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TRANSMISSION CHANNELS AS AN ARCHITECTURE OF ECONOMIC DEVELOPMENT IN THE CONDITIONS OF DIGITALIZATION AND NEO-INDUSTRIAL RECOVERY

The aim of the article is to systematize the key elements of transmission channels as an architecture of economic development in the conditions of digitalization and neo-industrial recovery and develop a conceptual model of their structural and functional relationships. In the article the key elements and examines the structural interlinkages of the transmission channels of economic development, informational, financial, investment, and institutional, are systematized. It is argued that the conventional interpretation of the transmission mechanism, developed mainly within monetary theory, is insufficient to explain how policy and market impulses translate into real shifts in output, employment, and welfare under conditions of structural economic transformation. The four channels are shown to be not parallel but hierarchically and functionally interconnected subsystems of a single: the informational channel shapes expectations and reduces information asymmetry; the financial channel converts these expectations into the cost and availability of capital; the investment channel transforms capital into real assets and growth potential; while the institutional channel functions as a "second-order channel" that determines the efficiency (density) of impulse transmission through all other channels via property-rights protection, contract enforcement, and regulatory quality. Based on the analysis, a cross-linkage matrix of the four channels is constructed, and an analytical (mathematical) model is proposed that formalizes the chain "information → cost of capital → investment → output" and derives a composite transmission elasticity, demonstrating the non-additive, threshold-like role of institutional quality in policy-impulse transmission. Practical implications of the proposed approach for economic policy design during Ukraine's post-war economic recovery are identified, in particular the need to synchronize informational transparency, financial stability, investment incentives, and institutional reform as preconditions for effective policy transmission into economic growth.

Keywords: transmission channels, economic development, digitalization, recovery, transmission loop, model, interlinkages of the transmission channel.

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ТРАНСМІСІЙНІ КАНАЛИ ЯК АРХІТЕКТУРА ЕКОНОМІЧНОГО РОЗВИТКУ В УМОВАХ ЦИФРОВІЗАЦІЇ ТА НЕОІНДУСТРІАЛЬНОГО ВІДНОВЛЕННЯ

Метою статті є систематизація ключових елементів каналів передачі як архітектури економічного розвитку в умовах цифровізації та неоіндустріального оновлення та розробка концептуальної моделі їх структурних та функціональних взаємозв'язків. У статті систематизовано ключові елементи та досліджено структурні взаємозв'язки трансмісійних каналів економічного розвитку – інформаційного, фінансового, інвестиційного та інституційного. Обґрунтовано, що традиційне трактування трансмісійного механізму, сформоване переважно в межах монетарної теорії, є недостатнім для пояснення того, як імпульси економічної політики та ринкових сигналів перетворюються на реальні зрушення у виробництві, зайнятості та добробуті в умовах структурної трансформації економіки. Доведено доцільність розгляду чотирьох каналів не як паралельних, а як ієрархічно й функціонально пов'язаних підсистем єдиного трансмісійного контуру, у якому інформаційний канал формує очікування та знижує асиметрію інформації, фінансовий — перетворює ці очікування на вартість і доступність капіталу, інвестиційний — трансформує капітал у реальні активи та потенціал зростання, а інституційний виконує функцію "каналу другого порядку", що визначає ефективність (щільність) передавання імпульсів усіма іншими каналами через захист прав власності, виконання контрактів і якість регулювання. На основі проведеного аналізу побудовано матрицю перехресних зв'язків між каналами та запропоновано аналітичну (математичну) модель, яка формалізує ланцюг залежностей "інформація → вартість капіталу → інвестиції → випуск" і виводить композитну еластичність трансмісії, що засвідчує немультіплікативну, порогову роль інституційної якості у передаванні імпульсів політики. Визначено практичні імплікації запропонованого підходу для формування економічної політики в умовах повоєнного відновлення економіки України, зокрема необхідність синхронізації інформаційної відкритості, фінансової стабільності, інвестиційних стимулів та інституційних реформ як передумови ефективної трансмісії політики в економічне зростання.

Ключові слова: трансмісійні канали, економічний розвиток, цифровізація, відновлення, трансмісійний контур, модель, взаємозв'язки трансмісійних каналів.

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STATEMENT OF THE PROBLEM IN GENERAL TERMS AND ITS RELATIONSHIP TO IMPORTANT SCIENTIFIC OR PRACTICAL TASKS

The effectiveness of state economic policy in the conditions of digitalization and neo-industrial recovery is determined not only by the quality of decisions made, but also by the ability of the economic system to transform these decisions into real results - growth in production, income and employment. This ability is described by the category of transmission mechanism, which is traditionally considered in a narrow, mainly monetary context: as the transmission of monetary policy impulses through interest rates, credit and asset prices. However, this interpretation does not cover the entire set of channels through which economic development policy is implemented in the conditions of structural transformations inherent in transitional and post-conflict economies.

Recent practice (the digitalization of public administration, the growing role of expectations and information transparency, increased sensitivity of investors to the institutional environment, as well as the need for rapid and effective transmission of recovery resources to the real sector of the Ukrainian economy) demonstrates that the information, financial, investment and institutional components do not function autonomously, but as elements of a single system, a failure in one link of which significantly reduces the effectiveness of all the others. Concurrently, in the scientific literature, these channels are mostly studied in isolation from each other, within separate industry areas (macroeconomics, financial theory, institutional economics, information theory), which complicates the formation of a holistic view of the architecture of the transmission process and limits the possibilities of informed policy coordination. This makes it urgent to systematize the key elements of each of the four channels and reveal the nature of the functional connections between them.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

The theoretical basis for the study of transmission channels in the conditions of digitalization and neo-industrial recovery is laid in modern empirical works devoted to monetary transmission channels. A. DaSilva and M. Farka, based on intraday stock market data, systematized the effectiveness of the interest rate and credit channels of monetary policy before and after reaching the zero-interest rate limit, showing the shift in the ratio between the channels depending on the policy regime [1]. S. Brissimis and M.-P. Papafilis extended the classical model of the credit channel [2], and H. Zhong and co-authors showed that banking regulation generates new transmission channels (capital, credit supply, bank balance), revealing the mechanism of action of the credit channel through the prism of modern banking regulation [3]. K. Zhemelko and K. Kočíšová, based on a meta-analysis of more than 70 empirical studies, proposed a generalized empirical framework for assessing the speed and completeness of interest rate transmission, covering several channels simultaneously [4]. The research of various transmission channels is devoted to the studies of R. Levine [5], J. Stiglitz, A. Weiss [6], M. R. Jazuli [7], D. Acemoglu and J. Robinson [8], P. Dykas, T. Tokarski and R. Wisła [9].

Formalization of transmission processes by means of mathematical modeling is an independent and actively developing direction of modern research. Structural VAR models remain the main tool for empirical assessment of the speed and completeness of transmission of monetary policy impulses to the real sector of the economy through interest rates; in particular, for the economy of Ukraine, H. Telnova and co-authors, based on VAR modeling, quantitatively estimated the transmission of the NBU discount rate to the rates of commercial banks [10]. More complex, micro-based dynamic stochastic general equilibrium (DSGE) models allow for the simultaneous formalization of multiple transmission channels and the assessment of their interaction under integrated central bank policy, as demonstrated in the model of K. Chen et al. for emerging market countries [11]. It is also worth noting the research conducted by Ilyash O. and co-authors [12], Prokhorova V. and co-authors [13], Antypenko N. V. and co-authors [14], Shevchuk O. and co-authors [15] and other scientists.

IDENTIFICATION OF PREVIOUSLY UNRESOLVED ASPECTS OF THE GENERAL PROBLEM ADDRESSED IN THE ARTICLE

While highly appreciating the contribution of these areas, it should be noted that the vast majority of studies analyze transmission channels either within the framework of purely monetary policy, or locally - in relation to a separate segment (financial, institutional, etc.), while the issue of systemic, including feedback, connections between information, financial, investment and institutional channels in the context of economic development policy remains insufficiently developed. This forms a scientific problem, the solution of which is devoted to this study.

FORMULATION OF THE OBJECTIVES OF THE ARTICLE

The aim of the article is to systematize the key elements of transmission channels as an architecture of economic development in the conditions of digitalization and neo-industrial renovation and develop a conceptual model of their structural and functional relationships.

PRESENTATION OF THE MAIN RESEARCH MATERIAL

The transmission channel of economic development is expediently defined as a stable set of interconnected elements (institutions, markets, entities, information flows), through which the impulse of economic policy, market conditions, or technological changes is consistently transmitted and transformed into changes in real development indicators - production volumes, employment, investments, and welfare. In contrast to the classical transmission mechanism of monetary policy, which describes a narrow range of channels (interest rate, credit, asset price channel, exchange rate, expectations channel) [1; 3], the transmission mechanism of economic development is a broader concept and covers channels that go beyond the purely monetary sphere - information, financial in a broad sense, investment and institutional. Each of these channels has its own internal structure of elements, while functioning as a link in a single transmission circuit.

Information channel ensures the formation, dissemination and interpretation by economic entities of information necessary for decision-making. Its key elements are: the level of information asymmetry between market participants [6]; inflation and business expectations of economic entities; business and consumer confidence indices; transparency and predictability of state economic policy (communication policy of the central bank and government); quality of statistical support and open data; degree of digitalization of public administration (e-government, registers, electronic services). Within the digital economy, as defined by the UNCTAD report "Digital Economy Report 2024", the processing and generation of information and data become an independent source of productivity and competitive advantage, and not just an auxiliary tool for decision-making [16]. The effectiveness of the information channel is reflected in how quickly and accurately policy signals (e.g., announcements of a change in the discount rate, fiscal decisions, reforms) are transformed into agreed-upon expectations of market actors, reducing uncertainty and transaction costs of information search. Empirical studies confirm the effectiveness of this mechanism: the digitalization of government services (e-declaration, registers, e-services) statistically significantly reduces information asymmetry between the state and economic actors and narrows the space for corrupt rent-seeking [17]; for the Ukrainian economy, an illustration of the increase in the quality of the information channel is the increase in the UN e-Government Development Index (EGDI) to 0.884 in 2024 (30th place among 193 countries in the world, compared to 46th place in 2022).

Financial channel converts information signals and monetary policy decisions into changes in the cost and availability of capital for the real sector. Its key elements include: interest rates and their structure (base rate, interbank, deposit and credit market rates); bank credit channel, the effectiveness of which depends on the capitalization and willingness of banks to increase lending [2; 3]; financial asset price channel (stock, bond prices, exchange rate), changes in which affect the cost of assets and the propensity to consume and invest; the degree of depth and development of financial intermediation, which determines the system's ability to mobilize savings and effectively allocate capital between projects with different returns and risks. Empirical research by R. Levine shows that it is the quality (and not just the size) of the financial system (competition, legal protection of creditors, information disclosure) that determines its contribution to economic growth [5], which directly links the financial channel with the institutional one. For post-conflict economies, this relationship is even closer: the systematization of 47 scientific sources for 2006–2026 showed that it is financial stability and institutional trust that are the determining factors that transform post-conflict risk into the restoration of investment activity [18, 19].

Investment channel is responsible for the transformation of financial resources (domestic savings, credit, foreign direct investment, budget funds) into real capital accumulation - fixed assets, infrastructure, human and technological capital. Its elements are: the volume and structure of private and state (public) investments; foreign direct investment and the conditions for their attraction; the acceleration effect (the sensitivity of investment demand to the expected dynamics of output); the effects of crowding out or attracting private investment by public spending (crowding-out/crowding-in); the quality of the investment climate and infrastructure provision. In the neoclassical growth model of R. Solow, the modern generalization and applied development of which is presented in the work of P. Dykas, T. Tokarski and R. Wisła, capital accumulation is the main channel through which savings and changes in the investment rate affect the trajectory of output until the economy reaches a steady state [9]; modern endogenous growth models add to this the channel of technological investment and investment in human capital as a source of long-term, not just transitory, growth.

Institutional channel determines the "rules of the game" – formal and informal norms that structure economic interaction: protection of property rights, contract enforcement, quality of the regulatory environment, efficiency of the judicial system, level of corruption, stability of economic policy [7]. D. Acemoglu and J. Robinson have shown that it is the inclusiveness of economic and political institutions (as opposed to extractive ones) that determines whether a country is able to transform technological and resource capabilities into sustainable growth of well-being [8]. Recent panel studies confirm this conclusion on current data: corruption control, accountability, and the rule of law statistically significantly explain cross-country differences in economic growth rates [20], and the decomposition of the channels of influence of institutions in 77 countries of the world for 2000–2020 shows that institutions transmit their effect on growth primarily through investment and trade channels, and not directly through total factor productivity [21], which empirically confirms the status of the institutional channel as a through-passage to the investment channel. Within the transmission circuit, the institutional channel differs from the previous three functionally: it does not generate an independent impulse so much as it determines the density and speed of impulse

transmission through all other channels - reducing (if the institutions are of high quality) or increasing (if they are weak) transaction costs of information exchange, conclusion of financial agreements and implementation of investment projects. This gives grounds to consider the institutional channel as a "second-order channel" (metachannel) in relation to information, finance and investment.

The analysis allows us to present the interaction of the four channels as a sequential-cyclical circuit. The primary impulse (policy decision, external shock, technological change) comes through the information channel, which forms the expectations of the subjects and reduces (or, conversely, increases) uncertainty. The adjusted expectations are transformed by the financial channel into a change in the cost and availability of capital. The change in financing conditions, in turn, is implemented by the investment channel in the form of actual capital accumulation, which determines the final impact on output, employment and welfare. The institutional channel acts through all three of the above links, acting as a regulator of their "bandwidth": the quality of institutions determines how fully the information signal is converted into a financial decision, and the financial decision into a real investment. At the same time, the circuit is not unidirectional: the results of investment activity (issue dynamics, borrower solvency) return to the financial channel in the form of changes in the quality of the loan portfolio and risk premiums, and to the information channel in the form of adjustments to expectations; the accumulation of successful experience in implementing contracts and protecting rights, in turn, strengthens trust in the institutional environment, forming a positive feedback loop, or, in the opposite scenario, an institutional trap of distrust. A schematic description of the transmission circuit is presented in Fig. 1.

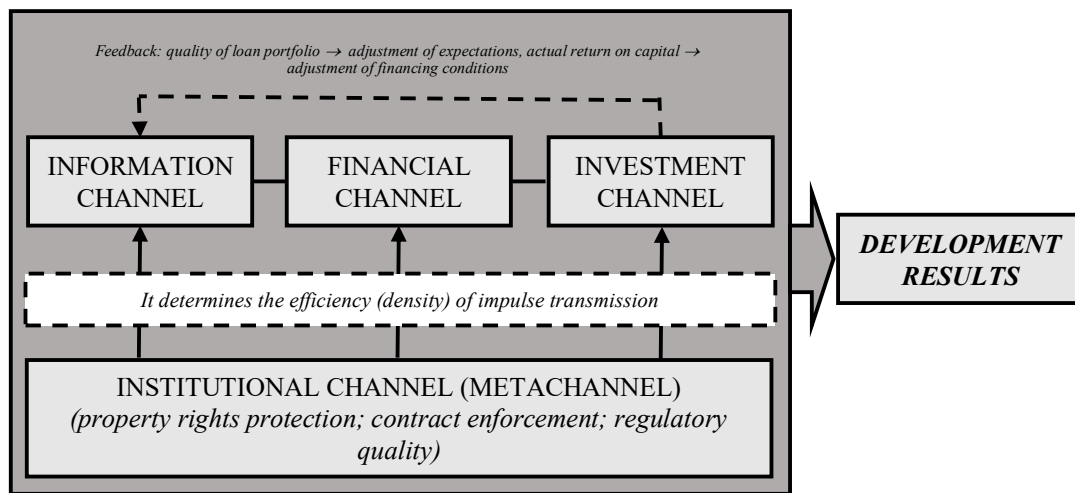


Fig. 1. Conceptual scheme of the interconnections of transmission channels of economic development

Source: developed by the authors

In Table 1, the structural cross-links between channels are summarized in the form of a matrix, where the rows correspond to the impulse source channel and the columns to the recipient channel.

Table 1

Matrix of cross-links of transmission channels of economic development

Channel-source \ Channel-recipient	Informational channel	Financial channel	Investment channel	Institutional channel
Informational channel	—	Reduction of risk premium, adjustment of cost of capital	Formation of investment expectations and planning horizon	Increasing transparency of regulatory decisions
Financial channel	Signals about the cost and availability of capital	—	Expansion/narrowing of access to credit resources	Discipline through market supervision and ratings
Investment channel	Data on actual return on capital, multiplier	Formation of collateral, cash flows, credit history	—	Formation of a request for protection of property rights
Institutional channel	Mandatory disclosure of information, reporting standards	Protection of the rights of creditors and investors, banking supervision	Guarantees of contract performance, permitting procedures	—

Source: compiled by authors based on [1; 2; 5; 7; 8]

This model allows you to diagnose "bottlenecks" in the transmission of economic policy: if, for example, a reduction in the discount rate (financial channel) does not translate into an increase in lending to the real sector, the reason should be sought not only in the financial channel per se, but also in the state of the institutional channel (weak protection of creditors' rights, unpredictability of court decisions) or the information channel (low trust in the

regulator's communication). For the Ukrainian economy during the post-war recovery period, this is of particular importance: the effectiveness of preferential lending programs, investment guarantees, and compensation mechanisms will be determined not only by the volume of allocated financial resources, but also by the synchronous operation of all four channels — the transparency and predictability of government decisions (information channel), the stability of the banking system (financial channel), the quality of investment projects and infrastructure (investment channel), and the reliability of property rights and contract protection, in particular for foreign investors (institutional channel). The scale of this task is confirmed by current assessments: according to a joint assessment of the World Bank, the Government of Ukraine, the European Union and the UN, the needs for the restoration and reconstruction of Ukraine over a 10-year horizon as of the end of 2024 amount to 524 billion USD, and direct physical damage to infrastructure and buildings reached 176 billion USD [22]; at the same time, the systematization of the architecture of post-war financing shows that its effectiveness is determined not only by the volume of resources involved (budget funds, donor grants, preferential loans from IFOs, private investments), but also by the synchronous work of all components - transparency of decisions, financial stability and institutional capacity [23].

To formalize the above-described impulse transmission circuit, a reduced-form analytical model has been developed that sequentially connects the four channels through a chain of functional dependencies and at the same time reflects the moderating role of the institutional channel. The model is built for discrete time t and is based on the following notations:

I_t is the quality index of the information channel (completeness, timeliness and transparency of information), $0 \leq I_t \leq 1$;

σ_t is the level of information uncertainty (information asymmetry) in the market;

r_t is the cost of capital (rate taking into account the risk premium), formed by the financial channel;

Q_t is the quality index of the institutional environment (protection of property rights, contract enforcement, regulatory quality), $0 \leq Q_t \leq 1$;

K_{td} is the demand for investment capital (investment channel);

L_{ts} is the supply of credit resources (financial channel);

K_t is the actual volume of implemented investments;

Y_t is the result of economic development (real output);

A_t, N_t are total factor productivity (exogenous) and the volume of labor resources involved;

$\alpha, \beta, \gamma, \varepsilon, \theta, \rho, \kappa, \lambda, \mu$ are positive parameters of the model reflecting the elasticities and sensitivities of the corresponding functional dependencies;

The information channel reduces subjective uncertainty according to a decreasing exponential dependence:

$$\sigma_t = \sigma_0 \cdot \exp(-\alpha \cdot I_t). \quad (1)$$

The financial channel translates information uncertainty into the cost of capital, while institutional quality directly reduces the risk premium:

$$r_t = r_f + \beta \cdot \sigma_t - \gamma \cdot Q_t. \quad (2)$$

Investment demand decreases with the cost of capital (with elasticity ε) and increases with the quality of the institutional environment:

$$K_{td} = K_0 \cdot A_t \cdot (1/r_t)^\varepsilon \cdot (1 + \rho \cdot Q_t). \quad (3)$$

The supply of credit resources (financial channel) is also a function of the cost of capital and institutional quality (due to the protection of creditors' rights):

$$L_{td} = L_0 \cdot (1 - r_t/r_{max}) \cdot (1 + \kappa \cdot Q_t). \quad (4)$$

The actual volume of realized investments is determined by the minimum of demand and supply of capital (credit constraint condition):

$$K_t = \min(K_{td}; L_{ts}). \quad (5)$$

The result of economic development is described by the Cobb–Douglas production function [10], extended by the institutional factor of total factor productivity:

$$Y_t = A_t \cdot K_t^\theta \cdot N_t^{1-\theta} \cdot (1 + \lambda \cdot Q_t). \quad (6)$$

Equations (1)–(6) formalize the sequential chain "information → expectations/uncertainty → cost of capital → investment → output", depicted in Fig. 1, and the terms with Q_t in each equation reproduce the through-effect of the institutional channel on each link. The cumulative (composite) effect of the primary information impulse on the final development result is obtained by sequentially applying the rule of differentiation of the composite function along the chain (1)–(3), (6), supplemented by a multiplicative institutional moderator of the entire circuit:

$$\partial Y_t / \partial I_t = Q_t^\mu \cdot \partial Y_t / \partial K_t \cdot \partial K_t / \partial \kappa_t \cdot \partial r_t / \partial \sigma_t \cdot \partial \sigma_t / \partial I_t. \quad (7)$$

Calculating the partial derivatives for each link and substituting them (assuming that investment demand is the determining constraint, $(K_t = K_{td})$) gives a compact reduced form:

$$\partial Y_t / \partial I_t = Q_t^\mu \cdot \theta \cdot \varepsilon \cdot \alpha \cdot \beta \cdot (\sigma_t \cdot Y_t) / r_t. \quad (8)$$

Equation (8) shows that the marginal effect of improving the information channel on the development outcome is positive and proportional to the product of the elasticities of all intermediate links $(\theta, \varepsilon, \alpha, \beta)$, as well as the ratio of current uncertainty to the cost of capital (σ_t / r_t) – that is, the effect is greatest precisely when uncertainty is high and the cost of capital is relatively moderate. The determinant role is played by the multiplier Q_t^μ : since $0 \leq Q_t \leq 1$, it performs the function of a "capacity valve" of the entire transmission loop. Under weak institutions ($Q_t \rightarrow 0$), the composite effect tends to zero regardless of the values of the remaining parameters – information, financial, or investment policy measures are not translated into real development. This formalizes the empirical observation of the "institutional trap": without a minimally acceptable quality of institutions, no improvement in other channels produces a sustainable effect. In contrast, under high institutional quality ($Q_t \rightarrow 1$), the (almost) full transmission potential embedded in the elasticities $\theta, \varepsilon, \alpha, \beta$ is realized.

The model has a dynamic development through the feedback loop depicted in Fig. 1: the quality of the information channel is updated according to the difference between the actual and expected development results:

$$I_{t+1} = I_t + \eta \cdot (Y_t - E_{t-1}[Y_t]). \quad (9)$$

where $\eta > 0$ is the learning rate parameter (adaptation of trust in the information channel according to the results of policy implementation);

$E_{t-1}[Y_t]$ is the expected development result based on the state of information at time $t - 1$.

A positive gap between the actual and expected outcome ("positive surprise") increases the quality of the information channel in the next period, which, according to equation (8), enhances the composite effect of the next transmission cycle, and vice versa. Thus, equations (1)–(9) reproduce in a formalized form the cyclical, rather than linear, nature of the interaction of the four channels (Fig. 1).

This model is a reduced analytical scheme: it abstracts from the dynamic optimization of economic agents and stochastic shocks, considering only deterministic functional dependencies between the average (expected) values of variables. It allows not to make precise empirical predictions, but to formalize the logic of channel interaction and substantiate a qualitative conclusion about the non-multiplicative, "threshold" role of the institutional channel. Empirical estimation of the parameters $\alpha, \beta, \gamma, \varepsilon, \theta, \rho, \kappa, \lambda, \mu, \eta$ for the economy of Ukraine is an independent direction of further research using econometric methods (in particular, vector autoregressive models and panel regressions based on regional or industry data).

CONCLUSIONS OF THE STUDY AND PROSPECTS FOR FURTHER RESEARCH IN THIS AREA

As a result of the study, the key elements of the four transmission channels of economic development were systematized. It was determined that the information channel forms expectations and reduces information asymmetry; the financial channel converts these expectations into the cost and availability of capital; the investment channel converts financial resources into real capital accumulation; the institutional channel performs the function of a metachannel, which determines the efficiency of transmitting impulses through all other channels through the protection of property rights, the execution of contracts, and the quality of regulation. It is substantiated that these channels form not a parallel, but a hierarchical-cyclical structure with direct and feedback connections, summarized in the proposed matrix of cross-interactions.

The proposed analytical (mathematical) model formalizes this circuit through the chain of functional dependencies "information → uncertainty → cost of capital → investment → output" and derives the composite elasticity of the impact of the information impulse on the final development result. Its key result is to prove the "threshold", rather than the additive role of the institutional channel: the composite effect of any improvements in the information, financial or investment channels is proportional to the institutional quality index to the power μ and tends

to zero with low quality of institutions regardless of the effectiveness of other channels, which formalizes the phenomenon of the "institutional trap".

Prospects for further research are related to the empirical verification of the proposed model, in particular, to the assessment of the elasticity of impulse transmission between channels based on econometric methods (vector autoregressive models, panel data), as well as to the adaptation of the model to the analysis of the transmission of recovery programs and post-war reconstruction of the Ukrainian economy.

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