikely to directly affect changes in Armenia's real GDP, particularly when used in lagged or averaged forms.

We also implement all the necessary tests of residuals for checking the fulfillment of the assumptions. To test for homoscedasticity of the model residuals, we used the Breusch-Pagan-Godfrey heteroskedasticity test. To test for residual independence, we applied the Breusch-Godfrey autocorrelation LM test. To assess the quality of the model, we used the Adj. R^2, and to test the statistical significance of the estimated parameters and hypotheses, we used the *t, F*, and *Chi-square* statistics.

Results

The descriptive analysis of the variables for the period 1996–2024 reveals that the average quarterly volume of remittance inflows to Armenia amounted to USD 162.107 million, with the minimum and maximum values recorded at USD 15.2 million in the first quarter of 1996 and USD 376.4 million in the fourth quarter of 2022, respectively. The graphical representations of the variables indicate pronounced seasonal patterns in GDPR, REM, CONS, INV, IM, and GDP_RUS. Accordingly, seasonal adjustment was performed using the Census X-12 procedure.

To establish the order of integration of the series, the Augmented Dickey–Fuller (ADF) unit root test was employed. The test results show that the CPI series is stationary at level, implying an I(0) process, while the remaining variables are integrated of order one, I (1) (see Table 1).

Table 1

ADF Unit root tests of the series

Variable	Statistic	Test critical value: 5% level	Variable	Statistic	Test critical value: 5% level
Δ(LGDPR)	-9.695372	-2.88719	**Δ(LGDPRUSS)**	-7.147880	-1.943688
Δ(LREM)	-10.83157	-3.450073	**Δ(EXR)**	-6.338892	-1.943662
Δ(INV)	-10.14826	-1.94369	**CPI**	-4.904290	-2.888157
Δ(LCONS)	-9.496611	-2.887190	**Δ(LIM)**	-9.309654	-2.887190

Two multiple regression models were estimated to examine the impact of remittances on economic growth in Armenia. Model (1) was estimated using the OLS method, while Model (2) employed the TSLS estimator to address potential endogeneity in the remittance variable. All variables- GDPR, REM, CONS, GDP_RUS, and IM -were

transformed into logarithmic form to stabilize variance and account for potential non-linear relationships.

The OLS estimates indicate that remittance inflows do not exert a statistically significant effect on real GDP growth in the short run (p>0.10), suggesting the absence of a direct contemporaneous linear relationship in the baseline specification. However, after correcting for potential endogeneity through the TSLS framework—where Δ(LGDPRUSS), Δ(EXR), CPI, Δ(INV(-1)), and Δ(LIM(-1)) were employed as instruments-the estimated coefficient of remittances becomes negative and statistically significant at the 5% level. Specifically, a 1% increase in remittance inflows in the current quarter is associated with a 0.16% decline in real GDP growth, ceteris paribus.

Instrument validity was assessed using the Hansen J-statistic for overidentifying restrictions (prob(J-statistic) = 0.1750>0.05), indicating that the null hypothesis of instrument exogeneity cannot be rejected. The endogeneity test further confirms that all explanatory variables are exogenous. Nonetheless, the Cragg–Donald F-statistic falls below the Stock–Yogo 5% critical value, implying the presence of weak instruments and warranting cautious interpretation of the TSLS estimates (see Table 2).

Table 2

Remittances: OLS and TSLS Regression Results

	Model (1) Dependent Variable: Δ(LGDPR)	**Model (2) Dependent Variable: Δ(LGDPR) with instrumental variables** Instrument specification: Δ(LGDPRUS) Δ(EXR) CPI Δ(INV(-1)) Δ(LIM(-1))
Variable	**Coefficient**	**Coefficient**
C	0.011776*** (0.004432)	0.011738** (0.005343)
Δ(LREM)	-0.037663 (0.032008)	-0.163338** (0.071374)
Δ(LCONS)	0.613483*** (0.066598)	0.568040*** (0.211792)
Δ(INV)	0.000222*** (0.000049)	0.000413** (0.000198)
Adjusted R-squared	0.542280	0.461107
F-statistic	45.62520	20.18881
Prob(F-statistic)	0.000000	0.000000
Durbin-Watson statistic	2.084183	2.108842
J-statistic	-	3.485481
Prob(J-statistic)	-	0.175040
Instrument rank		6
Cragg-Donald F-stat		1.32
Stock-Yogo 5% critical value		9.53

Notes: *** shows significance at the 1% level, ** at the 5% level, * at the 10% level.

This implies that the TSLS estimates are not reliable, and the GDP-remittances relationship is more appropriately interpreted based on the results of the first model.

This conclusion is further supported by the covariance analysis of the residuals and explanatory variables in model (1). For all explanatory variables, the p-value equals 1, indicating that the null hypothesis
$H_0: corr(X, \varepsilon) = 0$ cannot be rejected; therefore, the regression model does not require instrumental variables.

The specification of model (1) estimated using the OLS method is as follows:

$$\Delta(\ln(GDPR))_t = 0.012 - 0.038\Delta(\ln(REM))_t + 0.613\Delta(\ln(CONS)_t + 0.0002\Delta(INV)_t + e_t \quad (2)$$

The diagnostic tests conducted to evaluate the validity of the Gauss-Markov assumptions yield no evidence of violations. Specifically, the Breusch-Pagan-Godfrey test fails to reject the null hypothesis of homoscedasticity (Prob. Chi-Square = 0.337), indicating that the variance of the residuals remains constant across observations. Furthermore, the Breusch-Godfrey Serial Correlation LM test reveals no presence of autocorrelation in the residuals (Prob. Chi-Square = 0.671). The Ramsey RESET test supports the adequacy of the model's functional form, as the null hypothesis of correct model specification cannot be rejected (Prob. F-statistic = 0.278). The Variance Inflation Factor (VIF) values indicate the absence of multicollinearity in the model (see Table 3).

Table 3

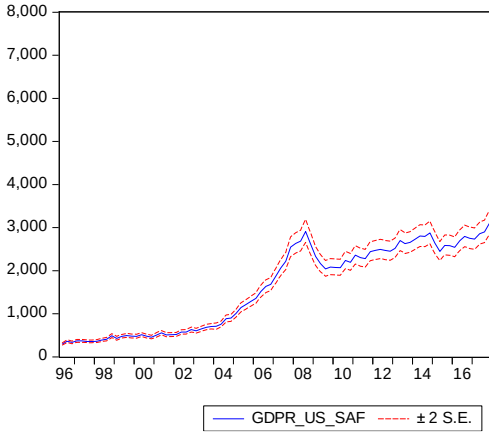
Residuals and Ramsey Tests, VIF

Residuals and Ramsey Tests			**Variance Inflation Factors**			
Heteroskedasticity Test: Breusch-Pagan-Godfrey			Variable	Coefficient Variance	Uncentered VIF	Centered VIF
Obs*R-squared Prob. Chi-Square(3)	3.380458 0.3366		C	2.34E-05	1.422824	NA
Breusch-Godfrey Serial Correlation LM Test			D(LREM)	0.002319	1.538247	1.318661
Obs*R-squared Prob. Chi-Square(2)	0.796586 0.6715		D(LCONS)	0.004426	1.331359	1.094209
Ramsey RESET Test			D(INV)	1.95E-09	1.465065	1.368370
F-statistic Probability	1.186577 0.2784					

Based on the estimated multiple regression model (1), out-of-sample forecasts were generated. As illustrated in Figure 3, the model demonstrates a strong forecasting performance. The Theil Inequality Coefficient, calculated at 0.017568, indicates a high degree of predictive accuracy. Furthermore, the mean deviation between the actual and forecasted series is relatively small, with a Bias Proportion of 0.011587, corresponding to an average discrepancy of 1.16%. These results suggest that the model exhibits both low systematic bias and strong alignment between predicted and observed values.

Figure 3

Forecast of Armenia's Real GDP Using the Regression Model

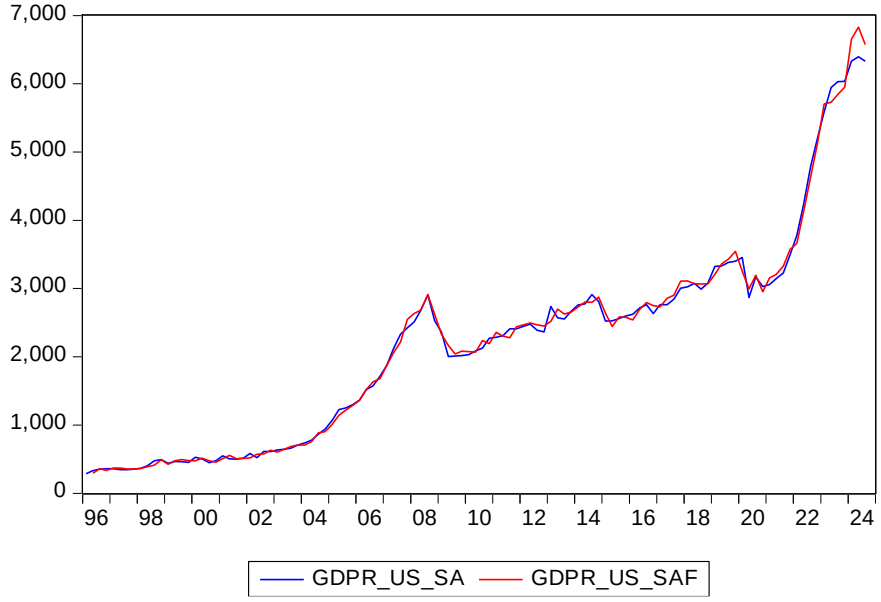


Forecast: GDPR_US_SAF	
Actual: GDPR_US_SA	
Forecast sample: 1996Q1 2024Q4	
Adjusted sample: 1996Q2 2024Q3	
Included observations: 114	
Root Mean Squared Error	93.85522
Mean Absolute Error	65.24327
Mean Abs. Percent Error	3.374394
Theil Inequality Coefficient	0.017568
Bias Proportion	0.011587
Variance Proportion	0.037442
Covariance Proportion	0.950971

The comparison between the actual and forecasted series of Armenia's real GDP further confirms the high predictive accuracy of the model. As illustrated in Figure 4, the close alignment of the observed and projected values indicates that the model effectively captures the underlying dynamics of real GDP, thus demonstrating its strong forecasting capability.

Figure 4

Statistical and Forecasted Series of Armenia's Real GDP Using the Regression Model (1).



Conclusion

Remittances represent a vital source of external financing for post-socialist economies, contributing significantly to economic development and improvements in living standards. In several countries across the region, remittance inflows account for a substantial share of GDP—reaching 49.9% in Tajikistan (2022), 33.9% in Moldova (2007), 32.6% in Kyrgyzstan (2021), and 22.0% in Armenia (2004). Empirical research on the remittance–growth nexus has produced mixed findings: while some studies report a positive impact of remittances on economic growth, others identify negative or neutral effects, reflecting the heterogeneity of country-specific conditions and methodological approaches.

This study empirically investigated the impact of remittance inflows on Armenia's economic growth using quarterly data covering the period 1996–2024. Two multiple regression models were estimated. The first employed the OLS method, whereas the second utilized the TSLS estimator to address potential endogeneity in the remittance variable. However, diagnostic tests for endogeneity, weak instruments, and residual covariances suggest that the instruments used in the TSLS specification do not satisfy the relevance and strength criteria. Consequently, the OLS model provides more reliable and interpretable results for the Armenian case.

The OLS estimation results indicate that, ***in the short run, personal remittances do not have a statistically significant effect on economic growth.*** The results further show that ***private consumption and gross investment exert positive and statistically significant effects.*** A 1% increase in private consumption in the current quarter contributes to a 0.61% increase in economic growth, ceteris paribus. Similarly, an increase of USD 10 million in gross investment leads to a 0.2% rise in economic growth in the current quarter, ceteris paribus. Thus, ***the hypothesis initially posited by this study—suggesting a positive contribution of remittances to short-term growth—is rejected***.

The constructed model demonstrates high predictive accuracy, as evidenced by the forecast quality indicators and the comparison between the actual and forecasted series of Armenia's real GDP. The findings of this study carry significant implications for both academic research and policy formulation. A more nuanced understanding of the complex effects of remittances is essential for designing effective economic policies that maximize the developmental benefits of remittance inflows while mitigating their potential adverse consequences. The analysis provides useful guidance for governments in developing strategies to reduce dependence on foreign remittances and enhance resilience to external shocks. Given the close link between remittances and labor migration, their study also offers insights into migration dynamics. Finally, in the Armenian context, the long-term nature of remittances and their appropriate channeling toward not only consumption but also investment-such as small businesses and infrastructure-can contribute significantly to sustainable economic growth.

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IMPACT OF BONUS-MALUS SYSTEM REFINEMENTS ON TIME-TO-ACCIDENT IN ARMENIA'S CMTPL INSURANCE: A SURVIVAL ANALYSIS APPROACH

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Abstract: This article investigates the impact of recent reforms in Armenia's Bonus-Malus (BM) system on the time-to-accident among Compulsory Motor Third-Party Liability (CMTPL) policyholders. Specifically, it evaluates whether the 2022 introduction of claim severity adjustments influenced policyholder behavior across different risk groups. Utilizing survival analysis methods on a dataset comprising over 2.3 million insurance contracts, the research identifies statistically significant improvements in accident-free durations post-reform. Results reveal that policyholders in certain vehicle categories and risk classes exhibited behavioral shifts, while others, such as public transport drivers and individuals in extreme BM classes, did not. The policyholder's gender emerged as a statistically significant risk factor, with female drivers showing consistently lower accident-free times. The findings underscore the effectiveness of claim severity-based malus policies and suggest that further personalization for example through telematics, can enhance fairness and incentivize safer driving.

Key words: *Bonus-Malus System, CMTPL Insurance, Survival Analysis, Risk Classification, Behavioral Incentives*

Introduction

The implementation of CMTPL insurance in Armenia has played a pivotal role in shaping the motor insurance landscape. A fundamental component of this system is the Bonus-Malus mechanism, which serves as a behavioral incentive by adjusting insurance premiums based on individual claims history. Since its initial deployment in 2013, Armenia's BM system has evolved considerably. Most notably, in 2022, a significant structural reform introduced claim severity into the malus calculation framework mainly based on (Chitchyan & Gulyan, 2015). This study aims to investigate the behavioral consequences of this reform, particularly its impact on the time elapsed between the commencement of a policy and the occurrence of the first reported claim event.

This research utilizes a survival analysis framework to statistically test the hypothesis that the revised BM system has led to an elongation of accident-free durations among

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policyholders. The findings aim to contribute to the broader discourse on behavioral insurance modeling and the empirical assessment of incentive-based policy instruments.

The BM system was introduced in Armenia in 2013, two years following the adoption of mandatory CMTPL insurance. Initially modeled on the Belgian system, it employed a relatively straightforward structure primarily based on claim frequency. Over the following decade, iterative refinements were implemented:

- **2013–2022:** Introduction of additional bonus and malus classes; revisions to transition rules.
- **2022 Reform:** Integration of claim severity into malus scoring. Minor accidents incurred smaller penalties compared to serious ones, promoting proportionality (AMIB, 2025).
- **2017 Technological advances: The Armenian Single Window for Automotive facilitated data exchange and transparency between insurers, regulators, and insureds. In addition to exchanging information on contracts and accidents, this platform also calculates the policyholders' BM classes** (ASWA, 2025)**.**

These modifications were designed to foster fairness, mitigate adverse selection, and enhance market competitiveness. According to the Armenian Motor Insurers' Bureau, these developments significantly improved insurer-client engagement and incentivized safer driving practices.

The main objectives of this research are as follows:

- To quantify behavioral shifts in driving risk subsequent to the 2022 Bonus-Malus reform.
- To identify policyholder segments (defined by risk class, gender, and vehicle characteristics) most affected by the reform.
- To statistically test the significance of behavioral variation using time-to-event metrics.

This investigation is grounded in actuarial science and risk classification theory, drawing on empirical data to inform regulatory and pricing policy decisions in the Armenian insurance sector.

Methodology

When we speak about survival, we mean probabilities. The probability of not occurring an event till some time can be taken as survival probability. In other words, the probability of an event occurrence after a certain time is survival probability. One of the purposes of survival analysis is to find out this probability distribution. A lot of other domain-specific statistical inferences can also be drawn from this. It can be observed that survival probability decreases over time. It is a very important feature of distribution (Nag, 2022).

Most survival analyses must consider a very important analytical problem called censoring. It is caused by not observing some subjects for the full time till failure (or event). A problem occurs when the event happens in between, after the end of or before the study, and hence censoring occurs. There can be two primary reasons for this:

- The event does not happen before the study ends,
- The object of a study left out during the study period.

In all the above cases, true survival time is not equal to the observed survival time, as the actual time could not be marked. Depending on these situations, there can be three

types of censoring. Right censoring happens when a study ends but no event is observed. Left censoring happens when an event has already occurred before the start of the study. Interval censoring happens when an event occurs within the study period in between two possible time limits, and, as usual, the actual time could not be noted.

This study analyzes a comprehensive dataset comprising over 2.3 million insurance contracts, covering the starting period from April 2021 to the ending period of the contracts, April 2024. The following methodological choices were employed:

- **Event of Interest:** First occurrence of a reported accident post-contract initiation.
- **Time Variable:** Duration measured in days from policy start date.
- **Censoring:** Contracts without reported accidents or those terminated before the occurrence of a claim were treated as right-censored observations.
- **Analytical Tools:** Survival analysis via the life-table method was conducted using the SPSS statistical package. The Wilcoxon (Gehan) statistic was applied to test for statistically significant differences between survival curves.

The Wilcoxon test statistic is given as:

$$W = \frac{(N-1)\sum \frac{SS_i^2}{n_i}}{\sum U_j^2}$$

Where:

- $U_j = Unc_j$, for a censored case at time j
- $U_j = 2 * Unc_j - UncEq_j + Cen_j - CenEq_j - N$, for an uncensored case j, where $UncEq_j$ and $CenEq_j$ are the number of uncensored and censored cases at each time period and Unc_j and Cen_j are the number of uncensored and censored cases at all current and previous time periods.
- SS_i is the sum of scores for group i.

The Wilcoxon test statistic accounts for both censored and uncensored observations over time, making it appropriate for non-parametric comparison of survival distributions across groups (StatsDirect, 2025).

Results

This section presents the core findings of the study, structured by key risk-related factors that influence policyholder behavior. The empirical results are grouped to highlight variations across risk classes, demographic features, and vehicle characteristics.

Before discussing the overall behavioral effects of the BM reform, it is important to highlight several conceptual distinctions across policyholder risk groups. Some segments, such as high-frequency claimants or drivers of service vehicles, may exhibit inertia in behavioral change due to structural or occupational exposure. Conversely, moderate-risk policyholders on mid-range BM classes, typically using vehicles for personal purposes, are more likely to adjust their driving behavior in response to incentive structures. Understanding these group-specific dynamics is critical to interpreting the differential impact of the reform.

✓ **General Behavioral Trends**

The survival function for policyholders in the post-reform period was statistically higher compared to the pre-reform period. The p-value (Sig.) of the Wilcoxon test was less than 0.05, indicating that the difference is statistically significant. This suggests that the 2022 BM reform positively influenced policyholders' behavior by increasing accident-free intervals.

Table 1

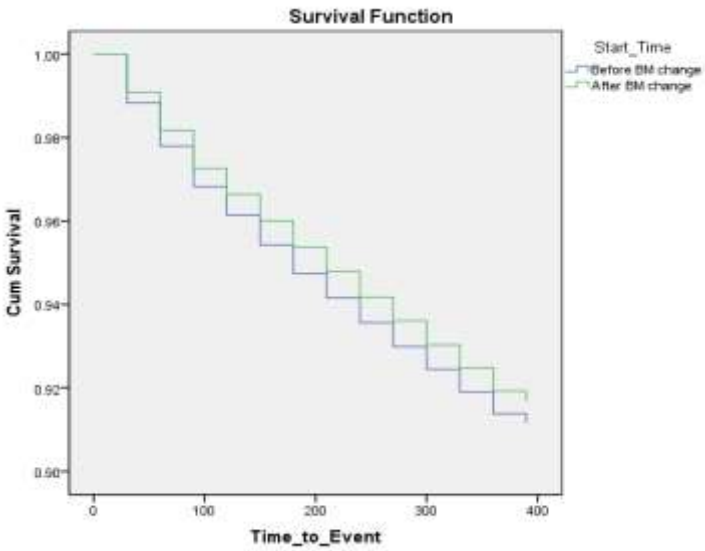
Wilcoxon (Gehan) test for comparison of survival changes before and after BM reform groups

Wilcoxon (Gehan) Statistic	df	Sig.
372.193	1	.000

Source: *Table created in SPSS by authors.*

Graph 1

Survival Function



Source: *Graph created in SPSS by authors*

Survival curve analysis shows that behavior change is in a positive direction as the survival curve before BM changes is lower than after that.

✓ **Behavior by Bonus-Malus Classes**

Insureds in the middle BM classes (classes 4-16) showed a statistically significant change in survival functions. Conversely, insureds in the extreme classes (the lowest BM levels 1-3 or the highest BM levels, 19-24) maintained stable behavioral patterns over both periods. This stability suggests that extreme risk groups may be less responsive to changes in incentive structures, possibly due to ingrained behavioral habits or structural risk factors.

Table 2

Wilcoxon (Gehan) test for comparison of survival changes by Bonus-Malus groups

		Wilcoxon (Gehan) Statistic	*df*	*Sig.*
BM Class	1	.064	1	.800
	2	.377	1	.539
	3	3.237	1	.072
	4	6.745	1	.009
	5	8.350	1	.004
	6	10.175	1	.001
	7	15.136	1	.000
	8	21.433	1	.000
	9	48.581	1	.000
	10	245.373	1	.000
	11	5.292	1	.021
	12	10.958	1	.001
	13	6.159	1	.013
	14	22.786	1	.000
	15	5.977	1	.014
	16	5.761	1	.016
	17	.436	1	.509
	18	6.938	1	.008
	19	.566	1	.452
	20	.028	1	.868
	21	3.518	1	.061
	22	13.570	1	.000
	23	.002	1	.967
	24	.024	1	.876
	25	4.662	1	.031

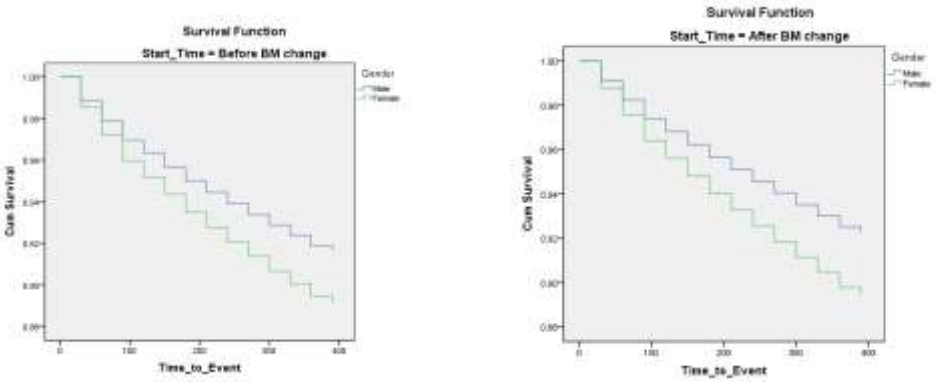
Source: *Table created in SPSS by authors*

✓ **Behavioral Differences Based on Gender and Other Personal Characteristics**

Across both pre-reform and post-reform datasets, female policyholders demonstrated consistently lower survival functions compared to male ones. This result was statistically significant (Sig. < 0.05), reinforcing gender as a material risk factor rather than a discriminatory pricing element. These findings align with prior studies in actuarial literature which document gender-based differences in claims frequency (OECD, 2021).

Graph 2

Survival Functions



Source: *Graph created in SPSS by authors.*

Table 3 shows that both males and females showed a positive change after the BM reform, with males experiencing a slightly higher increase (4.7 days) compared to females (3.2 days). This suggests that the BM reform had a generally beneficial effect on both groups, but the magnitude of the change was slightly greater for males.

Table 3

Average days to accident by gender

Gender	Before BM Change	After BM Change	Difference
Male	347.3	351.9	4.7
Female	341.8	345.0	3.2

Source*: Table created by authors.*

Gender as a valuation variable in insurance has been the subject of extensive debate. While statistical evidence supports its use as a relevant risk factor due to observed differences in accident frequency and severity, its application must balance actuarial accuracy with social fairness. Regulatory trends, such as the EU Test-Achats decision, prohibit gender-based pricing. This has led to a shift towards behavior-based personalization, which encourages individual driving patterns rather than relying on group classifications. Thus, gender as an insurance factor can be a fair and functional risk factor, but its application must be strictly controlled and based on proven differences, avoiding unjustified discrimination (Meyers & Hoyweghen, 2017).

The same suggestions can be made concerning other personal characteristics like the policyholder's citizenship and age group, which are also strong risk factors leading to change in the policyholder's behavior according to this study, but in some sense, they also can be discussed as discrimination factors.

✓ **Vehicle Type and Mark Effects**

In contrast to passenger, bus and truck drivers, motorcycle drivers showed no significant change in time-to-event metrics, indicating the reform did not alter their

behavioral risk profile. Among automobile models, Renault drivers were uniquely unaffected by the BM changes.

Table 4

Wilcoxon (Gehan) test for comparison of survival changes by vehicle mark groups.

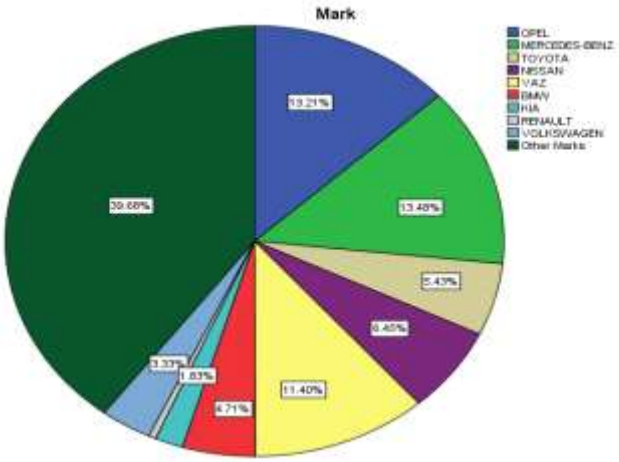
		Wilcoxon (Gehan) Statistic	Sig.
Mark	OPEL	59.452	.000
	MERCEDES-BENZ	36.062	.000
	TOYOTA	4.540	.033
	NISSAN	26.616	.000
	VAZ	113.452	.000
	BMW	7.418	.006
	KIA	10.839	.001
	RENAULT	**2.542**	**.111**
	VOLKSWAGEN	12.880	.000
	OTHER MARKS	108.245	.000

Source: *Table created in SPSS by authors.*

The distribution of vehicle marks in the study was as follows:

Graph 3

Distribution of vehicle marks



Source: *Graph created in SPSS by authors.*

Vehicle-related risk segmentation remains an important avenue for refinement in premium calculation.

✓ **Behavior by vehicle age, horsepower and use type**

According to the purpose of vehicle use, the analysis showed that there is no change in behavior in the case of public and service vehicles, which may be due to the fact that

the insurance premium for these vehicles is paid not directly by drivers, but by their employers or from the state budget. All other risk factors like vehicle age or horsepower significantly affect the change of policyholder's behavior in terms of time to event analysis.

Table 5

Wilcoxon (Gehan) test for comparison of survival changes by vehicle use type

		Wilcoxon (Gehan) Statistic	Sig.
Vehicle Use type	Personal	352.066	.000
	Commercial	21.685	.000
	Service	**.014**	**.904**
	Public transport	**.454**	**.500**
	Taxi or rental	24.213	.000

Source: *Table created in SPSS by authors.*

Conclusion

The empirical results affirm the effectiveness of Armenia's 2022 BM reform in extending accident-free durations among the general policyholder population. The incorporation of claim severity appears to have introduced greater behavioral sensitivity into the system, thereby enhancing its deterrent effect.

From a regulatory perspective, these findings support:

- Development of individualized premium models integrating telematics.
- Ongoing calibration of BM transition rules based on real-world behavioral data.
- Acknowledgement of gender and vehicle type as relevant, non-discriminatory risk factors.
- Continued development of transparent digital infrastructures like the Single Window platform to support data-driven supervision.
- Expansion of public policy tools that align insurance incentives with road safety objectives.

These insights may guide future refinements to the Armenian BM system and serve as a model for other emerging insurance markets.

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TRACING TARIFF IMPACTS THROUGH ELECTRICITY SUPPLY CHAINS: ASSESSMENT OF THE EFFECTS OF TRADE POLICY ON RETAIL ELECTRICITY PRICES[1]

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Abstract: This study examines the relationship between tariffs on electricity supply chain products and retail electricity prices in the United States, with a focus on Minnesota. Using a two-stage regression framework, we first estimate how a 1% increase in tariffs on 440 key electricity supply chain product categories—ranging from fuels and raw materials to advanced generation and grid technologies—affects imports of these products. We find that such a tariff increase is associated with a 4.55% reduction in imports. In the second stage, we link tariff-induced changes in imports to retail electricity prices across residential, commercial, and industrial sectors. Statistically significant and robust results are found only for the residential sector, where a 1% tariff increase corresponds to a 0.78 cent/kWh rise in retail prices. Applying these results to recent U.S. trade agreements with major partners—including the European Union, Japan, South Korea, and the United Kingdom—we project that Minnesota's electricity sector will incur an additional $2.29 billion annually or an average increase of $0.035/kWh, translating into an increase of $316 per year in electricity bills for an average residential ratepayer if these tariffs are maintained for a substantial period of time. The findings highlight strong historical co-movement between upstream input costs and residential electricity prices, underscoring the need for targeted policy responses to mitigate potential impacts on households, especially low-income consumers.

Key words: *Minnesota, Tariff, Wholesale Electricity Prices, Electricity Supply Chain, Lagged Effects, Fixed Effects Regression, Residential Sector.*

Introduction

Domestic prices of products that are part of the supply chain for electricity production can have significant impacts on the prices that retail consumers pay for electric energy.

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These products range from basic materials for the construction of electricity networks, such as aluminum, copper, iron, steel and nickel, to various fuels, such as natural gas, coal, uranium and petroleum, as well as more sophisticated products that are used in the construction of electricity-generating equipment, such as turbines, photovoltaic cells, glass for use in solar panels, industrial-size batteries, etc.

We consider 440 product categories in the six-digit Harmonized System (HS) classification of products that are most related to electricity supply chains. These product categories cover a wide-ranging array of tangible and intangible goods that we believe are most relevant in electricity price formation in the U.S. The period of analysis spans more than two decades – 2000 through 2023. During this period, the U.S. electricity grid underwent drastic changes, by transitioning from mainly fossil fuel-based sources of energy to more renewable and emission-free sources, such as wind, solar and nuclear. The mix of these products has also shifted, and increasing amounts of novel technologies have been incorporated into the grid. The ever-changing landscape of electricity supply chains in the U.S. has introduced new supply chain products to the electricity sector. In the 2000s, these supply chains were dominated by imports of fossil fuels, electricity transmission equipment, and large turbines used in coal- and gas-fired plants. The 2010s saw a steady rise in renewable sources of energy, including solar and wind, and since then this mix has been supplemented with imports of products such as photovoltaic panels and cells, wind turbines, large-scale energy storage equipment and smart grid components. The United States also imports electrical power from its neighbors. These imports of electrical power from neighboring countries can have a direct impact on retail electricity prices, so we include these electrical power imports as one of the 440 categories used in our analysis. The "Data and Methodology" section presents graphical representation of data on U.S. imports in the period of analysis in more detail.

The goal of this study is to estimate the pass-through of tariffs on these supply chain products to retail electricity prices in the U.S. For this, we collected data from multiple sources. Data on tariffs were collected from the UNCTAD TRAINS database using online tools from the World Bank, whereas data on yearly U.S. imports of relevant goods were collected from the website of the U.S. International Trade Commission (ITC). This dataset encompasses the period 2000-2023. Data on retail electricity prices was collected using the U.S. Energy Information Administration's (EIA) online tools.

This study conducts a two-stage mapping exercise in order to understand how increased tariffs on supply chain products are correlated with retail electricity prices. We make use of standard gravity models of trade, as well as linear regressions with lagged effects, in order to estimate this association. The ultimate goal is to estimate the change[2] in retail electricity prices associated with a 1% average increase in tariffs on electricity supply chain products, and apply the results obtained to evaluating the increases in costs associated with the recent changes in U.S. trade policy with key trading partners. This analysis had been done for three sectors – residential, commercial and industrial. We do not find any statistically significant effects in the commercial and industrial sectors, but retail electricity prices in the residential sector are significantly affected by tariff hikes on supply chain products. Using these estimates, we project the cost increases associated with recent U.S. trade agreements with its key trading partners.

[2] This change will be measured in cents per kWh.

Prior work has examined several channels through which trade policy and tariffs influence energy markets, though few papers estimate the direct pass-through from tariffs on upstream supply-chain inputs to retail electricity rates. Shapiro (2021) documents that trade policy is not neutral across industries: tariffs and non-tariff barriers tend to be systematically lower for more carbon-intensive ("dirty") industries, implying that tariff changes can reshape input price incentives and the relative competitiveness of clean versus dirty technologies. This environmental bias in trade policy suggests an important indirect channel by which tariffs could affect electricity supply costs and generation mixes. The author estimates that the environmental bias represents an implicit subsidy to CO_2 emissions in the amount of $550 to $800 billion per year (Shapiro, 2021). On the other hand, Zuo and Majeed (2024) investigate the effects of trade policy uncertainty on renewable energy consumption in China. The authors find that higher uncertainty negatively affects renewable energy consumption, and given the rise of protectionism and rising trade barriers in the modern world, they analyze how rapidly changing trade policies can impact the development of renewable energy.

Our study complements and extends these strands by providing a direct, supply-chain–focused estimate of tariff pass-through to residential electricity prices. We estimate a quantifiable mapping from a 1% average increase in tariffs on 440 electricity-relevant HS6 product categories to a 0.78 cents per kWh rise in average residential retail prices. Using data on recent tariff changes of the U.S., we estimate that these new trade policies will cost the State of Minnesota **$2.29 billion USD** annually, or an average cost of $0.035 per kWh of electricity sales in the state. Thus, while Shapiro's (2020) mechanism and Zuo and Majeed's (2024) findings emphasize composition and investment channels that operate over longer horizons, our results show empirically that upstream tariff shocks are associated with measurable near-term changes in retail bills, with distributional implications for households (particularly low-income ones) that complement the longer-run effects emphasized in the literature.

The case of Minnesota provides a well-suited context for examining how tariff shocks propagate through electricity supply chains and ultimately affect retail electricity prices. First, the state maintains a transparent and detailed regulatory environment, with extensive publicly available data on utility costs, generation inputs, and rate filings. This allows for precise tracking of how changes in fuel prices, equipment costs, and capital expenditures translate into retail rates.

Second, Minnesota's electricity sector represents a microcosm of broader U.S. trends. The state relies on a diverse resource mix—including coal, natural gas, wind, solar, and nuclear power—making it possible to trace tariff effects across multiple generation technologies. At the same time, Minnesota utilities participate in the Midcontinent Independent System Operator (MISO) wholesale market, exposing them to region-wide cost dynamics while retaining retail regulation at the state level. This hybrid structure enables analysis of both regulated and market-driven channels of cost pass-through.

Third, Minnesota has undergone significant infrastructure investment and generation turnover in recent years, particularly in renewable energy and transmission. Many of these projects depend on imported steel, aluminum, solar panels, and other tariff-sensitive inputs, making the state an informative case for studying the relationship between trade policy and electricity pricing.

In the next two sections, we explain Minnesota's electricity market and regulations, discuss the exact methodology we use in this study to conduct the mapping of tariffs on supply chain products to changes in retail electricity prices, as well as provide details concerning the dataset used and results obtained.

Overview of Electricity Markets in Minnesota

Minnesota's electricity market is characterized by vertically integrated investor-owned utilities, municipal utilities, and electric cooperatives. Investor-owned utilities—primarily Xcel Energy, Minnesota Power, and Otter Tail Power—serve the majority of customers and operate under cost-of-service regulation administered by the Minnesota Public Utilities Commission (PUC). Under this framework, utilities recover prudently incurred costs through regulated retail rates, which makes Minnesota an ideal environment for identifying how input cost changes feed into customer prices.

While retail regulation remains at the state level, Minnesota utilities participate in MISO's organized wholesale market. MISO centrally dispatches generation and determines locational marginal prices, influencing utility procurement costs. This connection to wholesale market dynamics introduces an additional channel through which tariff-induced cost shifts may affect retail prices.

The state's generation portfolio is diversified. As of recent years, Minnesota's electricity comes from roughly one-third coal, one-third renewables (primarily wind), and the remainder natural gas and nuclear. Ongoing coal retirements and rapid growth in wind and solar have increased reliance on imported equipment and materials—many of which were subject to trade actions during the period studied. These structural characteristics make Minnesota a compelling and policy-relevant setting for tracing the impact of tariff changes on electricity prices.

Data

As part of this study, we collected a list of 440 product codes in the six-digit Harmonized System (HS) classification of products, which is a standardized system of product classification used worldwide by government authorities and developed by the World Customs Organization. These include key fuels (natural gas, coal, uranium, and refined petroleum products), base materials (aluminum, copper, iron, steel, and nickel), and components essential for electricity generation and transmission (turbines, photovoltaic cells and panels, batteries, AC/DC motors, insulators, and other electrical equipment). Tariffs on these products, which raise their domestic prices, are likely to ripple through the supply chains and affect the final electricity bills of retail customers, even if it may take some time for these effects to become noticeable.

For this study, we employ a two-staged regression framework to estimate the desired effects of tariffs on retail electricity prices. We used a variety of data sources to estimate our first- and second-stage models. For the first stage, we use data on tariffs and imports of relevant supply chain products. Data on tariffs were collected using the World Bank's World Integrated Trade Solution (WITS)[3] online software, from the UNCTAD TRAINS database, and data on yearly U.S. imports of relevant goods was collected using the

[3] World Bank's World Integrated Trade Solution (WITS) online tool is available at: https://wits.worldbank.org/.

online DataWeb[4] tool of the U.S. International Trade Commission (ITC).[5] This dataset encompasses the period 2000-2023.

For the second stage, we collected data on state-level monthly imports of relevant electricity supply chain product categories and retail electricity prices in various sectors of the economy – including residential, industrial and commercial sectors. State-level data on imports was collected using the online DataWeb tool of the U.S. International Trade Commission (ITC). This online tool lists import data by trading hub, and we had to manually sum the trading hubs of each state to arrive at statewide import data. Additionally, we collected state-level retail electricity price data and matched this with state-level import data. Data on retail electricity prices was collected from the U.S. Energy Information Administration's (EIA)[6] Electricity Data Browser[7] online tool.

Comparing U.S. imports of high-tech products in 2000 and 2023, including batteries, AC/DC motors, transformers, and wind turbines (Figure 1), we can see a dramatic increase in imports across all categories: each category at least doubled, while imports of batteries grew eightfold. Overall, this demonstrates that U.S. imports of high-tech goods related to electricity production have become much more prevalent compared to two decades ago.

Figure 1

Total Annual U.S. Imports in Four Key Product Categories, Inflation-Adjusted, 2000 vs 2023

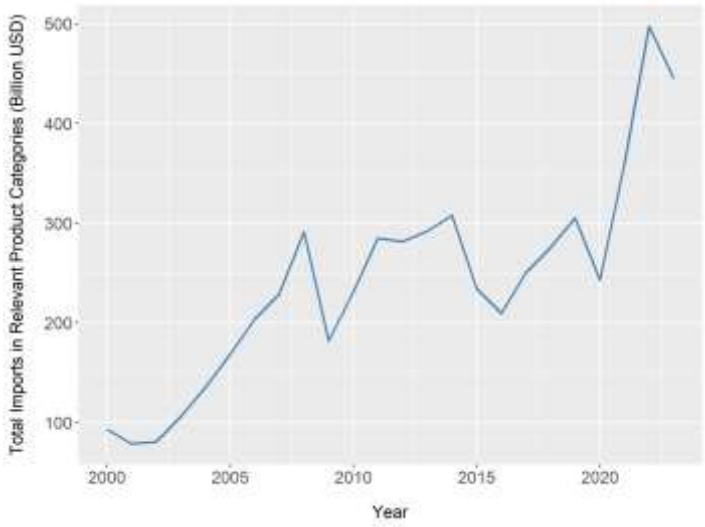
Source: *https://dataweb.usitc.gov/. Seen 20.07.25*

Next, we summarize total U.S. imports in the 440 product categories used for this study in the period of analysis – 2000-2023. U.S. imports of these products have steadily

[4] USITC's online DataWeb tool is available at: https://dataweb.usitc.gov/.
[5] USITC's main website is hosted at: https://www.usitc.gov/.
[6] USEIA's main website is hosted at: https://www.eia.gov/.
[7] USEIA's online Electricity Data Browser tool is available at: https://www.eia.gov/electricity/data/browser/.

increased over the period of analysis, rising from $93 billion in 2000 to over $445 billion in 2023 (Figure 2).

Figure 2
Total Annual U.S. Imports in 440 Electricity Supply Chain-Related Product Categories (HS-6), 2000-2023

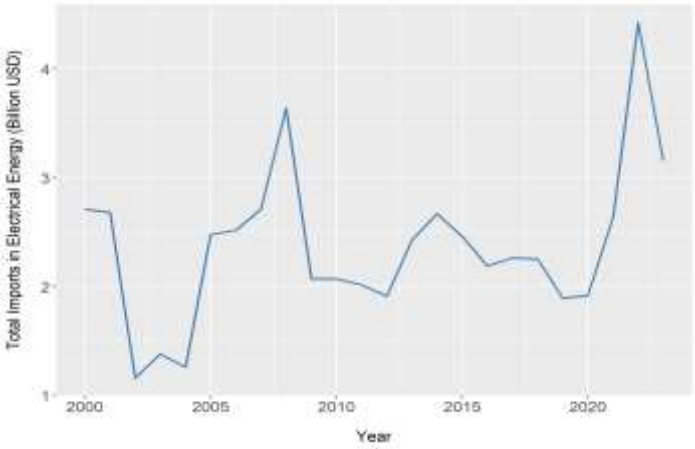


Source:*https://dataweb.usitc.gov/. Seen 20.07.25*

The United States is also a major importer of electrical power. The imports mainly come from Canada, as the United States electricity grid has major interconnections with some Canadian provinces. However, in some years, the U.S. also imported electric energy from Mexico. These imports of electrical power from neighboring countries can have a direct impact on retail electricity prices, and contribute to price formation in wholesale electricity markets as well. We thus included these electrical power imports as one of the 440 categories which factor into the electricity supply chains, even though the imports are not a tangible product, but are in the form of electrical energy and capacity supplied by generators located abroad. Historically, the U.S. imports about 2% of local electricity consumption. The total value of U.S. imports of electricity from its neighboring countries have been increasing from the 2000s into 2023 (Figure 3): however, it is less pronounced than the upward trend of the overall imports of electricity supply chain products.

Figure 3

Value of Total Annual U.S. Imports of Electrical Energy (HS-6 Code: 271600), 2000-2023

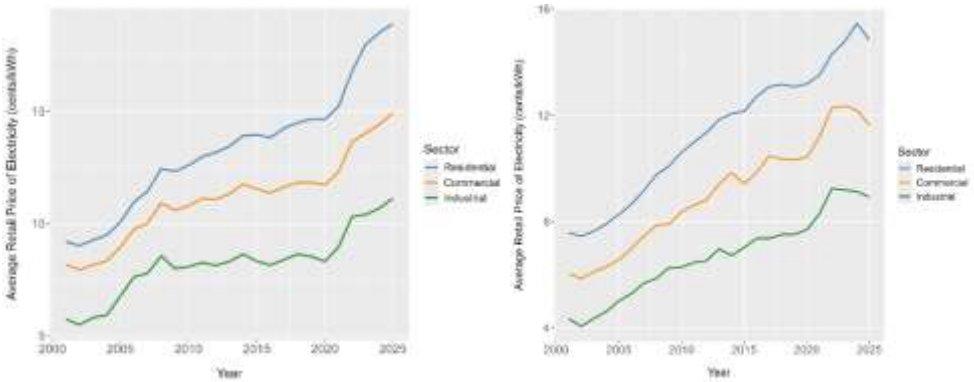


Source: *https://dataweb.usitc.gov/ . Seen 25.07.25*

In Figure 4, we summarize average retail electricity prices in the 30 states available in our dataset in 2001-2025, broken down by three sectors – residential, commercial and industrial. The residential prices have historically been the highest, followed by the commercial and industrial sectors, respectively. It is obvious that there is a trend of increasing prices from 2001 through 2025 – the period for which data on retail electricity prices was available in our dataset.

Figure 4

Average Annual Retail Prices of Electricity by Sector, in the U.S. (left) and in Minnesota (right), 2001-2025



Source: https://www.eia.gov/. *Seen 20.07.25*

In Minnesota, the retail electricity prices have historically been cheaper compared to the U.S. average in all sectors – residential, commercial and industrial. There is an upward trend in retail prices in the period 2001-2025, as with the U.S. average retail prices in all three sectors. Examining Minnesota's retail electricity prices in detail

provides valuable insights into how the state's energy market compares with national trends and how different consumer groups experience price changes. Breaking prices down by sector—residential, commercial, and industrial—allows us to identify which segments are most sensitive to cost drivers, such as trade policy and input prices that we examine as part of this study.

Methodology

In order to map the effect of tariffs on supply-chain products to retail electricity prices, we adopt a two-stage approach. In the first stage, we estimate how tariffs on these supply chain products influence imports of those goods. *Since imports are a function of prices—and tariffs effectively raise prices—this stage allows us to quantify the implied price increases of supply chain inputs resulting from tariff hikes.*

We use a linear regression model to estimate the impact of a 1% increase in average tariffs on these 440 product categories on the import of these supply chain products, expressed as a percentage change. We employ a standard gravity model of trade in order to estimate this effect. The gravity model of trade[8] is analogous to Newton's Law of Universal Gravitation, which states that the gravitational force between two objects is proportional to the product of their masses and inversely proportional to their distance (Feenstra & Taylor, 2021). Similarly, trade between two countries depends on the size of their respective economies (measured by GDP) and is inversely proportional to their distance (Feenstra & Taylor, 2021).

Cheong, Kwak & Tang (2018) utilize a gravity model of trade in order to estimate the impact of trade agreements on the intensive and extensive margins of trade volume between countries. We use modified versions of the gravity model presented in Cheong, Kwak & Tang (2018) to estimate *the first stage* of our model – which is to understand how increased tariffs are correlated with changes in imports in relevant product categories related to electricity supply chains. *In the second stage*, we examine how these tariff-induced changes in imports of relevant intermediate products are correlated with retail electricity prices across the residential, commercial, and industrial sectors. This stage provides estimates of the pass-through from higher input costs to end-user electricity prices, helping us understand the broader economic effects of trade policy on retail electricity markets.

A key assumption that we make in the second-stage regression model is that the effects of changes in imports of supply chain products on retail electricity prices in each state are homogeneous, after controlling for state and time fixed effects. Making this assumption significantly simplifies the analysis and makes sense, given that we are controlling for unobserved, state-level variables by including state-level fixed effects in the regression model.

We estimate the second-stage effects using a lagged imports framework, where retail electricity prices are linear functions of 3- to 10-month lagged imports in relevant electricity supply chain product categories. In addition, we include 0- to 4-month lagged gas prices as control variables, and also include time and state fixed effects. We then sum the effects of all lagged imports that are significant at least at the 1% level: this gives us an estimate of the overall impact of changes in imports in relevant supply chain product categories on retail electricity prices. We run this model for three different

[8] Bergstrand (1985) is a seminal work discussing the standard gravity model of trade in more detail.

sectors – residential, commercial and industrial. We only get statistically significant effects that are robust to model specification for residential retail electricity prices.

Gravity Model of Trade

The standard gravity model of trade takes the following form:

$$\boldsymbol{T_{i,j} = G \cdot \frac{GDP_i^{\beta_1} \cdot GDP_j^{\beta_2}}{Dist_{i,j}^{\beta_3}} \eta_{i,j}} \quad \textbf{(1)}$$

where G, β_1, β_2 and β_3 are constants to be estimated, GDP_i and GDP_j are the gross domestic products of countries i and j, respectively, representing the size of each respective economy, $Dist_{i,j}$ is the physical distance between countries i and j[9], and $\eta_{i,j}$ is an error term. Taking a logarithmic transformation of both sides, we can express the above equation in a linear form:

$$\boldsymbol{\log(T_{i,j}) = \alpha + \beta_1 \cdot GDP_i + \beta_2 \cdot GDP_j + \gamma \cdot Dist_{i,j} + \epsilon_{i,j}} \quad \textbf{(2)}$$

where $-\beta_3 \equiv \gamma$, $\log(\eta_{i,j}) \equiv \epsilon_{i,j}$ and $\log(G) \equiv \alpha$, and which now can be estimated using the method of Ordinary Least Squares (OLS).

In the first stage of projecting tariffs on imports of supply chain products, one of the trade partners remains the same – the United States. This removes one dimension from the first-stage gravity equation. However, we add back two more dimensions – the 6-digit product category in the Harmonized System of product classification, and time.

Finally, we add some other covariates that are included in standard gravity models of trade[10], which include the tariff rates on different product categories with different partner countries. After these modifications, the final equation is:

$$\boldsymbol{\log(T_{j,k,t}) = \beta_1 \cdot \log(1 + Tariff_{j,k,t}) + \beta_2 \cdot \log(GDP_{j,t}) + \beta_3 \cdot \log(Dist_{j,t}) + \gamma \cdot \chi_{j,k,t} + \epsilon_{j,k,t}} \quad \textbf{(3)}$$

where $Tariff_{j,k,t}$ are the tariff rates on country j in product category k and year t, and $\chi_{j,k,t}$ is a vector of added covariates, including population of trading partner, as well as dummy variables indicating whether the trading partner shares a border with the U.S. and whether it has prior U.S. colonial ties. $\epsilon_{j,k,t}$ is an error term.

We also estimate an alternative specification of the model, where we include trading partner-year and product-year interaction fixed effects instead of the covariates in Equation (3). This alternative equation is the following:

$$\boldsymbol{\log(T_{j,k,t}) = \beta_1 \cdot \log(1 + Tariff_{j,k,t}) + \zeta_{j,t} + \eta_{k,t} + \epsilon_{j,k,t}} \quad \textbf{(4)}$$

where $\zeta_{j,t}$ and $\eta_{k,t}$ are partner-year and product-year fixed effects.

We estimate Equations (3) and (4) and use the average of the two estimates for the parameter β_1 as the effect of a 1% increase in tariffs on relevant electricity supply chain product categories on imports of these products, measured in percentage terms. The results of regression assessment are presented in *Table 1* below.

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[9] The physical distance between two countries can be calculated using a variety of methods. One method is to use the geodesic distance between the capitals of the two countries. Another is to use a weighted distance between the most populous cities of the two countries, where the weights represent the populations of these cities.

[10] The added covariates include tariff rates on the trading partner in a given product category, colonial links between the U.S. and the trading partner, sharing of a land border of the U.S. with the trading partner, and population of the trading partner.

Table 1

First Stage Regression Results. Two-way clustered standard errors in parentheses

Log (Imports)	Model 1[11]	Model 2
Log (1 + Tariff Rate)	-3.850* (1.855)	-5.249*** (0.961)
Log (GDP)	-	0.574*** (0.017)
Log (Distance)	-	-0.079* (0.035)
Log (Population)	-	0.059*** (0.015)
Contiguous to the U.S.	-	1.500*** (0.074)
Former U.S. Colony	-	0.594*** (0.064)
(Intercept)	-	-3.105*** (0.434)
R2	0.415	0.161
R2 Adj.	0.376	0.161
Std. Errors	by: Partner-Year & Product-Year	by: Partner-Year & Product-Year
FE: Partner-Year	X	
FE: Product-Year	X	
• $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$		

Second-Stage Regression Approach

In the second stage of this study, we aim to estimate how a 1% change in imports of relevant electricity supply chain products is correlated with retail electricity prices. We use a linear regression model with lagged effects of the predictors to estimate this correlation. Mathematically, the linear model is the following:

$$\textbf{electricity prices}_{s,t} = \Sigma_{r=3}^{10}\beta_r \cdot \textbf{imports}_{s,t-r} + \Sigma_{r=0}^{4}\gamma_r \cdot \textbf{gas prices}_{s,t-r} + \zeta_t + \eta_s + \epsilon_{s,t} \quad (5)$$

where electricity $\text{prices}_{s,t}$ denote the monthly average retail electricity prices in state *s* and time t (time is denoted by month and year, i.e., August 2001, February 2002, etc.), $\text{imports}_{s,t-r}$ are lagged overall imports in relevant electricity supply chain categories in trading hubs located in state s at time $t - r$ (where r ranges from 3 to 10, corresponding to 3- through 10-month lagged imports), gas $\text{prices}_{s,t-r}$ corresponds to average gas prices in state s at time $t - r$ (where r ranges from 0 to 4, corresponding to 0- through 4-month lagged gas prices), ζ_t and η_s are time and state fixed effects, and $\epsilon_{s,t}$ is an error term corresponding to state s and time t. We run three separate models corresponding to three different sectors – residential, commercial and industrial, where the prices on the left correspond to residential, commercial and industrial sectors, respectively.

[11] Model 1 does not include any covariates because it includes partner-year and product-year fixed effects. These fixed effects would absorb any covariates that do not vary over products, years and trade partners.

In order to arrive at the overall correlation between imports in relevant electricity supply chain product categories and retail electricity prices, we sum the effects of all lags that exhibit statistically significant correlation with these prices. We estimate Equation (5) using fixed effects regression: we then arrive at estimates for the coefficients on lagged imports. The overall effect is then $\Sigma_{r=3}^{10}\hat{\beta}_r \cdot 1\{\hat{p}_r(\hat{\beta}_r < 0.1)\}$, which means that we sum our coefficient estimates on all those lagged imports which are statistically significant at the 1% level. *Tables 2*, *3* and *4* below summarize the results of regression estimation of Equation (5) in the residential, industrial and commercial sectors, respectively.

Table 2

Second Stage Regression Results – Residential Sector. Two-way clustered standard errors in parentheses

Average Retail Residential Electricity Prices	*Coefficients*
Log (3rd Lag of Imports)[12]	0.100 (0.091)
Log (4th Lag of Imports)	-0.171*** (0.040)
Log (5th Lag of Imports)	-0.040 (0.056)
Log (6th Lag of Imports)	0.014 (0.047)
Log (7th Lag of Imports)	-0.073 (0.071)
Log (8th Lag of Imports)	0.048 (0.083)
Log (9th Lag of Imports)	0.046 (0.073)
Log (10th Lag of Imports)	-0.060 (0.100)
Num. Obs.	3801
R2	0.900
R2 Adj.	0.892
Std. Errors	by: Year-Month & State
FE: Year-Month	X
FE: State	X
• p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001	

[12] The lags in the second stage regression are measured in months and not years. Gas prices and their first through fourth lags were also included in the regression, but are not presented in the table for the sake of brevity.

Table 3

Second Stage Regression Results – Industrial Sector. Two-way clustered standard errors in parentheses

Average Retail Industrial Electricity Prices	Coefficients
Log(3rd Lag of Imports)	0.113 (0.088)
Log(4th Lag of Imports)	-0.108 (0.060)
Log(5th Lag of Imports)	-0.046 (0.048)
Log(6th Lag of Imports)	0.023 (0.034)
Log(7th Lag of Imports)	-0.027 (0.071)
Log(8th Lag of Imports)	0.103 (0.078)
Log(9th Lag of Imports)	0.037 (0.054)
Log(10th Lag of Imports)	0.083 (0.112)
Num. Obs.	3803
R2	0.883
R2 Adj.	0.872
Std. Errors	by: Year-Month & State
FE: Year-Month	X
FE: State	X

Table 4

Second Stage Regression Results – Commercial Sector. Two-way clustered standard errors in parentheses

Average Retail Commercial Electricity Prices	Coefficients
Log(3rd Lag of Imports)	0.124 (0.070)
Log(4th Lag of Imports)	0.010 (0.047)
Log(5th Lag of Imports)	-0.040 (0.061)
Log(6th Lag of Imports)	-0.004 (0.084)
Log(7th Lag of Imports)	0.020 (0.068)
Log(8th Lag of Imports)	0.119 (0.066)
Log(9th Lag of Imports)	0.041 (0.048)

Average Retail Commercial Electricity Prices	Coefficients
Log(10th Lag of Imports)	0.039 (0.092)
Num. Obs.	3803
R2	0.896
R2 Adj.	0.887
Std. Errors	by: Year-Month & State
FE: Year-Month	X
FE: State	X

Results

In *Tables 1-4* presented in the previous section, we showed the results of the first- and second-stage regression estimation. First-stage estimates (*Table 1*) suggest that an average increase of 1% in tariffs on relevant electricity supply chain product categories is correlated with an average decrease in imports of these products between 3.85 to 5.25 percent. Taking the average of these two estimates, we arrive at an average decrease in imports of 4.55% associated with an average increase of 1% in tariffs on relevant electricity supply chain product categories. We also note that all the other covariates in the second version of our first-stage model have the expected sign. For example, distance between the U.S. and the trading partner is correlated with decreased trade, and higher GDP of the trading partner is associated with increased trade, as the standard gravity model of trade predicts.

Regarding model fit, Model 1 in *Table 1* achieves an R^2 of 0.415 and an adjusted R^2 of 0.376, reflecting that the pair of high-dimensional fixed effects absorbs much of the variation in bilateral trade. The lower R^2 in Model 2 (0.161) of *Table 1* is typical in gravity specifications when strong fixed effects are not included, and does not imply poorer identification. Both models use robust standard errors clustered at the partner-year and product-year levels, mitigating concerns about serial correlation or cross-sectional dependence along either dimension.

In the second stage, we assess how changes in imports of electricity supply chain products correlate with retail electricity prices. We only get statistically significant, robust results for the residential sector (*Table 2*). Industrial and commercial sectors enjoy lower and more stable electricity prices due to their large-scale usage of electricity and customized supplier agreements, which buffer them from abrupt or large price changes. Therefore, second-stage regression does not find statistically significant impacts of changes in imports of electricity supply chain products on retail electricity prices in commercial and industrial sectors (*Tables 3* and *4*).

For the retail electricity prices in the residential sector, lagged imports are used in order to evaluate the full impact of changes in imports of intermediary products. It is found that the strongest price response occurs with a **4-month lag** following changes in imports of tariff-affected electricity supply chain goods. This timing aligns with expected delays in utility procurement cycles, infrastructure project timelines, and cost pass-through mechanisms. Our estimates suggest that a 1% average increase in imports of the key supply chain products is correlated with a 0.171 cent per kilowatt-hour decrease in average residential retail electricity prices (*Table 2*).

The second-stage model for the residential sector exhibits excellent explanatory power, with an R^2 of 0.900 and an adjusted R^2 of 0.892. This high goodness-of-fit is

typical in panel regressions with rich fixed effects, particularly in energy markets where state-specific factors and national trends account for much of the variation in retail prices. The fixed effect's structure ensures that the estimated coefficients capture within-state, over-time deviations in imports rather than cross-sectional differences.

Putting together results from the two stages, we conclude that an average increase of 1% in tariffs on relevant electricity supply chain product categories raises retail residential electricity prices by 0.78[13] cents per kWh, but does not affect retail electricity prices in the industrial and commercial sectors.

Adopting a holistic approach to estimating the pass-through of tariffs on electricity supply chain products to retail prices of electricity, we considered products in the supply chain that have a great breadth of variation. The result obtained above thus estimates the average pass-through of tariffs through a comprehensive network of electricity supply chain product categories.

Based on the estimated pass-through rate of 0.78 cents per kWh for every 1% average increase in tariffs on electricity supply chain products, we estimate that a 1% tariff increase would raise the total annual cost to U.S. residential electricity consumers by approximately **$11.78 billion U.S. dollars.**[14] In particular, a 1% increase in tariffs on electricity supply chain products is estimated to raise annual residential electricity costs in Minnesota by **$179.4 million U.S. dollars**.

Finally, we evaluate the impact of recent increases in tariffs on U.S. trade partners and how these hikes fit with the aforementioned results. The average relative increase in tariffs compared to pre-2025 levels is around 12.76%. *Table 5* below summarizes the trade deals reached with key trading partners as of August 2025, along with the agreed-upon tariffs and the relative change in tariffs as compared to pre-2025 levels. Overall, the U.S. has reached trade deals with key trading partners, including Japan, the European Union, the United Kingdom and South Korea.

Table 5

Recent U.S. Trade Agreements with Key Trading Partners and Relative Changes in Tariffs Compared to Pre-2025 Levels

Trading Partner	Agreed Tariff Rate	Relative Change from Baseline
European Union	15%	11.65%
Indonesia	19%	15.53%
Japan	15%	11.65%
Philippines	19%	15.53%
South Korea	15%	11.65%
United Kingdom	10%	6.80%
Vietnam	20%	16.5%

Source: *Cerullo & Walsh, 2025.*

[13] In the first stage, we found that a 1% average increase in tariffs is associated with a 4.55% decrease in imports of relevant supply chain products. In the second stage, we found that a 4.55% average decrease in imports of relevant supply chain products is correlated with a 0.171 cent-per-kWh increase in average residential retail electricity prices. We multiply 4.55% by 0.171 cents to arrive at the estimate of 0.78 cents per kWh associated with a 1% average increase in tariffs on relevant electricity supply chain products.

[14] We multiply the added cost of 0.78 cents per kWh as a result of a 1% increase in tariffs on supply chain products by the 2022 U.S. residential electricity consumption (1.51 trillion kWh) to get this result.

Overall, we estimate that the recent changes in tariffs, if applied to all supply chain product categories discussed in this report, and sustained for a prolonged period of time, will cost the Minnesota electricity sector about **$2.29 billion USD** annually, or an average cost of $0.035 per kWh of electricity sales in the state. As a point of reference, Minnesota's total electricity consumption in 2023 (66,215,800 megawatt-hours), evaluated at an average price of 17 cents per kWh, amounts to $11.26 billion USD. The overall cost increase due to the recent increases in tariffs thus represents about **20%** of Minnesota's annual retail sales of electricity.

For an average household that consumes 9,024 kWh per year (U.S. Energy Information Administration, 2023), this corresponds to an increase of about $316/year in electricity bills.

Conclusion

Using a two-stage regression approach, we estimate that a 1% increase in tariffs on electricity supply chain inputs is associated with an increase of 0.78 cents per kWh in residential retail electricity prices. This correlation should not be interpreted as causal, but highlights a strong historical co-movement between upstream input costs and final retail electricity prices. We do not find statistically significant and robust associations of tariff hikes with changes in retail electricity prices in the industrial and commercial sectors. Industrial and commercial sectors benefit from lower and more stable prices due to their large-scale use of electricity and often-customized agreements with their electricity suppliers, as well as greater flexibility in their electricity usage, which guarantees that prices do not change abruptly, and when they do, the changes are not as pronounced as in the residential sector.

The analysis focused on a holistic review of 440 product categories that may be directly or tangentially associated with electricity supply chains. Our estimates suggest strong pass-through of tariffs via these product categories that are eventually reflected on residential electricity bills.

Based on this analysis, we project that the recently approved U.S. trade agreements with key trading partners will cost the Minnesota electricity sector **approximately $2.29 billion USD annually**, which translates to an average cost of $0.035 per kWh of electricity sold in Minnesota and represents 20% of the annual market value of electricity sales in the state. This effect, as mentioned above, is mostly expected to affect residential consumers, and may disproportionately affect low-income households, whose electricity bill constitutes a larger proportion of their income. We estimate that these additional costs translate into an increase of $316/year in electricity bills for an average household in Minnesota. This may result in policy implications for the state to more closely monitor residential electricity rates in the upcoming months and years and make sure there are necessary programs in place to help low-income families cope with increases in residential electricity bills. This may come in the form of targeted relief or bill assistance programs if tariffs remain in place.

Utilities may benefit from enhanced monitoring of cost pass-through mechanisms to understand which products are impacting residential prices the most. Diversification of supply chains, especially in those product categories which are most closely associated with residential electricity prices, may help utilities reduce their tariff exposure and

benefit from more favorable deals, which may result in reductions in additional costs related to tariffs and ultimately benefit residential consumers as well.

We find it important to mention a caveat to this analysis: our results are based on historical correlations — not causation — and could vary under different market or trade conditions. We tried to map the effects of tariffs using lags in pass-through mechanisms, but our data was limited in granularity and in time; the models were estimated using state-level trade data on a monthly or yearly basis. Furthermore, the recent tariffs imposed by the U.S. are unprecedented and thus extrapolating our results to this large and sudden policy change is inherently uncertain, as the historical relationships we observe may not hold under such extreme conditions. Studying tariff effects over a longer horizon and on a more granular spatial grid may enable future researchers to capture more precise effects of delayed pass-through of tariffs on retail electricity rates. It would also be interesting to assess other cost drivers, such as capital costs, and how these interact with tariff effects.

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