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The Research of Comparative Characteristics and Functional Features of the Co-integration of Technological Innovations and Business Activity and their Impact on the Formation of Macroeconomic Dynamics

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ABSTRACTS

The **subject** of the study is the causal relationship between the co-integration of technological innovations and business activity, and their impact on the formation of macroeconomic dynamics in the short and long-term. The **purpose** of the paper is to propose a comprehensive approach to determining the conditions for the co-integration of technological innovations and business activity for their subsequent stimulation of economic growth. The practical examination of the impact of changes in the dynamics of complex indicators of creative development and commercial activity on economic growth is the research's scientific contribution and **novelty**. Using vector error correction models, modular root testing models and other econometric methods, the author demonstrated that both business activity and innovation stimulate economic growth in the long-term. In the short-term, there are strong causal relationships, but they are not always homogeneous. The main **conclusion** is the fact that the results obtained by the author confirm the correctness of using the approach of determining the order of integration and the presence/absence of co-integration between indicators of innovative development, business activity and economic growth. The summary results confirm the existence of a close long-term equilibrium relationship between innovation, business activity and economic growth.

Keywords: macroeconomic theory; economic growth; technological innovations; business activity; co-integration; macroeconomic dynamics

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INTRODUCTION

A dynamic entrepreneurial culture and a strong national innovation ecosystem are key catalysts for improving the socio-economic well-being of countries around the world. There are numerous studies examining the relationship between innovation, business activity and economic growth [1]. Although there is a theoretical understanding of the basics of these three variables' interactions, research indicates that the causal relationships among them are properly complex and are supported by factors impacting them. Research on the microeconomic foundations (entrepreneurship) of macroeconomics (innovation and growth) continues to evolve, and factors that define the underlying structure of the economy continue to be the subject of discussion and research [2]. Within the framework of the new growth theory of macroeconomics, there is a popular belief that long-term economic growth is determined by technological progress supported by investments in human capital, research and innovation activity [3].

At the same time, there are also extensive studies that show that entrepreneurial culture is crucial to creating a dynamic economic environment that is capable of attracting capital, creative talent, networking and other resources to stimulate innovation and economic growth. Many important conclusions can be highlighted in which the authors examine the relationship between business activity, the national innovation ecosystem, and the increasing impact of other traditional factors of production on economic growth [3]. According to these studies, business contributes to the economy through a number of directions, including investment in resources to produce goods and services that satisfy market demands; job creation; revitalization of industrial clusters, creation of innovation accelerators and special economic regions; development and maintenance of regional trade and cooperation; investment in research; introduction of new market innovations; corporate social responsibility; increasing competition in the market, leading to improved service quality and cost structure; and continuous improvement of products and processes. The authors of the above-mentioned studies also show that large firms benefit from a well-developed network of suppliers consisting of small firms that provide cost-effective, timely and high-quality services. The interactions of these economic agents result in the formation of strong industrial clusters and economic regions, which improve the national economy's competitiveness. As noted by M. Porter [4], strong clusters are increasingly becoming an important basis for the formation of global supply chains, which contribute to improving the economic performance and competitiveness of firms, regions and states.

Based on the effective "spillover effects" of business activity, most of the world's advanced governments have invested significantly in company development and strengthening innovative ecosystems [5]. The most illustrative example here is the experience of the European Union presenting a 10-year plan in 2010,[1] to promote "smart", sustainable and inclusive economic growth in the eurozone [6]. According to this document, "smart" growth is defined as "development of a knowledge- and innovation-based economy"; sustainable growth as "contributing to a more resource-efficient, environmentally friendly and competitive economy"; and inclusive growth as "contributing to an economy with a high level of employment that provides social and territorial integration" [6, 7]. Furthermore, according to the plan, business activity and innovation are key to sustainable economic growth, job creation and an improved quality of life in Europe.

At the same time, despite numerous theoretical and empirical studies in which authors demonstrate the relationship between innovation, business activity, and economic growth, very few studies have quantified the endogenous relationship between these variables using appropriate econometric

[1] A Sustainable Europe by 2030. European Commission. URL: https://commission.europa.eu/publications/sustainable-europe-2030_en (accessed on 14.07.2023).

analysis, specifically to assess the direction of the cause-and-effect relationship between those variables in the short- and long-term dynamics. Consequently, the main objective of this article is to study an integrated approach to defining the conditions for the co-integration of technological innovations and business activity in order to stimulate their economic growth. Another purpose is to try to identify the macroeconomic implications of the results obtained.

THEORETICAL AND METHODOLOGICAL ANALYSIS AND HYPOTHETICAL BASES OF RESEARCH

According to macroeconomic theory, the concepts "innovation" and "business activity" have a wide range of definitions. In particular, J. Schumpeter [8, 9] identified five different types of innovation: the introduction of new products and services; the implementation of new methods that lead to process improvement; the entry into new and diverse markets; the acquisition of new sources of resources for the production of goods and services, and the establishment of new business models and industrial systems that prevent the formation of monopolistic market structures. Although the characteristics given by J. Schumpeter cover several types of innovation, the definition of innovation has not changed much during this time. Next, consider the M.D. Plessis definition [10], which describes innovation as "creating new knowledge and ideas to promote new business results aimed at improving internal business processes and structures and creating market-oriented products and services". Thus, as certain types of innovation change over time because of their very nature, the idea of innovation remains fundamentally the same.

The entrepreneur is often recognized as the primary driver of corporate activity. There are numerous definitions and explanations of entrepreneurs in macroeconomic theory. According to J. Schumpeter's definition [8, 9], an entrepreneur is defined as someone who carries out manufacturing processes using numerous possible combinations, providing him with a strategic market advantage and allowing him to generate entrepreneurial profit. Further, F. Knight [11] describes an entrepreneur as a person who assumes "assumed risks" and turns uncertain ventures into productive results. H. Leibenstein [12] characterizes entrepreneurs as "...institutions that create a dynamic corporate culture that contributes to reducing organizational entropy and inefficiency". The definition of individual modern researchers is interesting. In particular, D. Salman [13] defines an entrepreneur as "...an innovator inclined to risk, who contributes to economic growth by undertaking creative efforts to produce new products and services that will enable the enterprise to compete in international markets". In his research, R. Seymour [14] notes that entrepreneurship is often directed by professional managers, not "entrepreneurs", and that companies themselves can be entrepreneurial.

Since the introduction of the R. Solow growth model [15, 16] in the 1950s, the role of technical innovation in economic growth has received significant attention. Developing his concept and based on the theoretical model of R. Solow, P. Romer [3] introduced the endogenous growth model, which showed that investments in human capital led to the dissemination of knowledge and technological substitution, and all of this together contributes to economic growth. Later, J. Schmitz [17] improved the endogenous growth model by incorporating the role of employees and entrepreneurs in creating economic wealth. Calculations based on this model showed that the growth of entrepreneurship in the economy creates additional resources for economic growth. The J. Schmitz model was further expanded by C. Michelacci [18], who included two types of economic agents — researchers and entrepreneurs, which are necessary to stimulate innovation and economic growth. According to C. Michelacci, the primary role of researchers is to create inventions, whereas the role of entrepreneurs is to obtain commercial benefits from these inventions. C. Michelacci's model

demonstrates that supporting entrepreneurship to utilize the business value of research may increase innovation and thus economic growth. In addition, Z. Acs and S. Estrin [19] proposed a theory of knowledge distribution in their collaborative research, demonstrating that economic agents that acquire new knowledge through research and other innovative activities prefer to use opportunities to extract value from that knowledge. This theory suggests that the economic benefits of the "spillover effects of knowledge dissemination" will lead to the activation of entrepreneurship. In a number of other similar studies, the authors showed that entrepreneurship is crucial to stimulating innovation and economic growth.

ANALYSIS OF MACRODYNAMIC EVALUATION METHODOLOGY OF ENDOGENIC RELATIONS BETWEEN INVESTED INDICATORS

As noted above, although the relationship between innovation, business activity and economic growth has been studied, there is still no consensus on the causal relationship between them. Moreover, empirical studies of these relationships typically use a two-dimensional model and therefore consider only two of these variables at any given time. In the present study, an advanced two-dimensional model is used for the macrodynamic evaluation between all three variables by the author using the Granger causality panel tests. Given the simultaneous consideration of all three variables, the author's model enables two important macroeconomic aspects of economic growth to be covered: firstly, the impact of public policy aimed at stimulating innovation, in the presence (i.e. taking into consideration) business activity; secondly, influence of public policy designed to stimulate business activity when there are (i.e. taking into consideration) innovations. Furthermore, the use of long-term time series data (2000–2018) allows us to explore the short-term and longer-term interactions between the three variables. The survey is conducted for 20 eurozone countries using annual time series data from the annual World Economic Situation and Prospects[2] and Global Entrepreneurship Monitor.[3] The following indicators are included in the model for analysis: real per capita economic growth (REG_{pc}) and seven different indicators of innovative development ($INNODEV$): number of patent applications submitted by both residents and non-residents (per thousand population) ($PATAPPL$); number of trademark applications by both residents and non-residents (per thousand population) ($TMAPPL$); number of R&D researchers (per thousand population) ($RAND$); number of publications in scientific and technical journals (per thousand population) ($PSTJ$); R&D expenditure (in percentage of GDP) ($RANDE$); volume of exports of high-tech products and services (in percentage of GDP) ($HTEX$); consolidated index of innovation development ($TIINNODEV$), which represents the weighted average of all seven innovation development indicators.

With reference to the research on the Granger causality relationship between innovation, business activity, and economic growth, the inclusion of all seven indicators in the model could indicate a representative aspect of innovation development. Similarly, the importance of individual indicators of innovation varies from study to study. For example, R. Pradhan [20] considers that the number of patent applications (release rate) and R&D expenditure (cost rate) are important in regulating long-term economic growth in high-income OECD countries, but T. Brenner [21] suspects that publications in scientific and technical journals (rule rate) and R&D expenditure (custom rate) are important in regulating long-run economic growth in the group of developed and developing countries. For business activity (BA) in this model, the author uses three indicators, expressed as a percentage of the population aged 18 to 64. Total early-stage

[2] World Economic Situation and Prospects. URL: https://www.un.org/development/desa/dpad/publication/world-economic-situation-and-prospects (accessed on 14.07.2023).

[3] Global Entrepreneurship Monitor (GEM). URL: https://www.gemconsortium.org/report/50213 (accessed on 14.07.2023).

business activity ($TBAI$) takes into account the percentage of the population who are either start-up entrepreneurs or owners-managers of a new business. Potential business activity (PBA) is the percentage of the population that believes that they have the necessary skills and knowledge to start a business. Finally, the Local Business Activity Index (LBA) takes into account the percentage of people who believe that there are good opportunities to start a business in the area where they live. The present study examines three samples and seven cases based on three business activity indicators and seven innovation indicators. All variables are measured at constant prices of 2000 in USD. To normalize these variables, they are converted into natural logarithms. The set of dynamic panel regressions is measured according to the following equations:

$$\Delta REG_{pcit} = \mu_{1j} + \sum_{n=1}^{\delta} \psi_{1in} \Delta REG_{pc_{it-n}} + \sum_{n=1}^{\theta} \Delta INNODEV_{it-n} + \sum_{n=1}^{d} \eta_{1ik} \Delta BA_{it-n} + \varphi_{1i} ECT_{it-1} + \varepsilon_{1it}, \quad (1)$$

$$\Delta INNODEV_{it} = \mu_{2j} + \sum_{n=1}^{\delta} \psi_{2in} \Delta INNNODEV_{it-n} + \sum_{n=1}^{\theta} \rangle_{2in} \Delta REG_{pcit-n} + \sum_{n=1}^{d} \eta_{2ik} \Delta BA_{it-n} + \varphi_{2i} ECT_{it-1} + \varepsilon_{2it}, \quad (2)$$

$$\Delta BA_{it} = \mu_{3j} + \sum_{n=1}^{\delta} \psi_{3in} \Delta BA_{it-n} + \sum_{n=1}^{\theta} \rangle_{3in} \Delta INNODEV_{it-n} + \sum_{n=1}^{d} \eta_{3ik} \Delta REG_{pcit-n} + \varphi_{3i} ECT_{it-1} + \varepsilon_{3it}, \quad (3)$$

where Δ — first multiplier operator; i — country; t — period, and ε — random error. Innovative development $INNODEV$ is defined by the variable $PATAPPL$, $TMAPPL$, $RAND$, $PSTJ$, $RANDE$, $HTEX$, and $TIINNODEV$; and business activity (BA) is determined by variables $TBAI$, PBA and LBA. In addition, δ, θ and d are delayed durations for differential variables of corresponding equations and can be determined by the Engle-Granger equation. Equations with delayed correction of (ECT_{it-1}) errors are derived from long-term equilibrium properties inherent in equations (1)–(3). Equations with delayed error correction (ECT) represent long-term dynamics, while differential variables represent short-term. For short-term cause-and-effect relationships, if the zero hypothesis ϱ_{1in}, ϱ_{2in} *или* ϱ_{3in} is rejected, then there is a Granger causality relationship directed from the $INNODEV$ variable to the REG_{pc} variable (or from REG_{pc} to $INNODEV$). If the co-zero hypothesis $\varrho_{1in} = 0$, $\varrho_{2in} = 0$ *или* $\varrho_{3in} = 0$ is deviant, then there is a Granger causality relationship from the variable BA to REG_{pc} (or from REG_{pc} к BA). To confirm long-term causal relations, the zero hypothesis ($\varphi_{1i} = 0$, $\varphi_{2i} = 0$ and $\varphi_{3i} = 0$) must be rejected. The above tests are performed using the Wald test.

EMPIRICAL ANALYSIS OF THE RESULTS OF THE EVALUATION OF THE INVESTIGATED INDICATORS' CO-INTEGRATION

As already mentioned, the (VECM) is used in this study to explore possible Granger causality relationships between innovation, business activity and economic growth. The first step involves determining the order of integration and the presence/absence of co-integration between the three sets of variables. For this purpose, three panel modular root tests are used, namely the Levin-Lin-Chu test, the advanced Dickey-Fuller test and the Phillips-Perron test, to determine the order of integration of variables in our panel. The summary results of these tests show that all variables are integrated in the first order (see *Appendix, Table. 1*). The results indicate the possibility of integrating innovation, business activity, and economic growth. Furthermore, the Johansen panel co-integration test is used to evaluate the hypothesis that these three sets of data have a long-term relationship. The results of this test confirm the existence of a long-term balanced relationship between innovation, business activity and economic growth in all three samples and in seven cases within each sample (see *Appendix,*

Table 2). The results confirm the correctness of using the vector error correction model to identify possible Granger causality relationships between innovation, business activity and economic growth (see *Appendix, Table 3*). This table presents the long-term results of the Granger causality relationships, which are determined by determining the statistical significance of coefficients (ECT_{it-1}). It was found that when REG_{pc} is a dependent variable, the error correction delay coefficients (ECT) are statistically significant at the level of 1%. This indicates that, as a result of developments in both innovation and business activity, economic growth is approaching its long-term balancing trajectory. It is important to note that this is true for all of the situations in this sample (see *Appendix, Table 3*).

The above arguments support the hypothesis that both innovation and business activity have a significant influence on economic growth in eurozone countries. The consequence of this unambiguous conclusion is that it is essential to promote both innovation and business to stimulate long-term economic growth. However, short-term results are not always the same (see *Appendix, Table 4*). They show the heterogeneity of the Granger causality relationships and demonstrate that the dynamics of the short-time adjustment differ in the three samples and seven cases. *Table 4 of the Appendix* on the correlation between economic growth and innovation shows that 16 out of 21 cases confirm the feedback hypothesis, whereas four cases confirm supply economy 1 and one case confirms neutrality 4. As far as the relationship between economic growth and business activity is concerned, 11 out of 21 cases confirm hypothesis 1, based on the economy of supply, six cases confirm hypothesis 2, based on the demand economy, and four cases confirm the author's researched hypothesis 3, which testifies to feedback. Finally, as far as the relationship between innovation and business activity is concerned, the results show that in six out of 21 cases hypothesis 2 based on demand economy is confirmed, in eight cases hypothesis 1 based on supply economy, in five cases hypothesis 3 based on feedback, and in two cases, hypotheses 4 based on neutrality are confirmed.

Although short-term results are not always the same and sometimes depend on approaches to the definition of innovation and business activity, even in the short-term dynamics, important causal links between variables are revealed. In other words, hypothesis 4, which indicates neutrality, is confirmed in very few cases. This includes a short-term link between innovation and business activity, where factual evidence indicates a strong short-term link between these two variables. The general conclusion must therefore be that there are many short-term changes between variables. Moreover, all the long-term dynamics point to the same result, namely that innovation and business are key factors in economic growth. The author additionally conducted many more experiments to guarantee the reliability of the results. The formal requirements for publication greatly limit the scope of the article and do not allow full disclosure of the details of the test checks, and here are only the results. So, the results show the following. First, fully modified assessments of the least squares method (LSM) and dynamic LSM show that both innovation and business activity have a positive impact on economic growth. Secondly, the order of the vector error correction model has been changed. There were no significant changes compared to the previous results presented in *Table 3* of the *Appendix*. Thirdly, the method of generalized decomposition of forecast error dispersion (GFEVDs) based on generalized pulse characterization functions similar to Lanne-Newberg was used to verify the accuracy of the causality relationship between innovation, business activity and economic growth. The dispersion decomposition shows the expected percentage change of the dependent variable, explained by the expected percent changes of the independent variables on the forecast horizon beyond the sample period of the study. One of the greatest advantages of this approach, similar to the orthogonalized decomposition of the forecast error dispersion, is that it is insensitive

to the order of variables, since the order is unambiguously determined by the VAR system. Furthermore, the generalized decomposition approach of the forecast error dispersion assesses the simultaneous impact of shocks on variables; for example, it describes different degrees of shock caused by innovation and business activity for economic growth. The estimates obtained from this approach support the argument that in the eurozone countries, innovation and business activity will continue to influence economic growth over a long period of time.

CONCLUSION

The results of this study, based on the example of eurozone countries, show that the long-term and short-term impact of innovation and business activity on economic growth is obvious. They promote long-term economic growth despite the heterogeneity of short-term results. Although, even the short-term dynamics, there are strong endogenous links between innovation, business activity and economic growth, all three variables are closely interrelated. Thus, as a priority measure of a macroeconomic nature that the Government of the Russian Federation must take, it can be identified to stimulate innovation and business activity in order to take advantage in the short-term of the obvious causality relationships between these variables. Furthermore, regardless of how we define these variables, promoting innovation and business is a long-term strategy.

Thus, the empirical results obtained from the study of the experiences of the eurozone countries support the idea that long-term economic growth in the Russian Federation will depend on a carefully organized national innovation ecosystem that promotes both a dynamic business culture and an innovative climate in all regions. Strong support for innovation and business activity will boost the competitiveness of the economy's existing sectors, and the combination of these two variables will result in the formation of new sources of economic growth.

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APPENDIX

Table 1

Summary Table of Empirical Results of Levin-Lin-Chu, Dickey-Fuller, Phillips-Perron Panel Tests Between Sets of Variables of Innovative Development, Business Activity and Economic Growth

Variables name	Test results					
	Indicators of the differential of the first order			Level indicators		
	Levin-Lin-Chu test	Dickey-Fuller test	Phillips-Perron test	Levin-Lin-Chu test	Dickey-Fuller test	Phillips-Perron test
TBAI	–13.932	151.632	234.9	0.65988	11.664	21.924
PBA	–15.336	154.332	226.692	–0.5292	15.012	17.604
LBA	–11.232	115.02	166.428	0.7344	12.9276	14.0292
PATAPPL	–11.124	135.756	206.604	0.96012	26.244	26.892
TMAPPL	–8.64	125.388	181.548	–0.864	17.604	93.852
RAND	–6.7068	91.692	160.704	–0.4104	20.736	148.824
PSTJ	–4.2984	52.596	90.5904	–0.9288	11.448	137.808
RANDE	–7.2144	92.664	159.732	1.3824	18.252	49.896
HTEX	–10.0656	144.396	195.804	0.5832	17.928	65.016
INNODEV	–5.3028	78.3	46.7748	1.2636	17.064	11.556
REG_{pc}	–19.872	300.996	414.072	0.7884	22.248	30.348

Source: Author's calculations based on statistical data obtained from annual surveys on world economic development and global monitoring of business activity. World Economic Situation and Prospects. URL: https://www.un.org/development/desa/dpad/publication/world-economic-situation-and-prospects (accessed on 14.07.2023). Global Entrepreneurship Monitor (GEM). URL: https://www.gemconsortium.org/report/50213 (accessed on 14.07.2023).

Table 2

Summary Table of Empirical Results of the Panel Test for the Presence/Absence of Cointegration Between Individual Variables of Innovative Development, Business Activity and Economic Growth

Indicator of availability of cointegration	Case 1 ($PATAPPL$)		Case 2 ($TMAPPL$)		Case 3 ($RAND$)		Case 4 ($PSTJ$)		Case 5 ($RANDE$)		Case 6 ($HTEX$)		Case 7 ($INNODEV$)	
	Track statistics	Statistics of the maximum value	Track statistics	Statistics of the maximum value	Track statistics	Statistics of the maximum value	Track statistics	Statistics of the maximum value	Track statistics	Statistics of the maximum value	Track statistics	Statistics of the maximum value	Track statistics	Statistics of the maximum value
Sample 1: REG_{pc}, $TBAI$, $INNODEV$														
No one	139.6	122.31	108.25	105.40	122.45	107.8	149.92	123.66	110.35	95.81	179.61	149.45	139.67	108.32
Max. 1	49.23	44.68	29.52	26.17	71.33	61.76	90.09	68.04	54.32	45.64	68.92	55.87	55.43	61.34
Max. 2	25.13	25.13	18.72	18.72	39.87	39.87	52.34	52.34	35.98	35.98	41.54	41.54	44.98	45.88
Number of co-integrated vectors	2		2		3		3		3		3		3	
Sample 2: REG_{pc}, PBA, $INNODEV$														
No one	129.87	111.35	111.00	99.63	121.33	98.54	89.75	75.13	112.68	97.12	179.86	149.17	139.48	109.66
Max. 1	30.13	25.44	81.53	63.98	64.71	53.14	34.03	36.95	53.59	44.22	67.53	54.41	52.85	60.51
Max. 2	20.46	20.46	47.16	47.16	37.48	37.48	6.99	6.99	37.79	37.79	42.30	42.30	46.35	46.35
Number of co-integrated vectors	2		3		3		2		3		3		3	
Sample 3: REG_{pc}, LBA, $INNODEV$														
No one	35.78	31.07	132.95	112.77	106.80	87.54	108.24	91.82	95.02	77.60	156.31	128.78	114.61	85.24
Max. 1	22.54	20.66	52.16	46.82	71.53	57.46	74.32	70.51	64.52	60.35	68.15	59.38	60.84	50.94
Max. 2	10.56	10.56	27.98	27.98	40.36	40.36	56.27	56.27	33.87	33.87	33.98	33.98	42.28	42.28
Number of co-integrated vectors	1		3		3		3		3		3		3	

Source: Author's calculations based on statistical data obtained from annual surveys on world economic development and global monitoring of business activity. World Economic Situation and Prospects. URL: https://www.un.org/development/desa/dpad/publication/world-economic-situation-and-prospects (accessed on 14.07.2023). Global Entrepreneurship Monitor (GEM). URL: https://www.gemconsortium.org/report/50213 (accessed on 14.07.2023).

Table 3

Summary Table of Empirical Results of the Granger Causality Panel Test

Indicator of variables	Case 1 (PATAPPL)				Case 2 (TMAPPL)				Case 3 (RAND)				Case 4 (PSTJ)			
	ΔREG_{pc}	$\Delta TBAI$	$\Delta PATAPPL$	ECT_{it-1}	ΔREG_{pc}	$\Delta TBAI$	$\Delta TMAPPL$	ECT_{it-1}	ΔREG_{pc}	$\Delta TBAI$	$\Delta RAND$	ECT_{it-1}	ΔREG_{pc}	$\Delta TBAI$	$\Delta PSTJ$	ECT_{it-1}
ΔREG_{pc}	–	7.3	7.2	–0.76	–	7.3	3.9	–0.23	–	7.5	10.5	–0.23	–	6.8	35.1	–0.23
$\Delta TBAI$	0.8	–	7.8	–0.09	2.4	–	10.2	–0.08	4.01	–	2.02	–0.03	2.46	–	2.13	–0.09
$\Delta INNODEV$	2.9	4.3	–	–0.14	2.1	2.1	–	–0.16	11.2	3.68	–	–0.1	72.8	3.8	–	–0.1
Sample 2: $REG_{pc}, PBA, INNODEV$																
ΔREG_{pc}	–	12.8	15.6	–0.15	–	9.42	3.13	–0.17	–	4.2	6.34	–0.16	–	5.23	45.3	–0.22
ΔPBA	2.87	–	3.14	–0.06	2.85	–	0.52	–0.09	3.1	–	3.96	–0.05	2.01	–	4.01	–0.05
$\Delta INNODEV$	7.26	8.41	–	–0.23	3.42	1.02	–	–0.26	6.82	4.24	–	–0.08	49.4	6.95	–	–0.11
Sample 3: $REG_{pc}, LBA, INNODEV$																
ΔREG_{pc}	–	1.87	13.08	–0.10	–	2.45	4.09	–0.13	–	1.01	6.06	–0.12	–	4.12	46.7	–0.13
ΔLBA	2.87	–	2.23	–0.26	6.17	–	5.01	–0.39	4.14	–	2.11	–0.42	2.42	–	7.24	–0.06
$\Delta INNODEV$	9.13	6.02	–	–0.19	2.14	1.35	–	–0.15	9.53	4.51	–	–0.06	78.32	2.06	–	–0.19

Table 3 (continued)

Indicator of variables	Case 5 (RANDE)				Case 6 (HTEX)				Case 7 (INNODEV)			
	ΔREG_{pc}	$\Delta TBAI$	$\Delta PA\ TAPPL$	ECT_{it-1}	ΔREG_{pc}	$\Delta TBAI$	$\Delta TM\ APPL$	ECT_{it-1}	ΔREG_{pc}	$\Delta TBAI$	$\Delta RAND$	ECT_{it-1}
ΔREG_{pc}	–	2.99	27.5	–0.09	–	5.7	6.62	–0.23	–	5.31	8.15	–0.21
$\Delta TBAI$	1.97	–	3.92	–0.08	3.12	–	3.86	–0.09	1.02	–	5.75	–0.14
$\Delta INNO\ DEV$	9.65	2.13	–	–0.03	5.91	2.9	–	–0.2	6.62	5.97	–	–0.32
Sample 2: $REG_{pc}, PBA, INNODEV$												
ΔREG_{pc}	–	7.25	8.09	–0.14	–	14.3	11.7	–0.15	–	7.54	14.7	–0.12
ΔPBA	9.05	–	0.91	–0.16	7.94	–	3.03	–0.17	5.05	–	3.36	–0.11
$\Delta INNO\ DEV$	24.7	6.08	–	–0.09	5.96	2.84	–	–0.08	40.5	5.16	–	–0.68
Sample 3: $REG_{pc}, LBA, INNODEV$												
ΔREG_{pc}	–	3.12	7.68	–0.09	–	3.05	6.17	–0.10	–	2.23	11.87	–0.09
ΔLBA	6.26	–	5.09	–0.41	5.01	–	2.1	–0.40	5.91	–	4.98	–0.19
$\Delta INNO\ DEV$	28.31	3.26	–	–0.13	3.39	2.03	–	–0.10	39.04	2.04	–	–0.69

Source: Author's calculations based on statistical data obtained from annual surveys on world economic development and global monitoring of business activity. World Economic Situation and Prospects. URL: https://www.un.org/development/desa/dpad/publication/world-economic-situation-and-prospects (accessed on 14.07.2023). Global Entrepreneurship Monitor (GEM). URL: https://www.gemconsortium.org/report/50213 (accessed on 14.07.2023).

Table 4

Summary Table of Results of Granger's Short-Term Causal Relationship

Sample number	Sequence of cases	Directions of interaction between variables		
		INNODEV and ***BA***	***INNODEV*** and ***REG$_{pc}$***	***BA*** and ***REG$_{pc}$***
1	1	$PATAPPL \leftrightarrow TBAI$	$PATAPPL \rightarrow REG_{pc}$	$TBAI \rightarrow REG_{pc}$
	2	$TMAPPL \rightarrow TBAI$	$TMAPPL \rightarrow REG_{pc}$	$TBAI \rightarrow REG_{pc}$
	3	$RAND \leftarrow TBAI$	$RAND \leftrightarrow REG_{pc}$	$TBAI \rightarrow REG_{pc}$
	4	$PSTJ \leftarrow TBAI$	$PSTJ \leftrightarrow REG_{pc}$	$TBAI \rightarrow REG_{pc}$
	5	$RANDE \rightarrow TBAI$	$RANDE \leftrightarrow REG_{pc}$	$TBAI \rightarrow REG_{pc}$
	6	$HTEX \leftrightarrow TBAI$	$HTEX \leftrightarrow REG_{pc}$	$TBAI \rightarrow REG_{pc}$
	7	$TIINNODEV \leftrightarrow TBAI$	$TIINNODEV \leftrightarrow REG_{pc}$	$TBAI \rightarrow REG_{pc}$
2	1	$PATAPPL \leftarrow PBA$	$PATAPPL \leftrightarrow REG_{pc}$	$PBA \leftrightarrow REG_{pc}$
	2	$TMAPPL \varnothing PBA$	$TMAPPL \varnothing REG_{pc}$	$PBA \rightarrow REG_{pc}$
	3	$RAND \leftrightarrow PBA$	$RAND \leftrightarrow REG_{pc}$	$PBA \rightarrow REG_{pc}$
	4	$PSTJ \leftrightarrow PBA$	$PSTJ \leftrightarrow REG_{pc}$	$PBA \rightarrow REG_{pc}$
	5	$RANDE \leftarrow PBA$	$RANDE \leftrightarrow REG_{pc}$	$PBA \leftrightarrow REG_{pc}$
	6	$HTEX \leftarrow PBA$	$HTEX \leftrightarrow REG_{pc}$	$PBA \leftrightarrow REG_{pc}$
	7	$TIINNODEV \leftarrow PBA$	$TIINNODEV \leftrightarrow REG_{pc}$	$PBA \leftrightarrow REG_{pc}$
3	1	$PATAPPL \leftarrow LBA$	$PATAPPL \leftrightarrow REG_{pc}$	$LBA \leftarrow REG_{pc}$
	2	$TMAPPL \rightarrow LBA$	$TMAPPL \rightarrow REG_{pc}$	$LBA \leftarrow REG_{pc}$
	3	$RAND \leftarrow LBA$	$RAND \leftrightarrow REG_{pc}$	$LBA \leftarrow REG_{pc}$
	4	$PSTJ \rightarrow LBA$	$PSTJ \leftrightarrow REG_{pc}$	$LBA \rightarrow REG_{pc}$
	5	$RANDE \rightarrow LBA$	$RANDE \leftrightarrow REG_{pc}$	$LBA \leftarrow REG_{pc}$
	6	$HTEX \varnothing LBA$	$HTEX \rightarrow REG_{pc}$	$LBA \leftarrow REG_{pc}$
	7	$TIINNODEV \rightarrow LBA$	$TIINNODEV \leftrightarrow REG_{pc}$	$LBA \leftarrow REG_{pc}$

Source: Author's calculations based on statistical data obtained from annual surveys on world economic development and global monitoring of business activity. World Economic Situation and Prospects. URL: https://www.un.org/development/desa/dpad/publication/world-economic-situation-and-prospects (accessed on 14.07.2023). Global Entrepreneurship Monitor (GEM). URL: https://www.gemconsortium.org/report/50213 (accessed on 14.07.2023).