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MARKET TYPOLOGY AND DYNAMICS OF ECONOMIC GROWTH

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Market Typology and Dynamics of Economic Growth

It is found that the diversity of the economy's market (perfect competition, monopoly, oligopoly, and monopolistic competition) serves as a key to endogenous adaptation in studying economic evolution through computer modeling. The research is based on a multivariate dynamic model created by the authors, which encompasses the influences of foreign trade, international capital and labor mobility, sectoral interconnections, and other factors of State regulation. The numerical results of this modeling were compared (for validation) with data obtained using orthodox one dimensional models of nonlinear economic dynamics. For the empirical field of the computer study, information on 150 countries worldwide was used, covering a wide range of socioeconomic indicators, which allowed the formation of statistically significant conclusions regarding the dependence of economic growth rates on the type of market and its structure. The evaluation of model accuracy was conducted using various metrics, including measures of absolute and relative forecast errors, coefficients of determination, and mean squared error. The inclusion of an expanded set of variables characterizing market structure and types of competition significantly improved the accuracy of digital modeling of economic growth. In particular, the obtained results indicate a substantial reduction in forecasting errors compared to traditional approaches, which not only highlights the importance of considering market structure in macroeconomic research and economic policy planning, but also demonstrates the appropriateness of adaptive modeling as a tool for strategy development. Thus, the research deepens the theoretical understanding of the relationship between market type and the trajectory of economic dynamics and lays the groundwork for developing tools capable of accounting for the structural characteristics of the economy when forecasting its growth.

Keywords: *economic growth, models of economic growth, market structure, monopoly, oligopoly, perfect competition, monopolistic competition.*

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Позняк С. П., Коляда Ю. В. Типологія ринку і динаміка економічного зростання

З'ясовано, що різноманітність ринку економіки (досконала конкуренція, монополія, олігополія та монополістична конкуренція) виступає ключем ендогенної адаптації у вивченні економічної еволюції шляхом комп'ютерного моделювання. Дослідження здійснено на підставі багатовимірної динамічної моделі авторів, котрою охоплюються впливи зовнішньої торгівлі, міжнародного руху капіталу та робочої сили, секторальні взаємозв'язки й інші фактори державного регулювання. Числові результати зазначеного моделювання порівнювалися (для валідації) з даними, отриманими за допомогою ортодоксальних одновимірних моделей нелінійної економічної динаміки. Як емпіричне поле комп'ютерного дослідження використано інформацію щодо 150 країн світу за широким спектром соціально-економічних показників, що дозволило сформувати статистично значущі висновки про залежність темпів економічного зростання від типу ринку та його структури. Оцінювання точності моделей здійснювалося за допомогою різних метрик, зокрема показників абсолютної та відносної похибок прогнозу, коефіцієнтів детермінації та середньоквадратичної похибки. Залучення розширеного набору змінних, що характеризують ринкову структуру та тип конкуренції, дозволило суттєво підвищити точність цифрового моделювання економічного зростання. Зокрема, отримані результати свідчать про значне зниження похибок прогнозування порівняно з традиційними підходами, що не лише підкреслює важливість врахування ринкової структури у макроекономічних дослідженнях та плануванні економічної політики, але й демонструє доцільність адаптивного моделювання як інструменту розробки стратегій розвитку. Таким чином, дослідження поглиблює теоретичне розуміння взаємозв'язку між типом ринку та траєкторією економічної динаміки та створює передумови для формування інструментарію, спроможного враховувати структурні характеристики економіки при прогнозуванні її зростання.

Ключові слова: *економічне зростання, моделі економічного зростання, ринкова структура, монополія, олігополія, досконала конкуренція, монополістична конкуренція.*

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Introduction. Economic growth is a key indicator of the development of national economies, as it determines the level of welfare of the population, productivity of production factors, and the country's competitiveness in the global market. There are various approaches to the study of economic growth, including classical, neoclassical and endogenous dynamic models. Particular attention in modern economic science is paid to multivariate models that take into account not only traditional factors such as capital and labor, but also human capital, innovation, and institutional factors. The use of such models allows for a more accurate assessment of the impact of various variables and interrelationships in dynamic economic systems.

Most economic growth models are based on the assumption of a perfectly competitive market, which simplifies the analysis but does not always correspond to real-world conditions. Many countries are dominated by markets characterized by imperfect competition, such as monopolies, oligopolies, or monopolistic competition. Differences in market structure affect factors such as resource allocation, investment levels, price dynamics, and production efficiency. Ignoring market diversity or typology in traditional (one-dimensional) dynamic models leads to distorted conclusions about the mechanisms of economic growth and the effectiveness of government regulation.

The market typology has a significant impact on the functioning of the economy, as it determines the level of competition, availability of resources, efficiency of capital allocation, and innovation activity of enterprises. Perfect competition promotes the optimal use of resources and lowers prices, while monopolies can lead to inflated prices and reduced production. Oligopolies often create barriers to new market entrants, but at the same time can stimulate technological progress through competition between large players. Monopolistic competition promotes diversification of goods and services, which increases consumer choice. In general, the complex structure of a diverse market determines the dynamics of investment, economic growth and the effectiveness of government regulation, making it an important factor in the long-term development of the economy.

Taking into account market types in economic growth models has a number of theoretical advantages. First, it allows for a more accurate assessment of the impact of competition on innovation and firm productivity. Second, models that take into account structural features of the market can better explain the role of government policy in regulating economic activity. Third, such an approach contributes not only to a deeper understanding of the uneven distribution of income and capital among market participants. The diversity of the market provides grounds for the so-called endogenous adaptation [1] of the tools for studying nonlinear economic dynamics, when the capabilities of classical dynamic models of economic growth are expanded. Problem-oriented application of market typology allows to create more realistic and effective tools for analyzing and forecasting economic development.

Analysis of recent research and publications. Over the past few years, the literature has significantly advanced in modeling the influence of market structure and competitive dynamics on economic growth. Martin-Herran & Rubio [2] explore a dynamic Cournot oligopoly model, integrating green innovation under emission taxes in a differential game theoretical framework. Their results show a positive relationship between market competition and R&D investment—particularly in green technologies—and highlight the regulatory role of taxation in steering oligopolistic firms toward sustainable innovations. Similarly, Chen and Lee [3] compare Cournot and Bertrand competition in contexts of R&D and output subsidies, revealing that firms in Cournot settings invest differently in innovation and welfare outcomes depend critically on policy design—thereby reinforcing the argument that the modeling of firms' strategic interactions yields nuanced growth and policy insights.

In the context of broader macroeconomic modeling, recent work within new structural and digital-economy frameworks underscores the integration of market heterogeneity. Tang et al. [4] and Jia et al. [5] extend general equilibrium models by explicitly incorporating data elements and sectoral heterogeneity, thereby illustrating how market structure – especially in data-intensive industries – affects growth trajectories. Their results emphasize that ignoring structural diversity in markets may lead to underestimation of innovation dynamics and forecasting errors.

Spatial economics, another relevant stream, offers complementary insights. Thisse et al. [6] revisit core-periphery models by integrating agglomeration effects and firm clustering, illuminating how market structure – particularly in terms of spatial concentration – affects productivity and regional growth disparities. These studies collectively highlight the growing consensus that multidimensional, structure-aware models provide superior explanatory power and empirical fit compared to traditional homogeneous frameworks.

Highlighting previously unresolved parts of the overall problem. Previous studies on economic growth have predominantly relied on simplified one-dimensional models of nonlinear economic dynamics, often ignoring the diversity of market structures. Traditional approaches generally assume

homogeneity in market types or focus solely on the representative agent framework, thus neglecting the role of market diversity – including perfect competition, monopoly, oligopoly, and monopolistic competition – in shaping the evolutionary trajectory of economic systems. As a result, existing models fail to adequately reflect endogenous adaptation mechanisms that are intrinsic to real economies with heterogeneous market structures.

Furthermore, there has been a lack of integrated multidimensional dynamic models capable of simultaneously incorporating external trade, international capital and labor mobility, sectoral interdependencies, and various instruments of government regulation. Previous modeling attempts rarely combined these factors with an explicit representation of market type, leaving unresolved the issue of how market structure influences the accuracy and reliability of economic growth forecasts. This gap has hindered both theoretical understanding and practical forecasting capabilities in macroeconomic analysis.

Another unresolved aspect relates to empirical validation across a sufficiently large sample of countries. Many prior studies used limited datasets, preventing the generalization of results at the global level. The absence of comprehensive empirical testing with extended sets of market structure variables has raised concerns about the robustness and statistical significance of model outcomes. Consequently, assessing the precise impact of market diversity on economic growth trajectories remained an open problem in the field of nonlinear macroeconomic modeling and policy-oriented computational research.

Aim of the article. The aim of this article is to develop and validate a multidimensional dynamic model of economic growth that explicitly incorporates market structure diversity – including perfect competition, monopoly, oligopoly, and monopolistic competition – alongside external trade, international capital and labor flows, sectoral interdependencies, and government regulation mechanisms, in order to examine how different market types influence economic growth trajectories and to improve the accuracy of macroeconomic forecasting by overcoming the limitations of traditional one-dimensional models.

Methodology. We have chosen an endogenous model of economic growth that takes into account foreign trade and investment, as well as its modified version that divides the economy into sectors with an emphasis on their interaction, as discussed in detail in [7–9].

In the model, the main factors of production are private capital K_{pr}, public capital K_{gov}, human capital (knowledge) H, labor L and the variable factor R. Variable factor R in a single-sector production model is responsible for the land factor N. A modified Cobb-Douglas function of the form:

$$Y_p = AK_{pr}^{\alpha} K_{gov}^{\beta} H^{\gamma} N^{\varphi} L^{1-\alpha-\beta-\gamma-\varphi}, \qquad (1)$$

where α – is the coefficient of elasticity of private capital, β – public capital elasticity coefficient, γ – human capital elasticity coefficient, ϕ – elasticity of the variable factor, in this case, land [8,9].

In the multisectoral model, the factor R depends on the sector. For the primary sector Y_{agr} land is a factor, similar to the single-sector model. For the secondary sector Y_{ind} factor is the output of the primary sector Y_{agr}. For the tertiary sector Y_{serv} factor is the output of the secondary sector Y_{ind}.

For a multisectoral model, the production function takes the form:

$$\begin{aligned} Y_p = {} & A_1 K_{agr}^{\alpha 1} K_{gov}^{\beta 1} H_{agr}^{\gamma 1} N^{\varphi 1} L_{agr}^{1-\alpha 1-\beta 1-\gamma 1-\varphi 1} + \\ & + A_2 K_{ind}^{\alpha 2} K_{gov}^{\beta 2} H_{ind}^{\gamma 2} Y_{agr}^{\varphi 2} L_{ind}^{1-\alpha 2-\beta 2-\gamma 2-\varphi 2} + \\ & + A_3 K_{serv}^{\alpha 3} K_{gov}^{\beta 3} H_{serv}^{\gamma 3} Y_{ind}^{\varphi 3} L_{serv}^{1-\alpha 3-\beta 3-\gamma 3-\varphi 3}, \end{aligned} \qquad (2)$$

wherein $Y_p = Y_{agr} + Y_{ind} + Y_{serv}$,

similarly $K_{pr} = K_{agr} + K_{ind} + K_{serv}$ and

$H = H_{agr} + H_{ind} + H_{serv} \cdot L = L_{agr} + L_{ind} + L_{serv}$.

In the proposed model, capital is divided into private and public capital, which makes it possible to more accurately take into account the differences in their functions and role in the process of economic growth. Investments are made through aggregate savings, which reflect the ability of the economy to effectively allocate resources for development. Accordingly, capital dynamics is described by three key indicators: private sector capital intensity, which determines the volume of private investment; public sector capital intensity, which reflects investments in public infrastructure and public goods; and aggregate savings per unit of labor, which is the main source of investment in the economy. This approach allows for a more detailed analysis of the relationship between private and public investment, as well as an assessment of their combined impact on labor efficiency and long-term economic growth [8,9].

The innovation sector generates new knowledge by the production function:

$$\Delta H = BK_{rd}^{\upsilon} L_{rd}^{1-\upsilon}, \qquad (3)$$

where K_{rd} – capital raised in the innovation sector, L_{rd} – labor involved in the innovation sector, υ – capital elasticity in the innovation sector. Total capital in the economy K_{full} can be found by the formula: $K_{full} = K_{rd} + K_{pr} + K_{gov}$, similar to labor: $L_{full} = L_{rd} + L$.

Full single-sector multivariate model in general form [8,9]:

$$\begin{cases} k_{pr}^{\bullet} = i_{in} + i_f + (d_{pr} + n)k_{pr}, \\ k_{gov}^{\bullet} = g - (d_{gov} + n)k_{gov} + tx, \\ m^{\bullet} = sAk_{pr}^{\alpha} k_{gov}^{\beta} h^{\gamma} n_N^{\varphi} - (g - nm + i_{in} + i_{out}), \\ h^{\bullet} = Bk_{rd}^{\upsilon} l - nh, \end{cases} \qquad (4)$$

where K_{pr} – capital intensity of the private sector, d_{pr} – amortization rate of private capital, n – average growth rate of the employed labor force, i_{in} – domestic investment per unit of labor, i_f – foreign investment per unit of labor, K_{gov} – capital intensity of the public sector, g – taxes per unit of labor, d_{gov} – depreciation ratio for public capital, tx – net government international transfers, m – total savings per unit of labor, s – savings rate, n_N – land factor per unit of labor, i_{out} – external investment per unit of labor.

For a multisectoral modification, the formula for the derivative of total savings per unit of labor is as follows:

$$m^{\bullet} = A_1 \frac{L_{agr}}{L} k_{agr}^{\alpha 1} k_{gov}^{\beta 1} h_{agr}^{\gamma 1} n_N^{\varphi 1} + A_2 \frac{L_{ind}}{L} k_{ind}^{\alpha 2} k_{gov}^{\beta 2} h_{ind}^{\gamma 2} y_{\text{arg}}^{\varphi 2} + \\ + A_3 \frac{L_{serv}}{L} k_{serv}^{\alpha 3} k_{gov}^{\beta 3} h_{serv}^{\gamma 3} y_{ind}^{\varphi 3} + (g - nm + i_{in} + i_{out}). \quad (5)$$

After considering the general aspects of economic growth and its modeling, it is important to pay attention to one of the main components of these models - market structure, which can significantly affect the results of the analysis.

Different types of markets determine not only the behavior of firms, but also the efficiency of resources, the level of investment and innovation, and the possibility of government regulation.

The market is classified according to various criteria, the most important of which are the level of competition, the number of participants, access to information, and the ability of individual entities to influence pricing. According to the level of competition, there is perfect competition, where many small firms sell the same product without affecting the market price; monopolistic competition, characterized by a large number of producers with differentiated products; oligopoly, where the market is controlled by several large companies whose interaction significantly affects prices and production volumes; and monopoly, where a single producer controls the market and determines prices (Fig. 1).

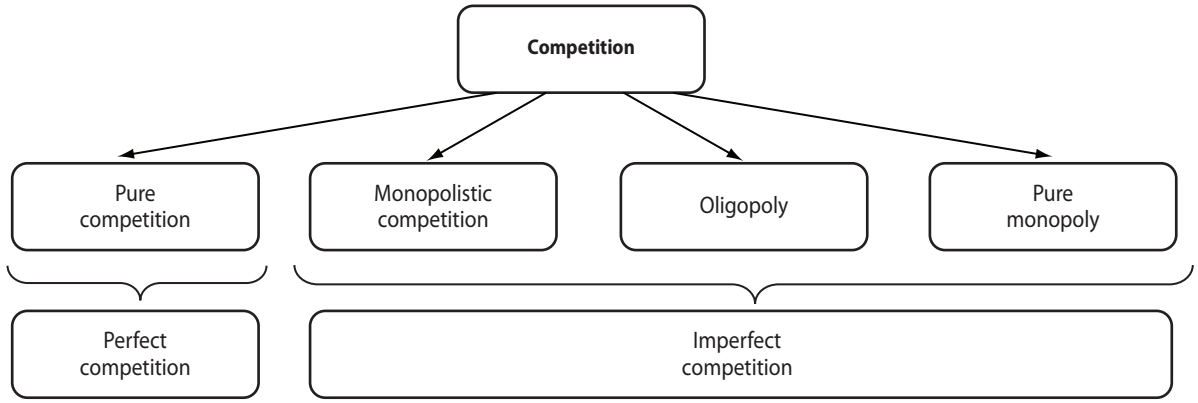

Fig. 1. Main market types by competition

Source: compiled by the author

Since the vast majority of classical models of economic growth assume a market operating under conditions of perfect competition, we will first consider this type of market.

Perfect competition is a market structure in which a large number of small firms sell identical goods or services without being able to influence the market price. The main characteristics of such a market are free access for new entrants, full awareness of consumers and sellers, and no barriers to entry or exit. In the real economy, there are almost no markets that fully meet these criteria, but markets for agricultural products (e.g., wheat or corn), commodities (gold, oil), and currency markets, where pricing is determined by global supply and demand, can be close to perfect competition.

The advantage of perfect competition is high allocative efficiency, as firms are forced to produce at the lowest possible cost to remain competitive. In addition, due to the absence of monopoly power, prices remain at marginal cost levels, which is beneficial for consumers. Perfect competition also stimulates innovation in reducing production costs and improving product quality as companies seek to increase their competitive advantage. In such an environment, there is no room for inefficient use of resources or the creation of artificial scarcity, which contributes to the maximum welfare of society.

Despite its advantages, perfect competition also has significant disadvantages. Since all companies are price takers, they cannot charge above market prices, which limits their profits and the ability to invest in large-scale technological development. This can lead to a slowdown in innovation in industries that require significant capital investment, such as pharmaceuticals or high-tech manufacturing. Also, the lack of economies of scale means that small enterprises may be less efficient than large companies in an oligopoly or monopolistic competition. In addition, perfect competition does not take into account externalities, such as environmental problems or public benefits from certain industries, which requires government intervention to correct market imbalances.

To model a market of perfect competition, we will use model (4) in its entirety, since it meets all the features of the relevant market type.

A *pure monopoly* is a market structure in which there is only one supplier of a good or service that has no close substitutes, and this supplier controls the entire supply in the market. Since the monopolist is the only producer, it determines the price of its product based on its ability to influence demand. Markets that can fit the definition of a pure monopoly typically include natural monopolies where the scale of production is so large that only one participant can be economically efficient, such as in the electricity, water, and transportation industries. The main difference from perfect competition is that in a monopoly, prices are often set above the level that would maximize social welfare, and it is difficult for new entrants to enter the market due to high barriers to entry.

An advantage of a pure monopoly is the possibility of significant investment in large infrastructure projects, as the monopolist has stable profits that allow it to finance long-term projects. In addition, economies of scale can be achieved in a monopoly, which reduces average production costs and allows the use of technologies that would be economically unfeasible

for small firms. It also makes it possible to plan production more efficiently and ensure stability of supply, which is important for infrastructure industries such as energy or water supply.

The disadvantages of a pure monopoly are that the monopolist can abuse its market power by raising prices and reducing the quality of products because there is no competition. This reduces the overall welfare of consumers, as they are forced to pay more for goods or services that could be cheaper in the case of competition. In addition, due to the lack of incentives for innovation, a monopolist can slow down technological development, which negatively affects the long-term dynamics of economic development. Monopolies often require government regulation to limit their pricing practices and ensure access to basic services for all citizens.

Summarizing all of the above, monopoly has one feature in economic growth that radically distinguishes it from perfect competition: at a higher price for a good, monopoly profits exceed those of perfect competition, which should increase savings and investment, but in practice, monopoly investment is usually lower. This is due to additional costs, which we will call the costs of securing monopoly power. To account for these costs, we introduce a coefficient θ equal to:

$$\theta = \frac{Y_m}{Y_p}, \tag{6}$$

where Y_m – output at a monopoly, Y_p – a similar output with perfect competition, and $0 < \theta < 1$, since output is always lower under a monopoly. Then the growth model for a monopoly will take the form:

$$\begin{cases} k_{pr}^{\bullet} = i_{in} + i_f - (d_{pr} + n)k_{pr}, \\ k_{gov}^{\bullet} = g - (d_{gov} + n)k_{gov} + tx, \\ m^{\bullet} = s\theta A k_{pr}^{\alpha} k_{gov}^{\beta} h^{\gamma} n_N^{\varphi} - (g + nm + i_{in} + i_{out}), \\ h^{\bullet} = B k_{rd}^{\upsilon} l - nh, \end{cases} \tag{7}$$

According to expression (7), the costs of securing monopoly power will reduce overall savings, which in turn will more severely limit investment opportunities and lead to lower economic growth.

Let us consider the coefficient θ in more detail. The equilibrium condition for perfect competition is equality of price and marginal cost, or *P=MC*, while the equilibrium condition for monopoly is equality of marginal cost and marginal revenue, or *MC=MR*. Consider the simplest linear demand function:

$$P(Y) = a - bY, \tag{8}$$

Then, for perfect competition, the equilibrium output will be equal to:

$$Y_p = \frac{a - MC}{b}, \tag{9}$$

and for a monopoly:

$$Y_m = \frac{a - MC}{2b}, \tag{10}$$

Since $MR = \frac{d}{dY}(P(Y)Y) = a - 2bY$. Therefore, as a result, we get that $\theta = 0{,}5$, i.e., the growth rate of savings under a monopoly is half that under pure competition, if the demand function is linear and the equilibrium condition is met.

Oligopoly — is a market structure in which a few large companies control the majority of the market and interdependently determine their pricing and production strategies. The main features of an oligopoly are high market concentration, significant barriers to entry for new firms, and the possibility of collusion between companies to limit competition. Real-life examples of oligopolies include the aviation industry, the automotive market, telecommunications companies, and large oil refining corporations. An oligopoly differs from a perfect competition by having fewer participants and the ability to influence prices, and from a monopoly by having several competitors, which forces companies to take into account the reaction of rivals when making decisions. In the context of economic development, an oligopoly can promote long-term investment and innovation, but at the same time, it risks limiting market access for new players.

The main advantage of an oligopoly is the ability of companies to achieve economies of scale, which reduces production costs and allows them to introduce the latest technologies. Oligopolists have significant financial resources that they can direct to research and development of new products, increasing the level of technological progress. Also, competition between several large players can contribute to market stability, as companies try to avoid price wars and provide high quality products to retain consumers. In addition, large corporations can invest in infrastructure development and international expansion, which contributes to global economic growth.

However, oligopoly also has significant drawbacks. Due to the limited number of participants, there is a risk of collusion between companies, which can lead to inflated prices and a reduced supply of goods or services. Oligopolists can also create barriers to entry for new competitors by using financial, administrative, or marketing levers to maintain their market power.

As a result, consumers may suffer from limited choice and insufficient competition. In addition, oligopoly does not always promote innovation, as companies may focus more on maintaining their market position than on developing new technologies.

This can slow down economic development, especially in high-tech industries where competition is an important incentive for innovation.

An oligopoly is an intermediate position between perfect competition and monopoly. It combines high profits, as in a monopoly, with a certain level of competition, which forces companies to innovate. In an oligopoly, there are also costs of securing market power, but they are smaller than in a pure monopoly. In the model, this can be defined as:

$$\begin{cases} k_{pr}^{\bullet} = i_{in} + i_f - (d_{pr} + n)k_{pr}, \\ k_{gov}^{\bullet} = g - (d_{gov} + n)k_{gov} + tx, \\ m^{\bullet} = s\theta^{\frac{1}{N}} A k_{pr}^{\alpha} k_{gov}^{\beta} h^{\gamma} n_N^{\varphi} - (g + nm + i_{in} + i_{out}), \\ h^{\bullet} = B k_{rd}^{\upsilon} l - nh, \end{cases} \tag{11}$$

where N – number of oligopolists.

Thus, in a monopoly, the expression $\theta^{\frac{1}{N}}=\theta^{\frac{1}{1}}=\theta,$, and with perfect competition $\theta^{\frac{1}{N}}=\theta^{\frac{1}{\infty}}\approx\theta^{0}=1,$ which is fully consistent with the limitations of market types.

Monopolistic competition is a market structure that combines elements of both competition and monopoly. Its main feature is a large number of firms offering similar but differentiated products, i.e. products with unique characteristics, brand or marketing strategy. The barriers to entry are low, allowing new players to enter the market all the time. Examples of markets that operate on the principle of monopolistic competition include the restaurant business, clothing, cosmetics, and travel services. This structure differs from perfect competition by the possibility of setting higher prices due to product differentiation, and from monopoly by the presence of a significant number of competitors. In terms of economic development, monopolistic competition promotes a variety of goods and services, stimulates innovation, and ensures more dynamic market development.

The main advantage of monopolistic competition is the high flexibility of the market and its ability to quickly adapt to changes in consumer preferences. Thanks to the ability to differentiate products, companies can create new products, improve quality, and expand their product range, which contributes to economic growth. Competition between manufacturers stimulates innovation as firms strive to offer unique solutions to attract customers. In addition, low barriers to entry allow new companies to enter the market, which increases employment and creates new opportunities for entrepreneurs.

However, monopolistic competition also has certain disadvantages. Due to the costs of marketing, advertising, and new product development, companies may use resources inefficiently, which increases production costs. In addition, excessive differentiation of goods can lead to a situation where it is more difficult for consumers to make a choice, and the market becomes saturated with similar but slightly different offers. Another disadvantage is the instability of firms' profits: due to the high level of competition and the constant change in consumer preferences, companies may have difficulty in forecasting long-term development and maintaining competitive positions.

In monopolistic competition, a new type of cost emerges - product differentiation costs, which are taken into account in the model using the coefficient *q*:

$$\begin{cases} k_{pr}^{\bullet}=i_{in}+i_{f}-(d_{pr}+n)k_{pr}, \\ k_{gov}^{\bullet}=g-(d_{gov}+n)k_{gov}+tx, \\ m^{\bullet}=sq\theta^{\frac{1}{N}}Ak_{pr}^{\alpha}k_{gov}^{\beta}h^{\gamma}n_{N}^{\varphi}-(g+nm+i_{in}+i_{out}), \\ h^{\bullet}=Bk_{rd}^{\upsilon}l-nh. \end{cases} \quad (12)$$

Product differentiation costs in the context of monopolistic competition are additional costs that companies incur to create unique characteristics of their goods or services in order to distinguish them from competitors. These costs include marketing and advertising, new designs, quality improvement, innovation, branding and packaging (costs that do not affect the volume of output or consumption of the product). They affect the firm's overall costs and can reduce market efficiency by raising prices for consumers. We will estimate these costs using the formula:

$$q=\frac{Y-C_{d}}{Y}, \quad (13)$$

where C_d – costs of differentiation, a Y – output volume. In the case of a monopoly, oligopoly or pure competition, these costs will approach 0, and the coefficient, in turn, will approach 1, so it will not affect.

The primary, secondary, and tertiary sectors of the economy usually operate in different market structures due to production characteristics, level of competition, and barriers to entry. The primary sector (agriculture, mining) is often close to an oligopoly or monopoly, as natural resource extraction is controlled by a limited number of large companies or even the state, and in agriculture, certain subsectors may have features of perfect competition due to the large number of small producers. The secondary sector (industry and manufacturing) is most often characterized by oligopoly or monopolistic competition, as large companies dominate industries such as automotive or electronics, while there are many small firms in less capital-intensive products. The tertiary sector (services, retail) is mostly characterized by monopolistic competition, as there are many companies offering similar services with differentiation in terms of quality, brand, or service (e.g., restaurants, tourism, financial services).

Similarly, we modify the Solow [10-12], Ramsey-Cass-Koopmans [13-15], and Mankiw-Romer-Weil models [16].

The prerequisites of the Solow model [10-12] include the variable capital intensity *k=K/L*, which, unlike Keynesian models, is not constant but changes depending on the country's macroeconomic conditions. Prices for goods, services, and resources are formed by the market mechanism, and the growth rate of the labor force corresponds to the average growth rate of the population, but the dynamics of wages is not taken into account. It is assumed that at the initial stage there is no population growth and no technological progress. At the same time, parameters such as the savings rate, depreciation rate, technological progress, capital and labor elasticities, and population growth are treated as constant, although in practice they change over time. The final modified Solow equation [10-12] takes the form:

$$k^{\bullet}=sq\theta^{\frac{1}{N}}AK^{\alpha}-(d+n)k, k_{0}=k(t_{0}). \quad (14)$$

The Ramsey-Cass-Koopmans model [13-15] has similar preconditions and production function to the Solow model, except for the exogeneity of the rate of accumulation. Then the equation of the Solow model takes the form:

$$k^{\bullet}=q\theta^{\frac{1}{N}}AK^{\alpha}-c-(d+n)k, k_{0}=k(t_{0}). \quad (15)$$

The Mankiw-Romer-Weil model [16] is a modification of the Solow model with the addition of human capital (H) to the model, and the basic equation becomes a two-dimensional system and is modified to look like:

$$k^{\bullet}=s_{k}q\theta^{\frac{1}{N}}AK^{\alpha}h^{\beta}-(d+n)k, k_{0}=k(t_{0}),$$

$$h^{\bullet} = s_h q\theta^{\frac{1}{N}} AK^{\alpha} h^{\beta} - (d+n)h, h_0 = h(t_0). \qquad (16)$$

where s_k – rate of accumulation of physical capital, a s_h - rate of human capital accumulation.

Modeling results and discussion. The modeling was based on World Bank statistics [17]. The total sample included 150 countries out of the 217 available (see Figure 2), which allowed for a sufficiently wide range of observations to identify patterns. The analysis did not include countries and periods for which data were incomplete or missing, as their use could distort the results and complicate the construction of models.

The study period was chosen to be as long as possible, which made it possible to assess the long-term impact of demographic changes on economic growth in different time intervals. This approach made it possible not only to trace short-term fluctuations but also to identify stable trends. In addition, the analysis of the impact of the length of the observation period helped to determine how the time horizon of the study can affect the accuracy and reliability of the modeling results.

Fig. 2. Countries that participated in the study

To assess the accuracy of the modeling, a wide range of metrics were used, including the coefficient of determination (R^2), mean absolute error (MAE), mean square error (MSE), root mean square error (RMSE), mean relative error (MRE), mean square logarithmic error (MSLE) and its root (RMSLE). This approach provides a comprehensive evaluation of models:

- The coefficient of determination (R^2) allows you to determine how much of the variation in the dependent variable is explained by the model.
- MAE and MSE provide an indication of the average error, but MSE penalizes large deviations more.
- RMSE simplifies the interpretation of MSE because it preserves the units of the variable.
- MRE provides a scale-independent comparison of errors between different models and samples.
- MSLE and RMSLE are especially useful when modeling exponentially varying data because they reduce the impact of large values and emphasize relative errors.

In general, taking into account market typology in economic growth models leads to an increase in the coefficient of determination in 14% of cases (Figure 3), while in the remaining cases no changes were observed, indicating the dominance of pure competition as the best explanatory structure. This is because economic growth models are usually based on free market assumptions, where resource mobility, lack of barriers to entry, and a large number of participants ensure efficient allocation of capital and technology. In a monopoly or oligopoly, by contrast, there is a redistribution of profits in favor of a limited group of producers, which can distort the effects of innovation and investment. Monopolistic competition, although it includes elements of product differentiation, also does not provide the flexibility and efficiency in the long run as pure competition.

Taking into account the market typology improved the quality metrics of economic growth models with varying degrees of efficiency: for the Solow model in 29% of cases, for the Ramsey-Cass-Koopmans model in 33%, and for the Mann-Romer-Weil model in 19% (Figure 3). The greatest impact was observed in the intertemporal Ramsey-Cass-Koopmans model, as the optimization behavior of consumers and investors is more sensitive to market structures. The Solow model, although simpler, also benefits from market differentiation, as factor incomes and savings may depend on the degree of com-

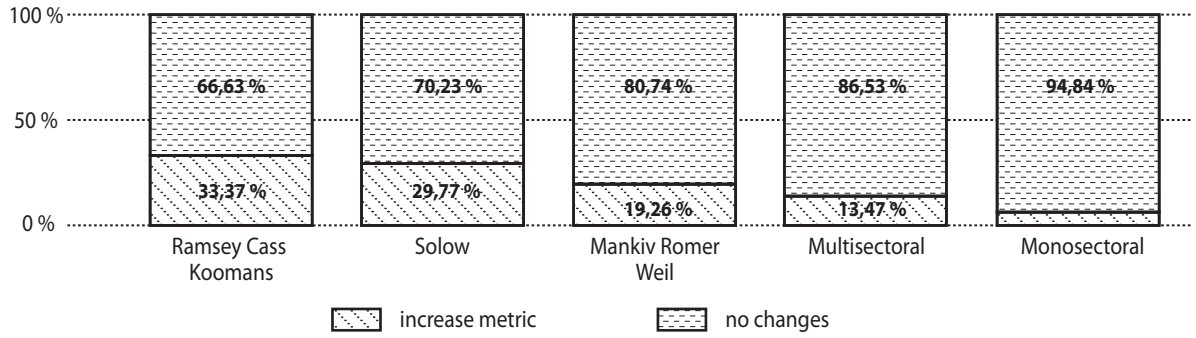

Fig. 3. Dynamics of the coefficient of determination in the context of economic growth models

Source: compiled by the author

petition. The lesser improvement in the Mankiw-Romer-Weil model is explained by the fact that it already takes into account human capital, which partially compensates for the impact of market structure.

Taking into account the market typology improved the quality metrics for the author's single-sector model in 9% of cases, while in 91% of cases no changes were observed (Figure 3), indicating a limited influence of market structures in the overall macroeconomic dynamics. However, for its multisectoral modification, which distinguishes between primary, secondary, and tertiary sectors, a statistically significant improvement in quality metrics has already occurred in 13% of cases. This is because different sectors of the economy have different sensitivities to market structure: the primary sector (agriculture, mining) is often dominated by oligopolies or monopolies due to limited resources, the secondary sector (industry) can have both competition and monopolistic elements, and the tertiary sector (services) is more likely to have monopolistic competition.

Next, let's take a closer look at the situation in terms of economic growth models, starting with the Solow model (Fig. 4).

For the Solow model, taking into account market typology increases forecasting accuracy by 19-20% in the short run and by 38-40% in the long run (Figure 4). This is because in the short run, market structure can have a limited impact on capital accumulation and growth rates, as the main factors-investment, savings, and productivity-have not yet had time to adapt to changes in market conditions. At the same time, in the long run, market structure has a significant impact on the allocation of resources, the level of competition, innovation, and the efficiency of capital use. For example, in competitive markets, capital and labor are allocated more optimally, which contributes to sustainable economic growth, while in monopolized sectors, distortions arise that can hinder development. Accordingly, over time, the cumulative effect of market structures becomes more noticeable, which explains the growth of the model's accuracy in the long run.

Similarly, taking into account market typology increases forecasting accuracy in 33% of cases for underdeveloped countries and in 26% of cases for highly developed countries (Figure 4). This difference can be explained by the fact that in developing economies, market structure plays a more critical role in resource allocation, as such countries often face underdeveloped financial markets, high barriers to entry, and dominance of monopolies or oligopolies in key industries. Depending on the market structure, access to investment, technology, and productive capital can be either stimulated (in a competitive environment) or restricted (in a monopolistic environment), which significantly affects growth rates. In highly developed countries, economies are more diversified, and the effects of market structure are partially offset by effective regulatory policies, developed financial systems, and high capital and labor mobility. Thus, although the impact of market typology on the accuracy of the Solow model is observed in both groups of countries, it is more pronounced in underdeveloped economies due to their greater sensitivity to market constraints and incentives.

The Ramsey-Cass-Koopmans model shows similar results to the Solow model, with an improvement in the coefficient of determination of 25% for the short-term period and up to 45% for the long-term period (40-50 years), but after 50 years this figure begins to decline (Figure 5).

This is because in the short and medium term, the market structure has a significant impact on the dynamics of savings, investment, and resource allocation, which is reflected in the model's increased accuracy. In the long run (up to 50 years), the effect of capital accumulation and the optimizing behavior of agents are most fully manifested, which explains the peak in accuracy. However, after this period, the decline in accuracy can be caused by several factors: first, structural changes in the economy (technological shifts, demographic changes, evolution of financial markets) begin to play a greater role than the initial conditions of the market structure. Secondly, models based on intertemporal optimization assume rationality of agents in a very long period, which in reality may not correspond to the behavior of economic agents due to uncertainty, shocks, and changes in macroeconomic policy. As a result, after 50 years, the effect of the market typology gradually weakens, and the accuracy of the model begins to decline. Similarly to the Solow model, the improvement for underdeveloped countries is more widespread than for highly developed ones.

For the Mankiw-Romer-Weil model, there is an increase in accuracy with an increase in the modeling period: in the short term, the improvement occurs in less than 10% of cases, while in the long term it is up to 32%, which is a larger gap than in the Solow and Ramsey-Cass-Kupmans models (Figure 6).

This is explained by the role of human capital, which is a key complementary factor in this model. On short horizons, the impact of market structure on human capital is minimal, as educational processes and the accumulation of knowledge and

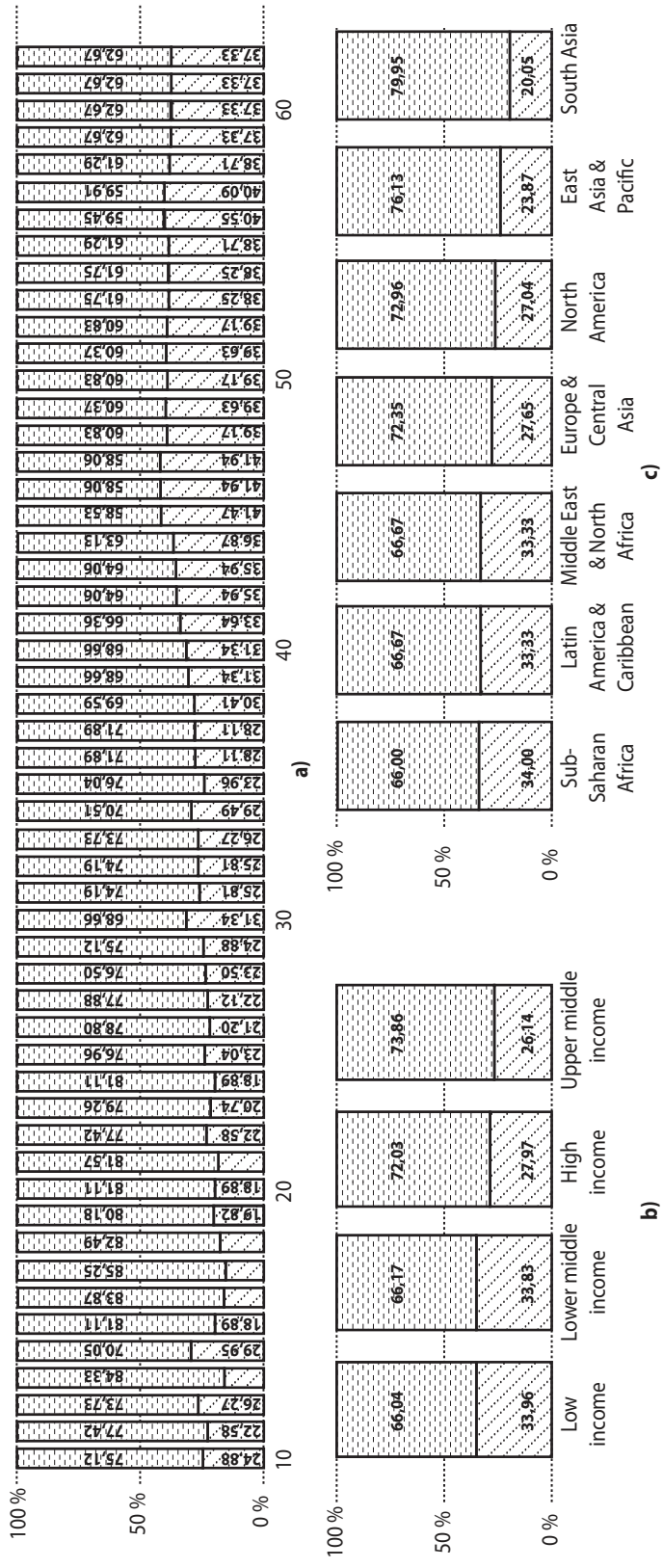

Fig. 4. Dynamics of the coefficient of determination by the length of the modeling period (a), country groups by income level (b) and geographical location (c) for the Solow model

Source: compiled by the author

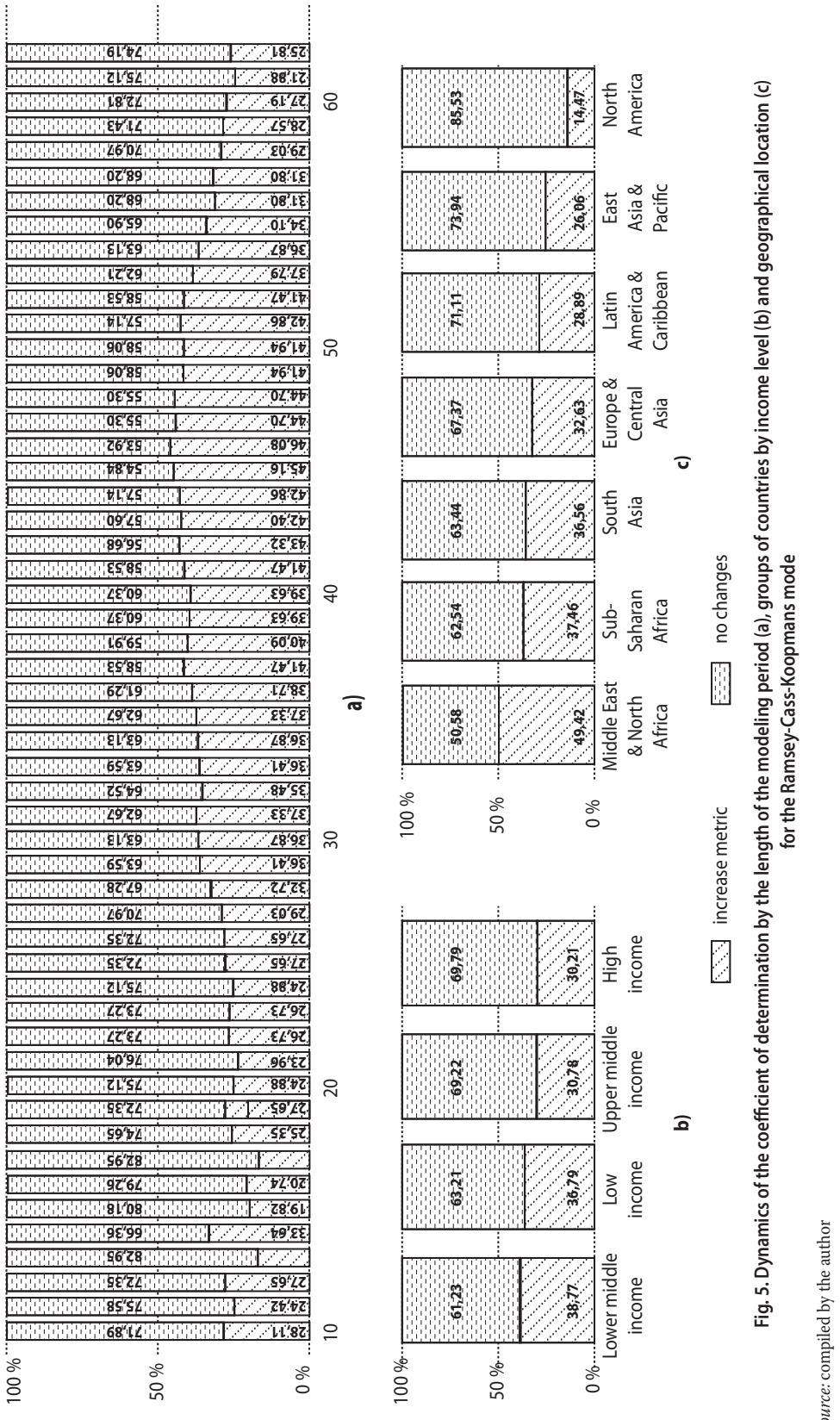

Fig. 5. Dynamics of the coefficient of determination by the length of the modeling period (a), groups of countries by income level (b) and geographical location (c) for the Ramsey-Cass-Koopmans mode

Source: compiled by the author

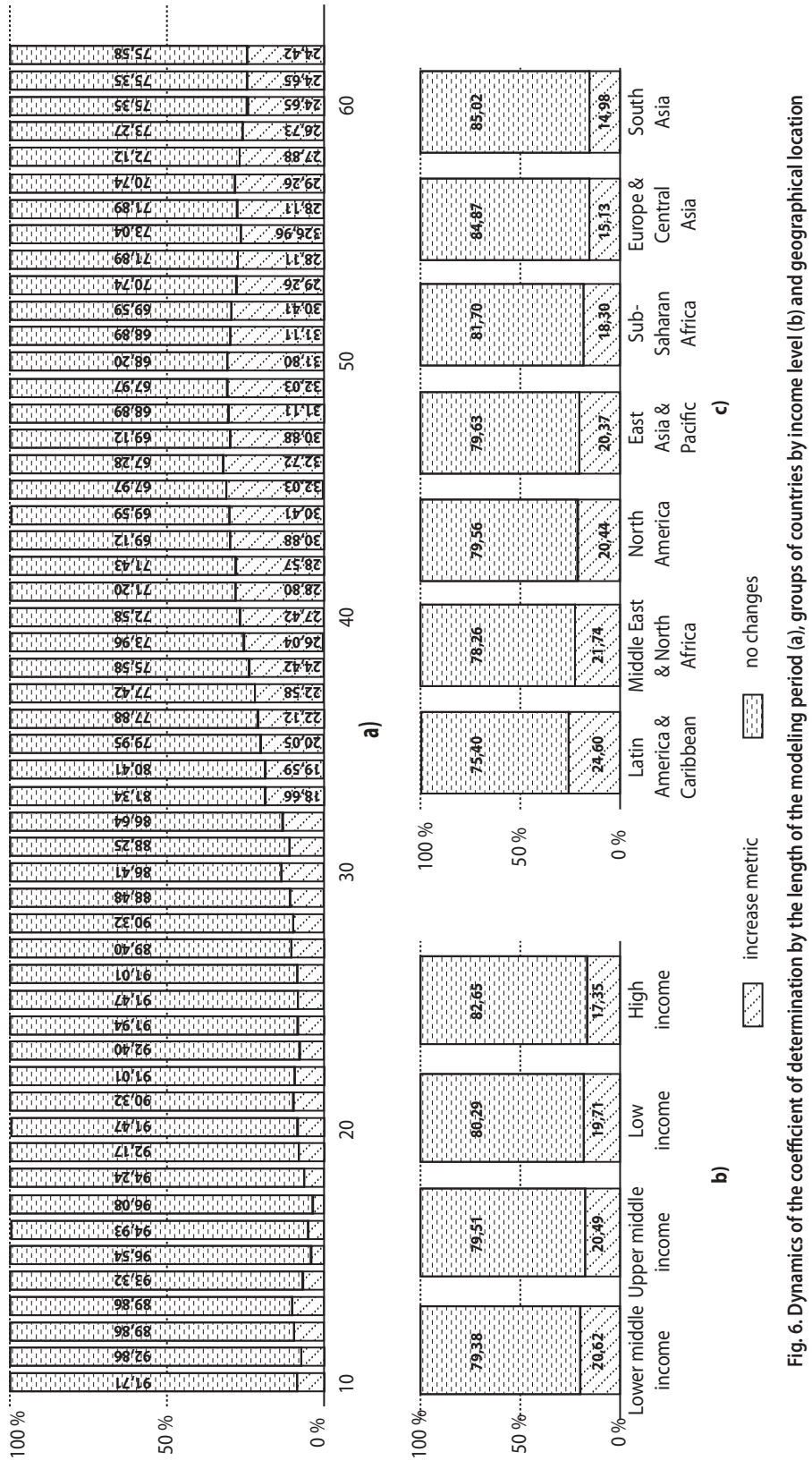

Fig. 6. Dynamics of the coefficient of determination by the length of the modeling period (a), groups of countries by income level (b) and geographical location (c) for the Mankiw-Romer-Weil model

Source: compiled by the author

skills are long-term, and their direct effect on productivity is only manifested over time. In the long run, the consideration of market typology becomes more critical, as market structure determines incentives to invest in education, the level of competition in the labor market, access to quality education, and the efficiency of human capital use. For example, in competitive markets, labor is used more efficiently, which increases its productivity, while in monopolized industries, there may be limitations in professional development and a decrease in motivation to learn. As a result, in the long run, market structure begins to have a significant impact on economic growth through the accumulated human capital, which explains the sharper gap in forecasting accuracy compared to models where human capital is not explicitly taken into account.

When the author's multivariate single-sector economic growth model is modified, the increase in forecasting quality is observed only in 9% of cases (Figure 7), and this effect remains relatively stable regardless of the level of economic development of the country, its geographical location, or the length of the modeling period. This is due to the overall complexity of the model, which integrates a large number of variables and multidimensional relationships, which reduces the marginal impact of individual factors, including market structure. The main mechanism of influence of the market typology in this model is mainly realized through the savings component, since they determine the level of investment and the dynamics of accumulation of production resources.

At the same time, when forecasting economic indicators, it should be borne in mind that although the model's accuracy gains are relatively low, the sheer volume of changes in key macroeconomic variables, such as investment, GDP, and productivity, can be much more significant due to the long-term effects of the interaction between savings and other components of economic growth. This suggests that even with a relatively weak correlation between market structure and forecast quality, the impact of market conditions on economic dynamics remains significant, especially when analyzing future changes in key macroeconomic parameters.

If we focus only on the component of savings dynamics in the modified author's multivariate single-sector model of economic growth, the quality of the model in terms of the coefficient of determination increases significantly, reaching an improvement of 40% over time (Figure 8).

If we consider the RMSLE metric, the result is absolutely similar to the previous analysis regarding the coefficient of determination (Figures 9,10).

For the multidimensional three-sector model, when modified to take into account market typology, there is an increase in quality in 14% of cases, which is higher than 9% for the one-sector model (Figure 11). This increase can be explained by the fact that the multi-sector approach allows for a better accounting of the diversity of economic processes in each sector (primary, secondary, and tertiary), which allows the market structure to influence economic growth in a more comprehensive manner. Different market conditions in each sector have a significant impact on the level of savings and investment, as sectors may have different sensitivities to monopoly, oligopoly, or competition, which in turn changes economic dynamics.

The increase in quality in more than 60% of cases (Figure 12) when considering the savings component in the multidimensional three-sector model, taking into account market typology in the medium and long term, is explained by several important factors that distinguish the multidimensional approach from the one-sector model.

First, multidimensional models allow for different types of market structures in each of the sectors of the economy (primary, secondary, and tertiary), which significantly affects the level of savings and investment in each sector. Different market conditions, such as the level of competition or monopolies in certain sectors, have a significant impact on capital accumulation and savings. For example, in competitive sectors, there is greater efficiency in the allocation of resources, which encourages savings, while in monopolized sectors there may be fewer incentives to save due to high barriers to entry and reduced incentives to invest.

Second, in the medium and long term, capital accumulation becomes more sensitive to changes in market conditions, as most investments and strategic savings decisions take time to realize their effects. This is especially important for long periods, where the effects of different types of market structures are more significant, as they determine not only the volume of investment but also its efficiency through the presence or absence of innovation, technological progress, and access to financial resources.

In addition, multivariate models allow for a more accurate modeling of the interrelationships between economic sectors, which makes it possible to assess in more detail the impact of changes in market typology on each sector separately, which significantly improves the accuracy of savings forecasting. That is why, when modified with market typology in a multivariate three-sector model, the accuracy of savings component forecasts increases significantly more than in single-sector models, reflecting more complex mechanisms of market influence on economic dynamics.

On average, for the savings component, the quality of the modified model, as assessed by the RMSLE indicator, increases regardless of the length of the modeling period (Figures 13,14).

In conclusion, we forecast economic growth for Ukraine using a multivariate three-sector model (Figure 15).

According to the modeling results, there is a significant decline in the rates of all major components of economic growth if we take monopoly instead of pure competition as the prevailing market type. This indicates that the dominance of monopolies negatively affects economic dynamics by limiting innovation and production efficiency compared to more competitive market conditions.

Conclusions. The article thoroughly analyzes the impact of market structure on economic growth by modifying the author's multidimensional model, which includes additional coefficients for different types of markets. For monopolistic competition, the coefficient of product differentiation costs is taken into account, for monopoly - the coefficient of volume decline adjusted for the number of market participants, which is also typical for oligopoly. The model for perfect competition remained unchanged, which made it possible to compare the accuracy of forecasts for different market conditions.

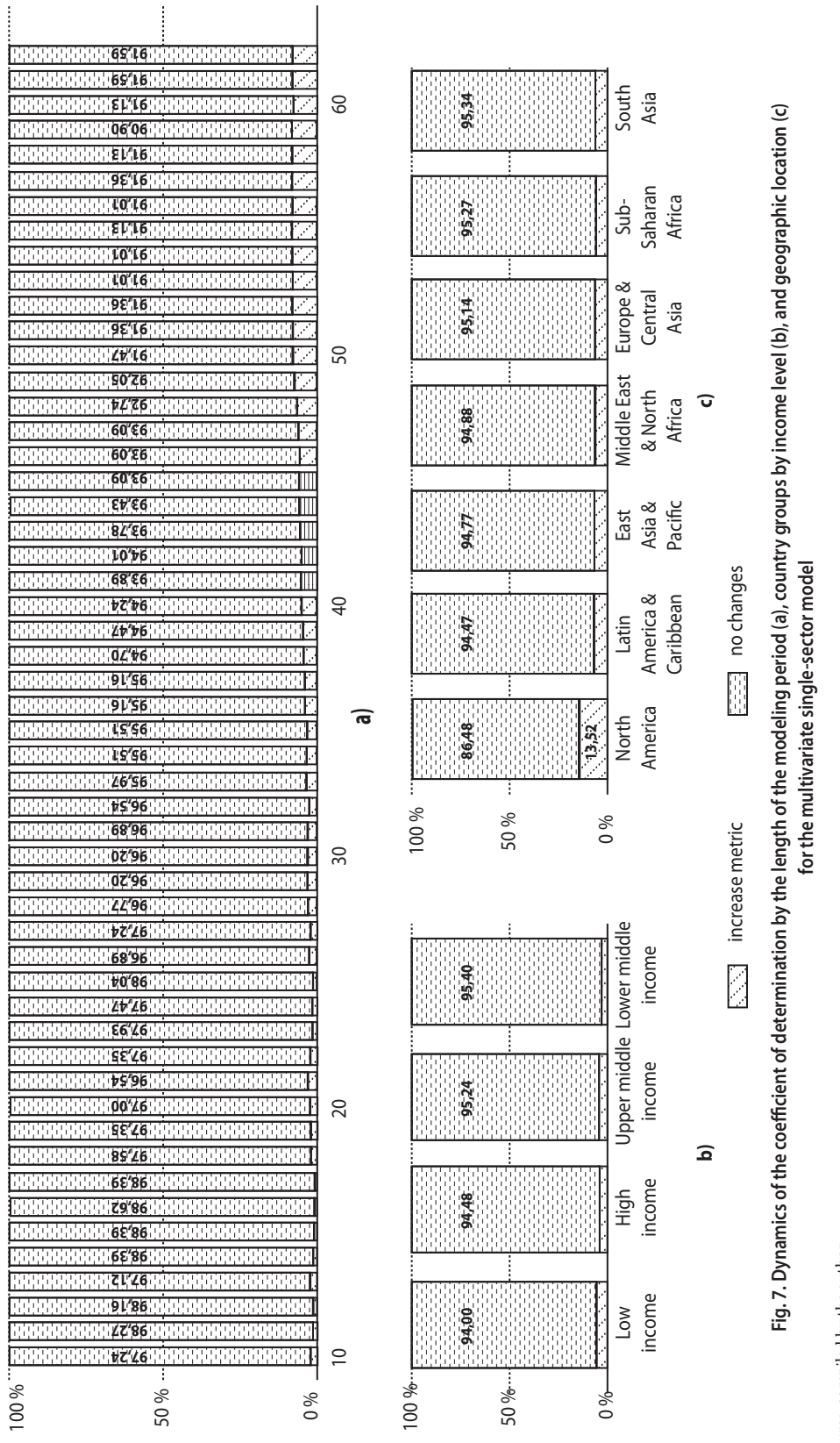

Fig. 7. Dynamics of the coefficient of determination by the length of the modeling period (a), country groups by income level (b), and geographic location (c) for the multivariate single-sector model

Source: compiled by the author

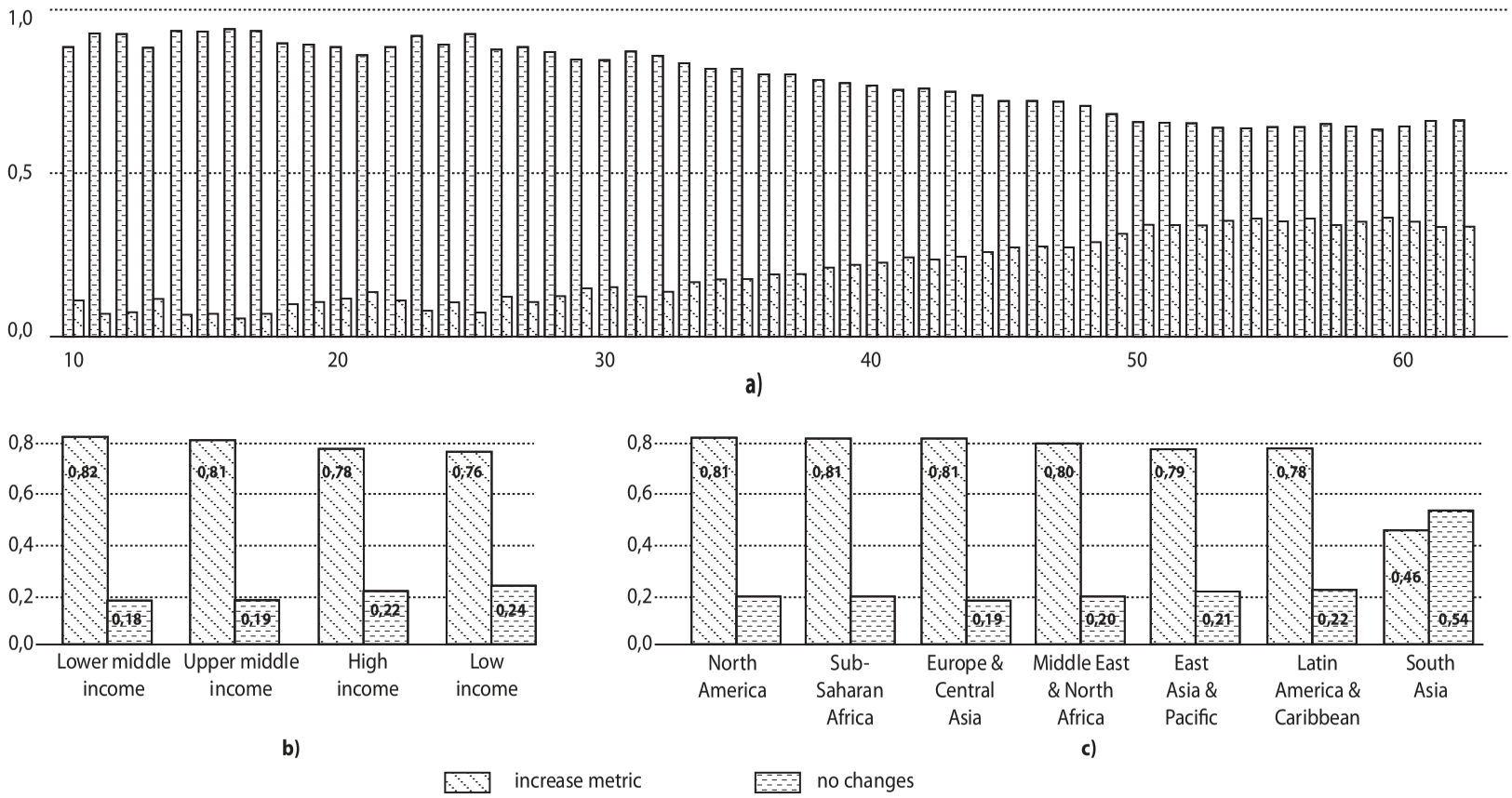

Fig. 8. Dynamics of the coefficient of determination of the savings component by the length of the modeling period (a), income groups (b), and geographic location (c) for the multivariate single-sector model

Source: compiled by the author

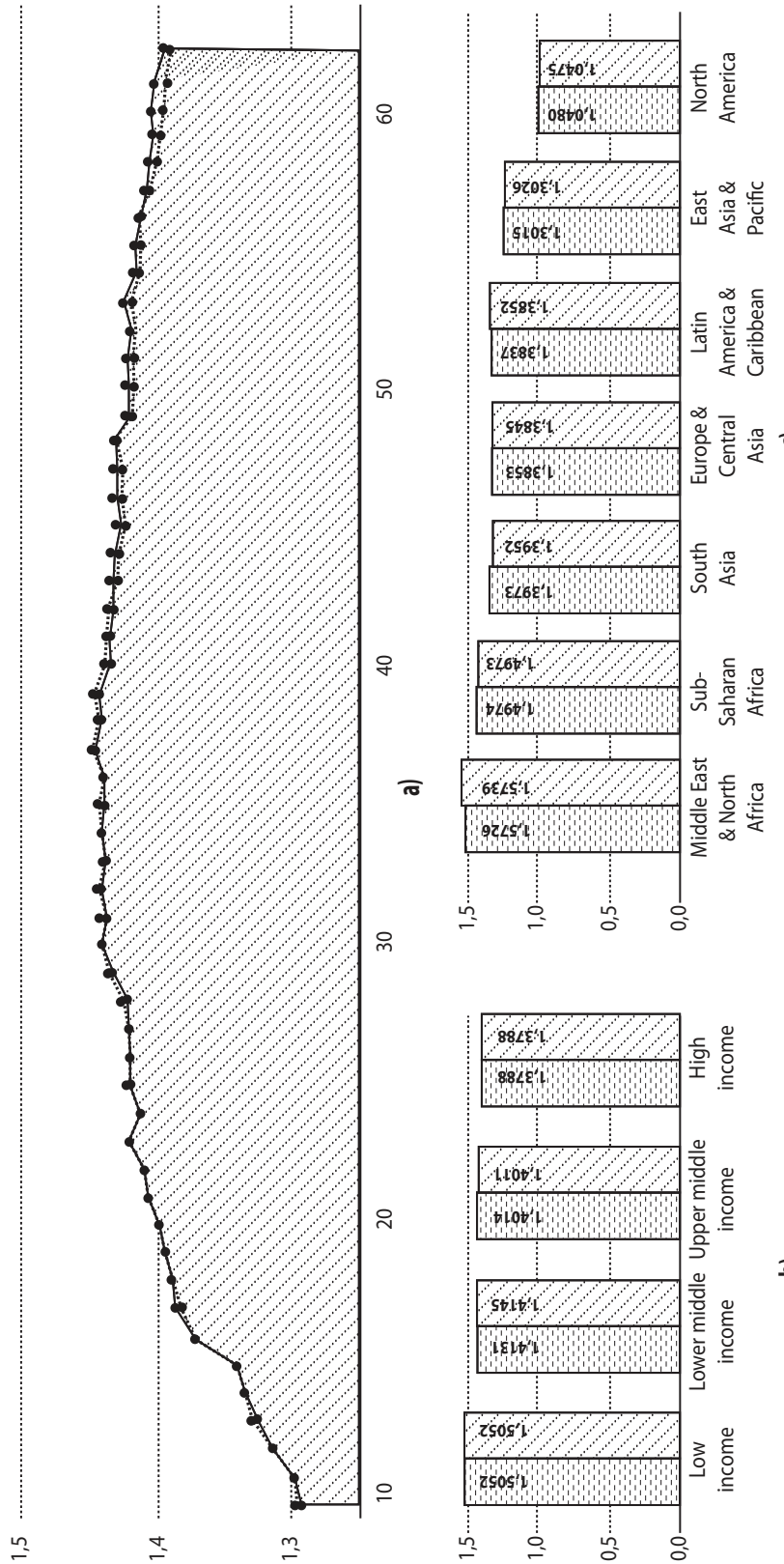

Fig. 9. RMSLE by the length of the modeling period (a), country groups by income level (b), and geographic location (c) for the multivariate single-sector model

Source: compiled by the author

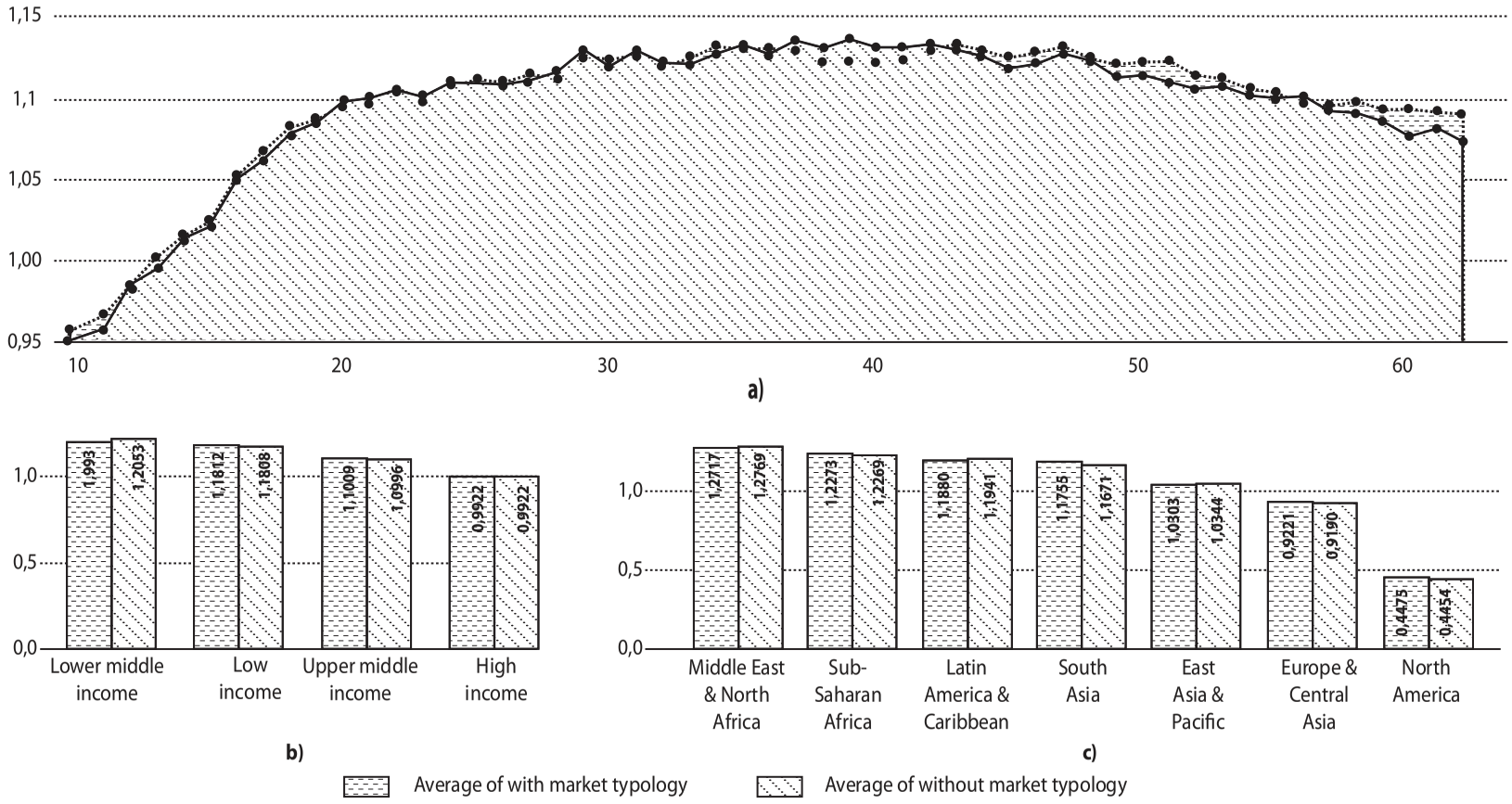

Fig. 10. RMSLE components of savings by length of the modeling period (a), income group (b), and geographic location (c) f or the multivariate single-sector model

Source: compiled by the author

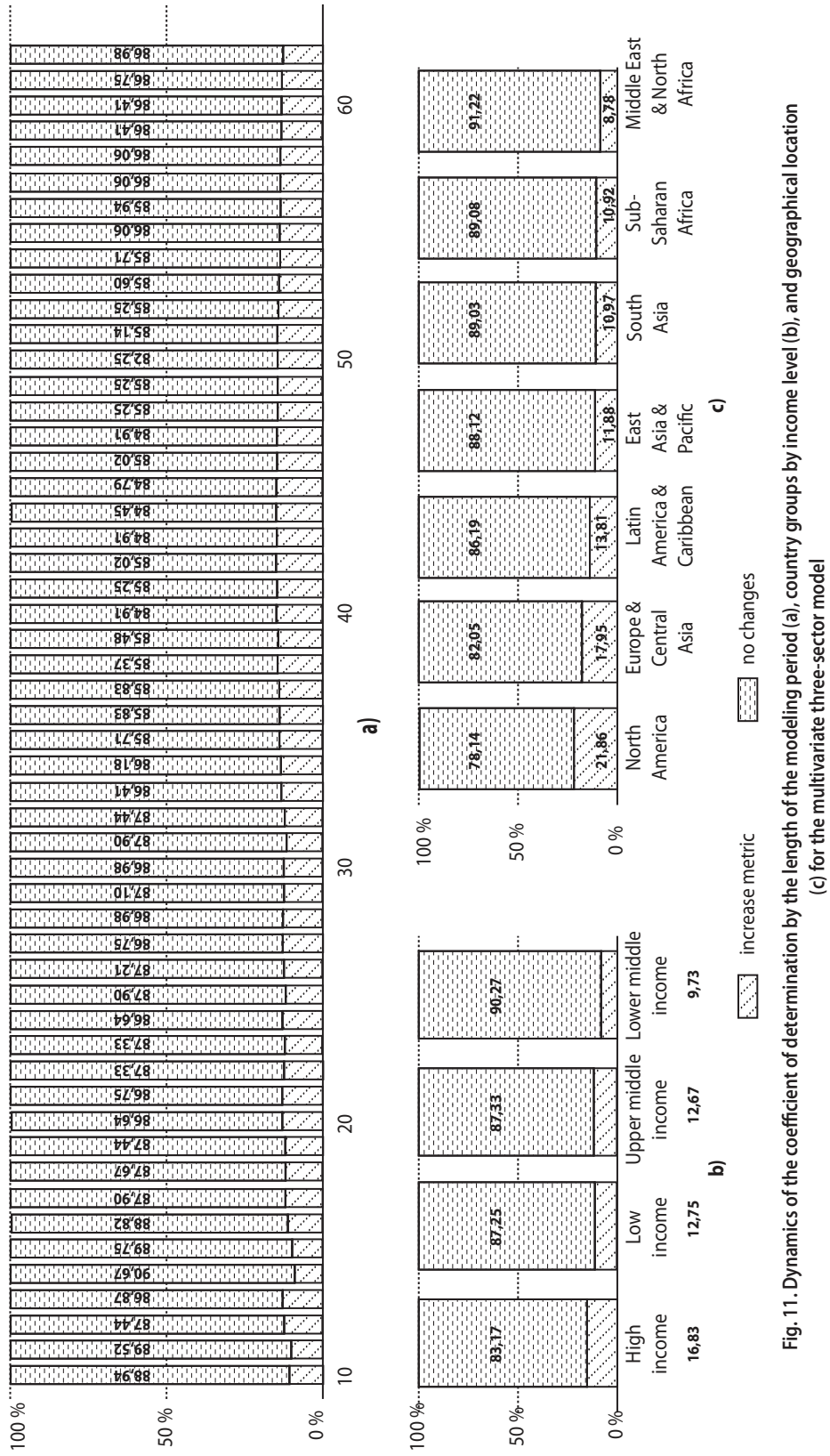

Fig. 11. Dynamics of the coefficient of determination by the length of the modeling period (a), country groups by income level (b), and geographical location (c) for the multivariate three-sector model

Source: compiled by the author

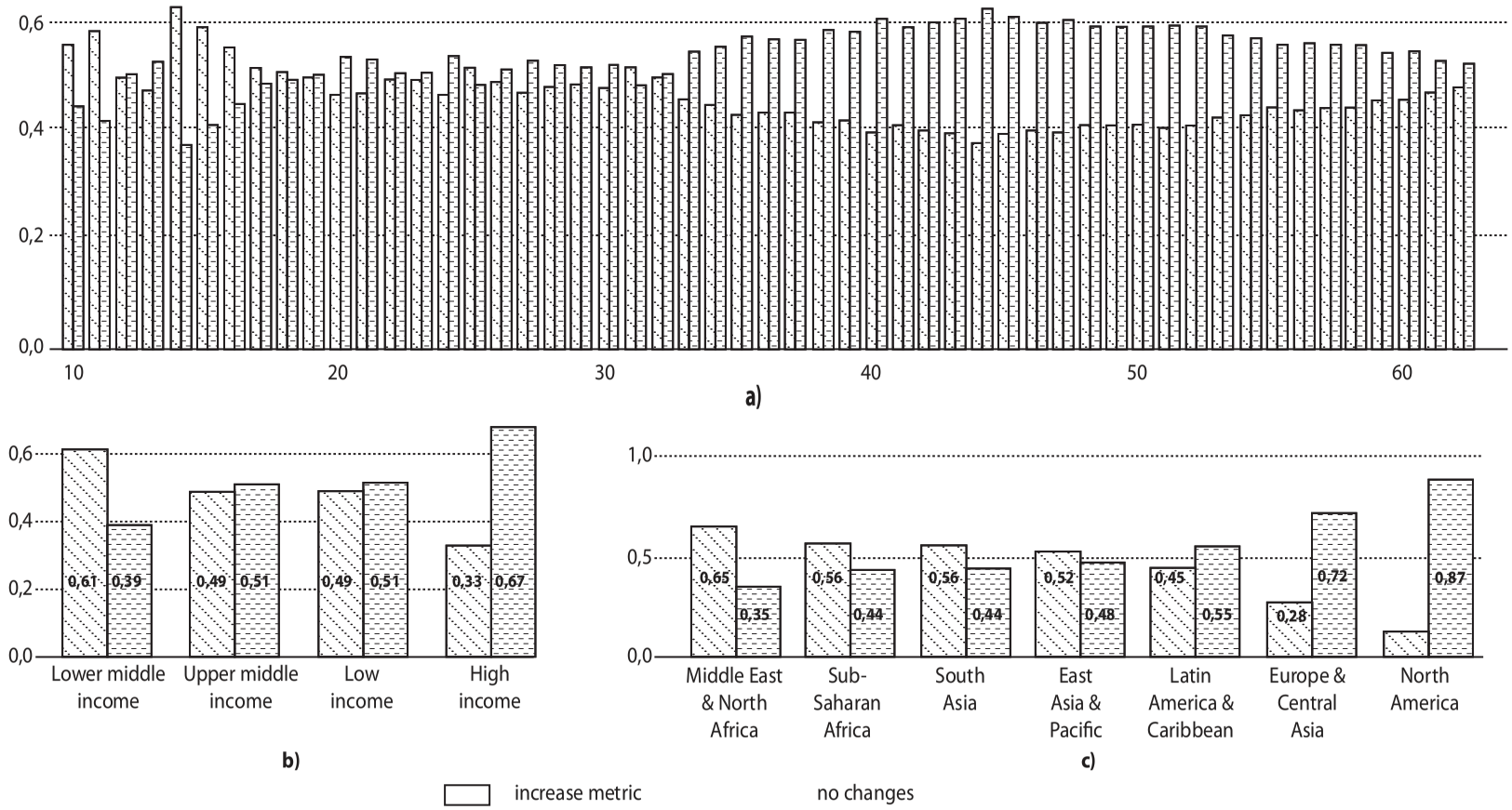

Fig. 12. Dynamics of the coefficient of determination of the savings component by the length of the modeling period (a), income groups (b), and geographic location (c) for the multivariate three-sector model

Source: compiled by the author

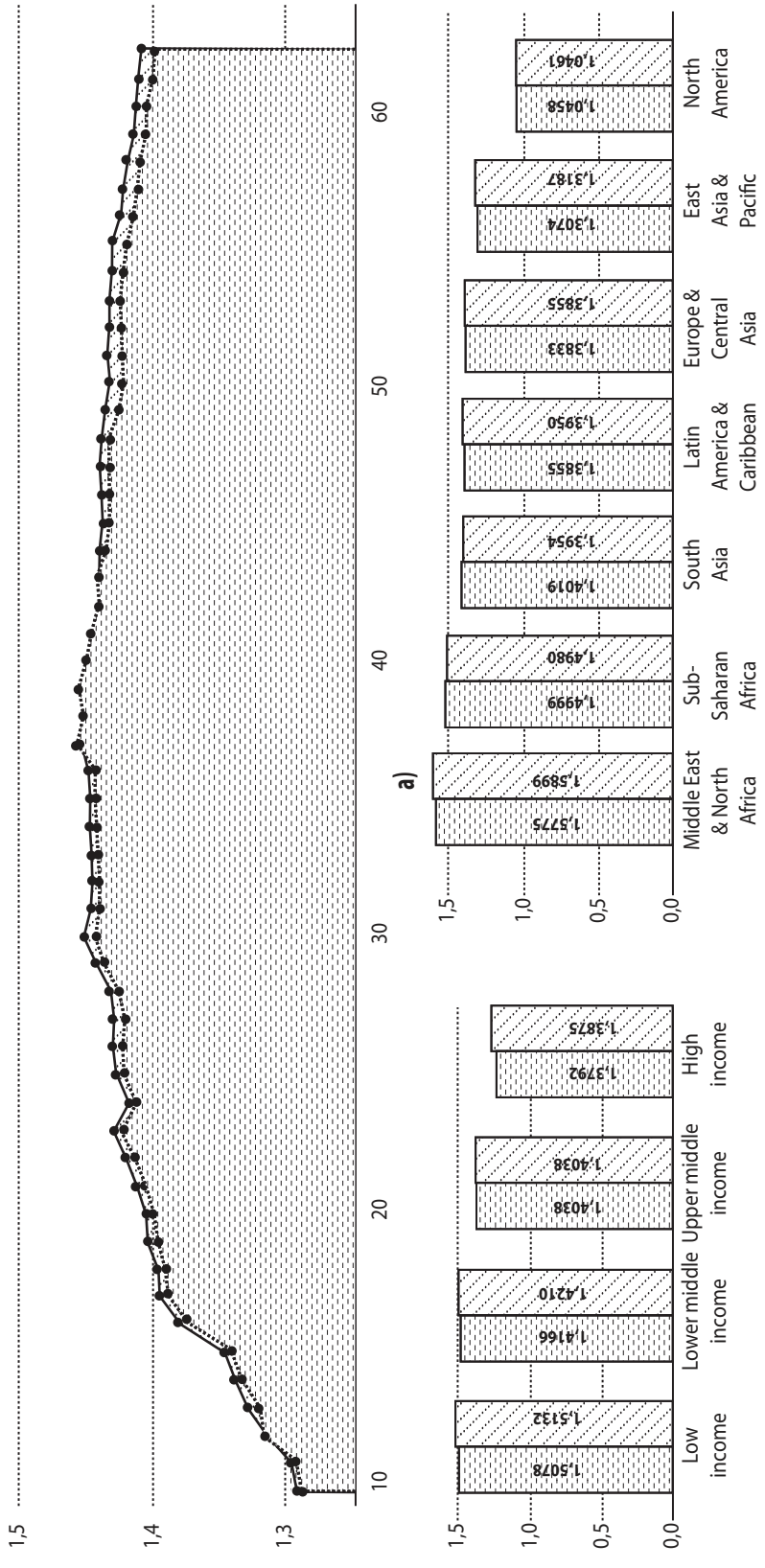

Fig. 13. RMSLE by the length of the modeling period (a), country groups by income level (b), and geographic location (c) for the multivariate three-sector model

Source: compiled by the author

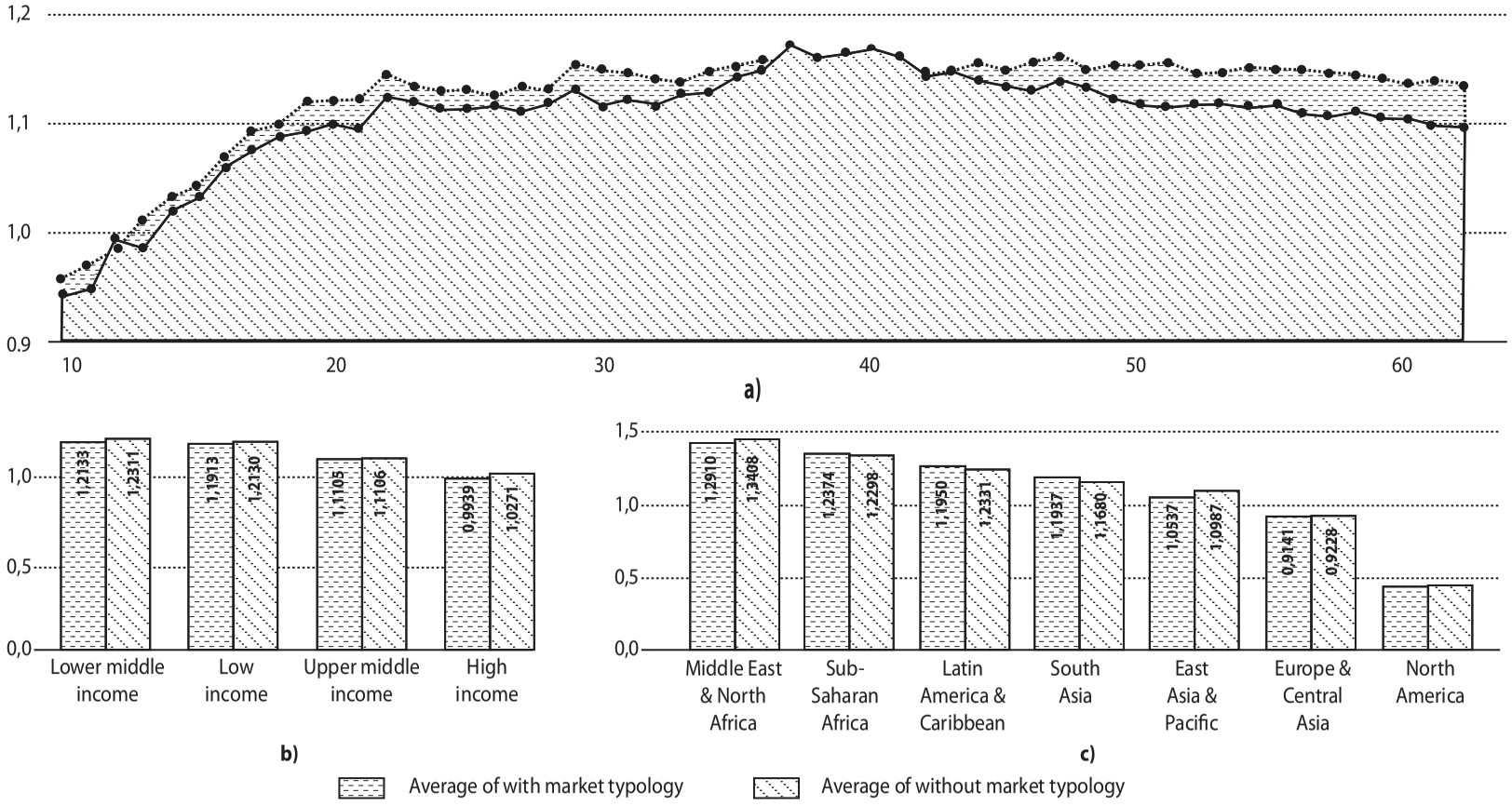

Fig. 14. RMSLE components of savings by length of the modeling period (a), income group (b), and geographic location (c) for the multivariate three-sector model

Source: compiled by the author

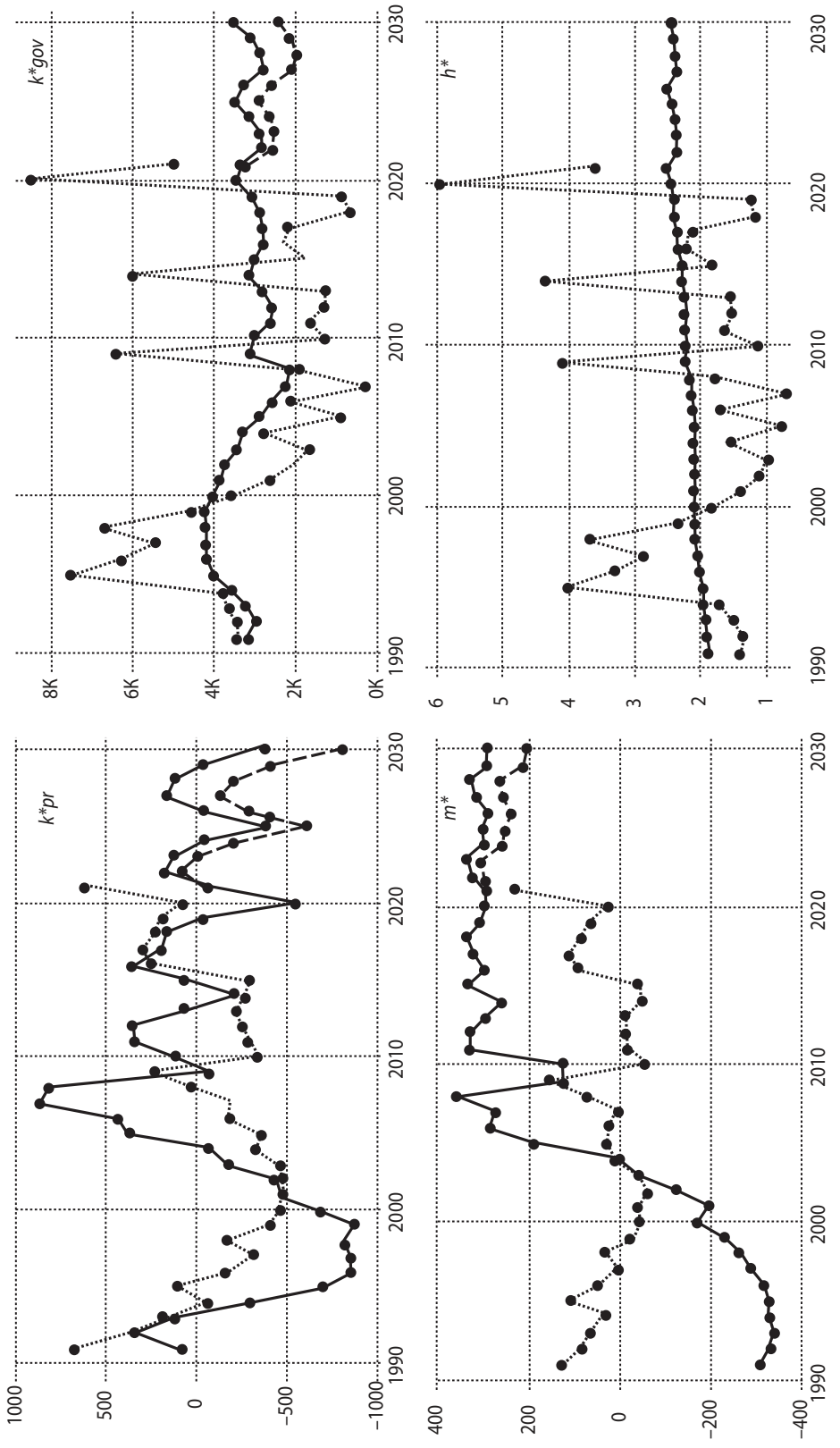

Fig. 15. Forecast for Ukraine's economy based on pure competition (dark green graph) and monopoly (light green graph)

Source: compiled by the author

Comparison of the modified and original model confirmed a significant improvement in modeling accuracy of up to 60% of cases, in particular those related to long-term economic growth, underdeveloped countries, especially for the three-sector model.

On the one hand, the results obtained indicate that it is expedient to integrate market characteristics into macroeconomic models, as this can significantly improve the accuracy of economic growth forecasting, in particular for countries at different stages of economic development. On the other hand, there is a vivid example of adaptive modeling of nonlinear economic dynamics. The involvement of additional variables describing the market structure makes the model more flexible and able to reflect the realities of the modern economy, which is important for analyzing the effectiveness of economic policies.

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