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Article

Computational Modelling of Equilibrium Growth and Sustainable Development in Kazakhstan's Financial and Insurance Activities

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Abstract: It is known that the input-output model is based on the balance of inter-industry linkages, however, these conditions do not ensure equilibrium transactions among its agents, both producers and consumers. To address this issue, this work focuses on creating, justifying, and computational models for determine equilibrium transactions within the platform industry and ecosystems of Kazakhstan's financial and insurance activities industry. The research employs a conceptual design for computational models, integrating input (produce/selling, payments, imports) and output (purchase/buying, final demand, exports) transactions to analyze equilibrium growth in platform industries and ecosystems using OECD data from Kazakhstan's statistics (1995–2018). The main results of this study include computational models for determine equilibrium within the platform industry and its ecosystems of Kazakhstan's financial and insurance activities. Their application involves identifying time phases of undervalued and overvalued transactions, classifying time phases by their alignment with equilibrium transactions within the domain of feasible solutions, and analyzing the dynamics of equilibrium growth, enabling more efficient resource allocation and promoting sustainable growth for the industry and its ecosystem.

Keywords: computational models; equilibrium growth; sustainable development; financial and insurance activities; Kazakhstan

1. Introduction

The incorporation of intelligent systems and sophisticated econometric models into the insurance and financial sectors has accelerated in recent years, driven by advancements in IoT, cloud computing, and machine learning. For example, Yu et al [1] developed a hierarchical game model to optimize job offloading in IoT-Edge-Cloud systems, while Zhang et al [2] introduced a blind post-decision state-based reinforcement learning (b-PDS) to improve decision-making efficacy. Furthermore, Huang [3] highlighted the relevance of IoT in enhancing logistics systems, demonstrating its capacity to improve efficiency within financial ecosystems.

The importance of sustainable development and balanced growth in the financial and insurance sectors of Kazakhstan has been extensively discussed. Daniya and Tang [4] studied the impact of

green finance on the transition to a low-carbon economy, and Serkebayeva et al [5] analyzed liquidity issues in country's stock market.

The insurance industry has also attracted the attention of researchers. Tasdemir and Alsu [6] analyzed the relationship between insurance activity and economic growth in G-20 countries, while Ahn and Park [7] showed the impact of corporate social responsibility (CSR) in the insurance sector on sustainable development. In addition, Avazov et al [8] noted the important role of investment activities in the insurance sector in shaping financial markets.

Technological advances are a significant factor in the development of financial analysis and decision-making processes. Lei et al [9] and Chou et al [10] proposed intelligent systems based on machine learning methods and metaheuristic optimization to improve the accuracy of financial forecasting results. The results achieved in this area were deeply studied in the scientific papers of Zhong and Fan [11] using cloud algorithms for optimizing corporate financial decisions, while Chen [12] was able to improve the accuracy by using the association rule search method in processing big data in the financial direction.

In this regard, the research below provides important concepts for developing the methods for studying equilibrium and growth models. Balbus et al [13] in their studies analyzed models of economic growth that take into account the interests of society and are based on mutual support among society, while Georgescu and Zhang [14] studied the long-term stability and coexistence of several economic agents or systems in logistic growth models. Thus, Jung [15], using a general equilibrium model, studied changes in the labor market from the perspective of the impact of skill diversity and skill levels of the workforce.

The extensive ramifications of these advances are seen in Shinozaki's research [16] regarding the influence of digital finance on small enterprises amid economic instability. Guo [17] and Liu [18] augmented the literature by introducing interactive systems for financial data analysis, highlighting real-time decision support.

The work of Balbus et al [13] on intergenerational growth and Svoboda and Fischer [19] on non-equilibrium thermodynamic models extends these frameworks to dynamic systems analysis. Both of these studies concern the analysis of dynamic systems. Last but not least, Li [20] and Zhong and Fan [11] demonstrated the significance of big data and genetic algorithms in the realm of financial control and investment decision-making, underlining the fact that these technologies are applicable to countries ever-evolving capital market environment.

More advanced computational methods and data-driven methodologies will make intelligent systems increasingly valuable for assessing the scope of balanced development of the insurance and financial sectors. Since financial systems are inherently complex and volatile, effective decision-making approaches must combine technical and economic knowledge. When asked about ways to improve operational efficiency and allocate resources more effectively, they mentioned deep learning and clustering. Several studies have investigated these intersections, providing both practical frameworks and theoretical advances. For example, Wang [21] and Song et al [22] demonstrated how intelligent analysis frameworks based on project and engineering management can optimize decision-making for regional economic development, emphasizing the utility of clustering algorithms and deep learning techniques in improving operational efficiency and resource allocation. Similarly, Farooq et al [23] employed input-output analysis to estimate the economic impact of Intelligent Transportation Systems (ITS), giving a methodology that may be adapted to financial ecosystems for assessing inter-industry effects [20].

To address the potential financial effects of renewable energy on profitability and operational expenditures, Suresh and Jagatheeswari [24] developed a smart grid-based hybrid intelligent optimization system. Consistent with the findings of Li's [20] study on financial big data control, this provides support for the notion that intelligent systems ought to be included in economic and environmental decision-making. Zhang et al [25] extended the employment of hybrid models by examining economic data using Long Short-Term Memory (LSTM) networks and showing that their predicted accuracy was better than that of conventional approaches like ARIMA and SVM.

Moreover, Deshkar's [26] economic modeling of the world cities with deep shallow learning networks and optimization algorithms shows the extensive applicability of intelligent systems to urban financial management. He [27] supports this by constructing a hybrid methodology for studying inequalities in economic development, emphasizing the contribution of machine learning in curbing regional growth imbalances.

Such studies quoted collectively emphasize the adaptability of intelligent systems in financial analysis, varying from project management to city economic forecasting. Nevertheless, such studies sometimes concentrate more on technical efficiency or industry insights and thus fall short in the integration of such systems in inclusive equilibrium growth models for the insurance and financial sectors. Therefore, we stated the following features of the systematization of scientific research and development:

- New modeling methods, – articles like Wang [21] and Song et al [22] provide new frameworks combining machine learning and project management;
- High predictive accuracy, – research such as Zhang et al [25] and Deshkar [26] highlight the success of hybrid models in prediction;
- Sectoral flexibility, – Farooq et al [23] and Suresh and Jagatheeswari [24] illustrate intelligent systems flexibility in application, spanning transport to energy;
- Partial integration in financial sectors, – most research has had general or sector-specific applications, with less focus on equilibrium growth analysis for financial and insurance sectors specifically;
- Scalability issues, – some frameworks, particularly those built on complex algorithms, may experience difficulties if expanded to national or sectoral levels, as He [27] points out.

This research seeks to address these limitations by developing an intelligent system for equilibrium growth analysis in Kazakhstan's financial and insurance sectors, drawing from the strengths of existing studies to build a comprehensive, integrative framework.

Thus, the purpose of this study is to create, justify and apply an algorithm of the algorithms for determine equilibrium transactions of the platform industry and its ecosystems of Kazakhstan's financial and insurance activities industry. To achieve the purpose of this work we plan to present the research in the following sequence: Introduction (Section 1); Materials and methods: Conceptual design of the an algorithm for analyzing equilibrium growth (Section 2.1), Data, indicators and equilibrium transaction definition for the platform and its ecosystems (Section 2.1); Results: An algorithm to determine the equilibrium on the platform industry and its application (Section 3.1), An algorithm to determine the equilibrium on the internal ecosystem and its application (Section 3.2), An algorithm to determine the equilibrium on the external ecosystem and its application (Section 3.3); Discussion (Section 4); and Conclusions (Section 5).

2. Materials and Methods

2.1. Conceptual Design of Computational Modelling of Equilibrium Growth

Section 2.1 presents the conceptual design of computational modelling for analyzing equilibrium growth in the platform industry and its ecosystem. It emphasizes the role of total input and total output transactions in managing resource-commodity and nominal-monetary flows. In particular, according to [28], we combine the design of computational modelling at the input platform produce/selling, payments and import, and at the output platform purchase/buying, final demand, and export agents. Next, we explore the problem of organizing transaction flows between structures from the point of view of effective support of the technological chain in ensuring equilibrium growth in the platform industry and its ecosystem.

Platform industry – economic activity based on an intelligent information system, providing complex standard solutions for the hold and management of transactions of both resource-commodity and nominal-monetary values between agents of the platform and of the ecosystem.

The concept of computational modelling for analyzing the equilibrium growth of the platform industry consists of a block of the total input (see Figure 1a) and a block of the total output (see Figure 1b), as well as flows of resource-commodity values (see solid line of Figure 1) and nominal-monetary values (see dotted line of Figure 1) between the agents of the platform and the ecosystem [28]:

- A block of the total input is based on platform produce/selling, internal ecosystem: payments and external ecosystem: import agents (see Figure 1a);
- Resource-commodity values of the total input of the industry consist of the platform produce/selling, internal ecosystem payments, and external ecosystem imports transactions sum (see Figure 1a), i.e.

$$\text{Total input} = \text{Produce/selling} + \text{Payments} + \text{Imports};$$

- A block of the total output is based on platform purchase/buying, internal ecosystem final demand, and external ecosystem export agents (see Figure 1b);

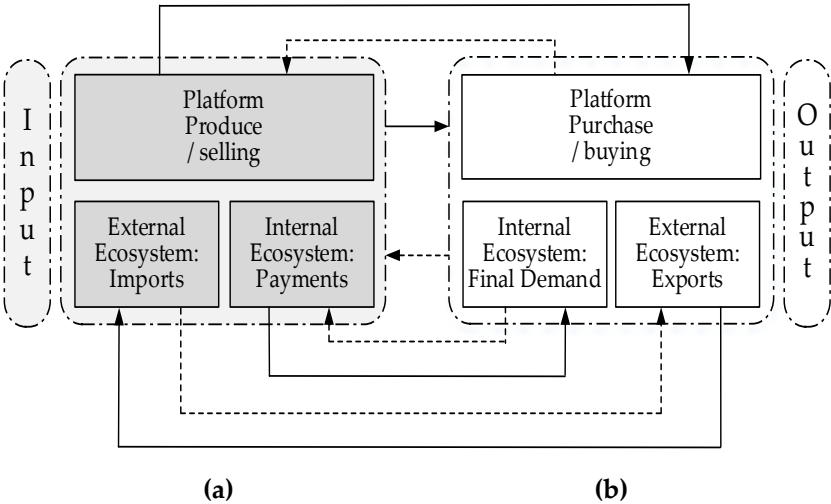


Figure 1. Conceptual design computational model for the transactions of resource-commodity and nominal-monetary values between agents of the industry and its ecosystems.

- Nominal-monetary values of the total output of the industry consist of the platform purchase/buying, internal ecosystem final demand, and external ecosystem exports transactions sum (see Figure 1b) [28], i.e.

$$\text{Total output} = \text{Purchase/buying} + \text{Final demand} + \text{Exports}.$$

Thus, based on the received nominal-monetary values from the total output of the industry as feedback (see the dotted line between Figure 1a and Figure 1b) total input agents based on the distribution of resource-commodity values organize and manage the technological chain obtaining products for formations of values on the total output agents (see solid line between Figure 1a and Figure 1b). Then a necessary condition for the equilibrium growth of the transactions in the industry is equality between the total input and the total output [28]:

$$\text{Total input} = \text{Total output}.$$

However, aggregate equality between total inputs and total output does not give equality to its components. Then the hiding of the equilibrium between:

- platform produce/selling and purchase/buying,
- internal ecosystem payments and final demand,
- external ecosystem imports and exports are the main subjects of this study.

As a result of Section 2.1, we conclude that achieving equilibrium growth requires not only aggregate equality between total inputs and total outputs but also balance among individual components, including platform produce/selling and purchase/buying, internal ecosystem payments

and final demand, and external ecosystem imports and exports. Addressing these hidden imbalances is vital for understanding and managing the complexities of transaction flows, ultimately supporting sustainable growth within the platform industry and its interconnected ecosystems.

2.2. Data, Indicators, and Equilibrium Transaction Definition for the Platform and Its Ecosystems

Section 2.2 outlines the data, indicators, and definitions necessary to analyze equilibrium transactions for the platform industry and its ecosystems in Kazakhstan’s financial and insurance activities sector. It focuses on the flows of produce/selling and purchase/buying transactions between the platform, and internal, and external economic agents, providing a detailed framework for determine the equilibrium state based on transaction flows from OECD-sourced economic statistics [29].

2.2.1. Data, Indicators, and Equilibrium Transaction Definition for the Produce/Selling and Purchase/buying

Let us have the initial data set the flow of the platform produce/selling transactions to the platform purchase/buying of this industry and to the platform purchase/buying of the rest of economics, and of the platform produce/selling of the rest of economics to the platform purchase/buying of total output of the financial and insurance activities industry received from source OECD [29]:

- $z_{11}(t)$, – the flow of transactions from platform produce/selling to platform purchase/buying of the total output of the financial and insurance activities industry, $t = \overline{1995}; \overline{1995 + T}$, $T = \overline{1}; \overline{24}$, a billion U.S. dollars (see Table 2, row (1), column (1));
- $z_{1r}(t)$, – the flow of transactions from platform produce/selling to platform purchase/buying of the rest of economics of total output of the financial and insurance activities industry, $t = \overline{1995}; \overline{1995 + T}$, $T = \overline{1}; \overline{24}$, a billion U.S. dollars (see Table 2, row (1), column (2));
- $z_{r1}(t)$, – the flow of transactions from platform produce/selling of the rest of economics to platform purchase/buying of the total output of the financial and insurance activities industry, $t = \overline{1995}; \overline{1995 + T}$, $T = \overline{1}; \overline{24}$, a billion U.S. dollars (see Table 2, row (2), column (1)).

Now, we obtain the sum of the transactions from platform produce/selling to platform purchase/buying this industry and of the transactions from platform produce/selling of the rest of economics to platform purchase/buying of the total output of the financial and insurance activities industry, a billion U.S. dollars (see Table 1, column (a)) [28]:

$$z_{11}(t) + z_{r1}(t) = \sum_{i=1}^r z_{i1}(t), \quad t = \overline{1995}; \overline{1995 + T}, \quad T = \overline{1}; \overline{24},$$

and we denote it by $z'(t)$, $t = \overline{1995}; \overline{1995 + T}$, $T = \overline{1}; \overline{24}$.

Also, we obtain the sum of the transactions from platform produce/selling to platform purchase/buying this industry and of the transactions from platform produce/selling this industry to platform purchase/buying of the rest of economics of total output of the financial and insurance activities industry, a billion U.S. dollars (see Table 1, column (b)) [28]:

$$z_{11}(t) + z_{1r}(t) = \sum_{j=1}^r z_{1j}(t), \quad t = \overline{1995}; \overline{1995 + T}, \quad T = \overline{1}; \overline{24},$$

and we denote it by $z(t)$, $t = \overline{1995}; \overline{1995 + T}$, $T = \overline{1}; \overline{24}$.

Table 1. Data set for the platform industry and its internal and external ecosystem of the financial and insurance activities transactions of Kazakhstan’s economic statistics.

Year	(a)	(b)	(c)	(d)	(e)	(f)	Year	(a)	(b)	(c)	(d)	(e)	(f)
1995	0.090	0.536	0.741	0.336	0.059	0.018	2007	0.568	4.805	3.855	0.922	1.484	0.181
1996	0.097	0.497	0.758	0.404	0.064	0.018	2008	0.732	5.687	4.902	1.135	1.570	0.383

Year	(a)	(b)	(c)	(d)	(e)	(f)	Year	(a)	(b)	(c)	(d)	(e)	(f)
1997	0.114	0.548	0.799	0.447	0.102	0.021	2009	0.509	4.844	4.267	1.069	1.458	0.320
1998	0.113	0.488	0.788	0.490	0.100	0.022	2010	0.801	6.209	5.390	1.057	1.274	0.200
1999	0.092	0.462	0.605	0.317	0.106	0.023	2011	1.784	5.765	3.829	0.936	1.301	0.213
2000	0.076	0.612	0.649	0.285	0.198	0.025	2012	2.001	6.229	4.418	1.110	1.187	0.268
2001	0.092	0.742	0.785	0.338	0.228	0.026	2013	2.352	8.250	6.554	1.359	0.881	0.178
2002	0.128	0.867	0.874	0.426	0.320	0.029	2014	2.186	7.787	6.738	1.381	0.525	0.281
2003	0.162	1.053	1.100	0.506	0.331	0.034	2015	1.725	6.745	6.494	1.726	0.586	0.334
2004	0.237	1.466	1.557	0.679	0.395	0.044	2016	1.533	5.698	4.909	1.753	1.242	0.234
2005	0.320	2.125	2.059	0.862	0.647	0.040	2017	2.191	7.139	6.091	1.700	0.810	0.253
2006	0.462	3.893	2.927	0.797	1.361	0.060	2018	2.971	8.352	6.013	1.090	0.749	0.290

Note. (a) Produce/selling transactions of the platform industry. (b) Purchase/buying transactions of the platform industry. (c) Payment transactions of the internal ecosystem. (d) Final demand transactions of the internal ecosystem. (e) Import transactions of the external ecosystem. (f) Exports transactions of the external ecosystem. A Billion U.S. dollars. Compiled by the author based on the Input-Output Tables data from source OECD [29].

Then on the equilibrium transactions state on the platform produce/selling and purchase/buying for the total input, respectively, the total output of the financial and insurance activities industry will have been in, if exists $\exists! t^* = \overline{1995; 1995 + T}$, $T = \overline{1; 24}$ such that:

$$z'(t^*) = z(t^*). \tag{1}$$

2.2.2. Data, Indicators, and Equilibrium Transaction Definition for the Internal Ecosystem Payment and Final Demand

Let us have the initial data set the flow of the payment transactions: taxes less subsidies on intermediate and final products and of gross value added of the internal ecosystem to the total output of financial and insurance activities industry received from source OECD [29]:

- $\tau_1(t)$, – the flow transactions from taxes less subsidies on intermediate and final products included in the internal ecosystem for payments on the total output of financial and insurance activities industry, $t = \overline{1995; 1995 + T}$, $T = \overline{1; 24}$, a billion U.S. dollars (see Table 2, row (4), column (1));
- $v_1(t)$, – the flow transactions from gross value added included in the internal ecosystem for payments on the total output of financial and insurance activities industry, $t = \overline{1995; 1995 + T}$, $T = \overline{1; 24}$, a billion U.S. dollars (see Table 2, row (5), column (1));

Now, we obtain the sum of the transactions the taxes less subsidies on intermediate and final products and the transactions of the gross value added included in the internal ecosystem for payments in the total input of financial and insurance activities industry, a billion U.S. dollars (see Table 1, column (c)) [29]:

$$\tau_1(t) + v_1(t) = p(t), \quad t = \overline{1995; 1995 + T}, \quad T = \overline{1; 24},$$

and we denote it by $p(t)$, $t = \overline{1995; 1995 + T}$, $T = \overline{1; 24}$.

Let us have the initial data set the flow of the final demand transactions: final total consumption expenditure and gross fixed capital formation of the internal ecosystem to the total input of financial and insurance activities industry received from source OECD [29]:

- $c_1(t)$, – the flow transactions from final total consumption expenditure included in the internal ecosystem for final demand on the total input of financial and insurance activities industry, $t = \overline{1995; 1995 + T}$, $T = \overline{1; 24}$, a billion U.S. dollars (see Table 2, row (1), column (4));

- $g_1(t)$, – the flow transactions from gross fixed capital formation included in the internal ecosystem for final demand on the total input of financial and insurance activities industry, $t = \overline{1995; 1995 + T}$, $T = \overline{1; 24}$, a billion U.S. dollars (see Table 2, row (1), column (5)).

Now, we obtain the sum of the transactions the final total consumption expenditure and the transactions of the gross fixed capital formation included in the internal ecosystem for final demand in the total input of financial and insurance activities industry, a billion U.S. dollars (see Table 1, column (d)) [28]:

$$c_1(t) + g_1(t) = f(t), \quad t = \overline{1995; 1995 + T}, \quad T = \overline{1; 24},$$

and we denote it by $f(t)$, $t = \overline{1995; 1995 + T}$, $T = \overline{1; 24}$.

Then on the equilibrium transactions state on the internal ecosystem payment and final demand for the total input, respectively, the total output of the financial and insurance activities industry will have been in, if exists $\exists! t^* = \overline{1995; 1995 + (T - 1)}$, $T = \overline{1; 24}$ such that:

$$p(t^*) = f(t^*). \tag{2}$$

2.2.3. Data Set and Equilibrium State on the Import and Exports for the External Ecosystem Transactions

Let us have the initial data set the flow of the import (or outflow of foreign currency) and the exports (or inflow of foreign currency) transactions of the external ecosystem to the total output, respectively, to the total input of financial and insurance activities industry received from source OECD [29]:

- m_1 , – the flow transactions from the import (or outflow of foreign currency) included in the external ecosystem to the total output of the financial and insurance activities industry, $t = \overline{1995; 1995 + T}$, $T = \overline{1; 24}$, a billion U.S. dollars (see Table 1, column (e); Table 2, row (7), column (1));
- e_1 , – the flow transactions from the exports (or inflow of foreign currency) included in the external ecosystem to the total input of the financial and insurance activities industry, $t = \overline{1995; 1995 + T}$, $T = \overline{1; 24}$, a billion U.S. dollars (see Table 1, column (f); Table 2, row (1), column (7))).

Then on the equilibrium transactions state on the external ecosystem import (or outflow of foreign currency) and the exports (or inflow of foreign currency) for the total input, respectively, the total output of the financial and insurance activities industry will have been in if exists $\exists! t^* = \overline{1995; 1995 + (T - 1)}$, $T = \overline{1; 24}$ such that:

$$m(t^*) = e(t^*). \tag{3}$$

Table 2. Design of the transactions for the platform industry and its internal and external ecosystem of economic flows.

Platform: Purchase/buying				Internal ecosystem: Final demand			External ecosystem: Exports	Total output
Platform: Produce/selling	z_{11}	z_{1r}	$\sum z_{1j}$	c_1	g_1	$c_1 + g_1 = f_1$	e_1	x_1
	z_{r1}	z_{rr}	$\sum z_{rj}$	c_r	g_r	$c_r + g_r = f_r$	e_r	x_r
	$\sum z_{i1}$	$\sum z_{ir}$	$\sum z_{ij}$	$\sum c_j$	$\sum g_j$	$\sum f_j$	$\sum e_j$	$\sum x_j$
Interna 1	τ_1	τ_r	$\sum \tau_i$					

	Platform: Purchase/buying	Internal ecosystem: Final demand	External ecosystem: Exports	Total output
	v_1	v_r	$\sum v_i$	
	$\tau_1 + v_1$ $= p_1$	$\tau_r + v_r = p_r$	$\sum v_i$	
External ecosys- tem: Import	m_1	m_r	$\sum m_i$	
Total input	x_1	x_r	$\sum x_i$	

As a result of Section 2.2, we emphasize the critical role of transaction flow data in determining the equilibrium state of the platform industry and its ecosystems. By analyzing the interactions between platform produce/selling and purchase/buying transactions and its internal and external agents, it establishes a basis for determine equilibrium conditions and offers a systematic approach to studying transaction dynamics within Kazakhstan’s financial and insurance activities sector.

3. Results

3.1. Computational Modelling of Equilibrium Transactions on the Platform Industry and Its Application

In Section 3.1 details the development and application of computational model to detect equilibrium transactions in the platform industry for Kazakhstan's financial and insurance activities sector. By leveraging normalized transaction data, supply and demand functions, regression equations, operations research, operations research, mathematical programming and gradient methods, the computational model we detect the equilibrium points between produce/selling and purchase/buying transactions, offering a systematic approach to analyzing transaction dynamics and achieving balance within the platform industry.

3.1.1. An Algorithm for Determine the Equilibrium on the Platform Industry

Entry: $z'(t)$ – the platform produce/selling transactions of the total input of financial and insurance activities industry, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1; 24}$, a billion U.S. dollars (see Table 1, column (a)); $z(t)$ – the platform purchase/buying transactions of the total output of financial and insurance activities industry, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1; 24}$, a billion U.S. dollars (see Table 1, column (b)).

Outcome: Equilibrium transactions of the platform produce/selling and purchase/buying, respectively, of the total input and the total output of the financial and insurance activities industry.

Step 1: To create the supply function as a data set on the normalized platform produce/selling transactions $[0;1]$ from the domain of the observation $z'(t)$,

$t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1; 24}$.

(i) Sorting by the growth of data $z'(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1; 24}$, i.e. rearrange the elements of observation data $z'(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1; 24}$, into a sequence such that the following chains of inequalities hold: $z'(\overline{1995}) \leq z'(\overline{1995 + 1}) \leq \dots \leq z'(\overline{1995 + 23})$, and denote by $z'(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1; 24}$ (see Table 3, column (a)), where

$$z'(\overline{1995}) = \min_{t \in \overline{1995}; \overline{1995 + (T - 1)}} \{z'(t)\}, \quad T = \overline{1; 24},$$

and

$$z'(\overline{1995} + (T - 1)) = \max_{t \in \overline{1995}; \overline{1995} + (T - 1)} \{z'(t)\}, \quad T = \overline{1}; \overline{24};$$

(ii) Calculate the cumulative sum of sorted data $z'(t)$, $t = \overline{1995}; \overline{1995} + (T - 1)$, $T = \overline{1}; \overline{24}$:

$$\text{SUM}_{T=\overline{1}; \overline{24}} \left(z'(t = \overline{1995}g): z' \left(t = \overline{1995}; \overline{1995} + (T - 1) \right) \right);$$

Table 3. Sorted data set for the platform industry and its internal and external ecosystem of the financial and insurance activities transactions of Kazakhstan’s economic statistics.

Year	(a)	(b)	(c)	(d)	(e)	(f)	Year	(a)	(b)	(c)	(d)	(e)	(f)
$\overline{1995}$	0.076	8.352	0.605	1.753	0.059	0.383	$\overline{2007}$	0.509	3.893	3.829	0.862	0.647	0.060
$\overline{1996}$	0.090	8.250	0.649	1.726	0.064	0.334	$\overline{2008}$	0.568	2.125	3.855	0.797	0.749	0.044
$\overline{1997}$	0.092	7.787	0.741	1.700	0.100	0.320	$\overline{2009}$	0.732	1.466	4.267	0.679	0.810	0.040
$\overline{1998}$	0.092	7.139	0.758	1.381	0.102	0.290	$\overline{2010}$	0.801	1.053	4.418	0.506	0.881	0.034
$\overline{1999}$	0.097	6.745	0.785	1.359	0.106	0.281	$\overline{2011}$	1.533	0.867	4.902	0.490	1.187	0.029
$\overline{2000}$	0.113	6.229	0.788	1.135	0.198	0.268	$\overline{2012}$	1.725	0.742	4.909	0.447	1.242	0.026
$\overline{2001}$	0.114	6.209	0.799	1.110	0.228	0.253	$\overline{2013}$	1.784	0.612	5.390	0.426	1.274	0.025
$\overline{2002}$	0.128	5.765	0.874	1.090	0.320	0.234	$\overline{2014}$	2.001	0.548	6.013	0.404	1.301	0.023
$\overline{2003}$	0.162	5.698	1.100	1.069	0.331	0.213	$\overline{2015}$	2.186	0.536	6.091	0.338	1.361	0.022
$\overline{2004}$	0.237	5.687	1.557	1.057	0.395	0.200	$\overline{2016}$	2.191	0.497	6.494	0.336	1.458	0.021
$\overline{2005}$	0.320	4.844	2.059	0.936	0.525	0.181	$\overline{2017}$	2.352	0.488	6.554	0.317	1.484	0.018
$\overline{2006}$	0.462	4.805	2.927	0.922	0.586	0.178	$\overline{2018}$	2.971	0.462	6.738	0.285	1.570	0.018

Note. (a) Produce/selling transactions of the platform industry, sorted by growth. (b) Purchase/buying transactions of the platform industry, descending sorted. (c) Payment transactions of the internal ecosystem, sorted by growth. (d) Final demand transactions of the internal ecosystem, descending sort. (e) Import transactions of the external ecosystem, sorted by growth. (f) Exports transactions of the external ecosystem, descending sorted. A Billion U.S. dollars. Compiled by the author based on the Input-Output Tables data [29].

(iii) To normal the cumulative sum of sorted data $z'(t)$, $t \in \overline{1995}; \overline{1995} + (T - 1)$, $T = \overline{1}; \overline{24}$:

$$\frac{\text{SUM}_{T=\overline{1}; \overline{24}} \left(z'(t = \overline{1995}): z' \left(t = \overline{1995}; \overline{1995} + (T - 1) \right) \right)}{z'(\overline{1995} + (T - 1))},$$

and denote by $\check{z}'(t)$, $t = \overline{1995}; \overline{1995} + (T - 1)$, $T = \overline{1}; \overline{24}$ (see Table 4, column (a));

Table 4. Normalized data set for the platform industry and its internal and external ecosystem of the financial and insurance activities transactions of Kazakhstan’s economic statistics.

Year	(a)	(b)	(c)	(d)	(e)	(f)	Year	(a)	(b)	(c)	(d)	(e)	(f)
$\overline{1995}$	0.004	0.092	0.008	0.083	0.003	0.110	$\overline{2007}$	0.117	0.897	0.227	0.762	0.216	0.915
$\overline{1996}$	0.008	0.183	0.016	0.165	0.007	0.205	$\overline{2008}$	0.143	0.920	0.277	0.800	0.260	0.927
$\overline{1997}$	0.012	0.269	0.026	0.245	0.013	0.297	$\overline{2009}$	0.178	0.936	0.332	0.832	0.307	0.938
$\overline{1998}$	0.016	0.347	0.036	0.311	0.019	0.380	$\overline{2010}$	0.215	0.948	0.389	0.856	0.359	0.948
$\overline{1999}$	0.021	0.422	0.046	0.375	0.025	0.460	$\overline{2011}$	0.287	0.957	0.453	0.879	0.429	0.956
$\overline{2000}$	0.026	0.490	0.056	0.429	0.037	0.537	$\overline{2012}$	0.368	0.965	0.516	0.900	0.502	0.964
$\overline{2001}$	0.032	0.559	0.066	0.481	0.050	0.609	$\overline{2013}$	0.452	0.972	0.586	0.920	0.577	0.971
$\overline{2002}$	0.038	0.622	0.078	0.533	0.069	0.676	$\overline{2014}$	0.545	0.978	0.664	0.940	0.654	0.978
$\overline{2003}$	0.045	0.685	0.092	0.583	0.089	0.737	$\overline{2015}$	0.648	0.984	0.743	0.956	0.734	0.984

Year	(a)	(b)	(c)	(d)	(e)	(f)	Year	(a)	(b)	(c)	(d)	(e)	(f)
2004	0.056	0.747	0.112	0.633	0.112	0.795	2016	0.751	0.990	0.828	0.971	0.820	0.990
2005	0.071	0.801	0.139	0.678	0.143	0.846	2017	0.861	0.995	0.913	0.986	0.908	0.995
2006	0.093	0.854	0.177	0.721	0.177	0.897	2018	1.000	1.000	1.000	1.000	1.000	1.000

Note. (a) Produce/selling transactions of the platform industry, normalized. (b) Purchase/buying transactions of the platform industry normalized. (c) Payment transactions of the internal ecosystem, normalized. (d) Final demand transactions of the internal ecosystem, normalized. (e) Import transactions of the external ecosystem, normalized. (f) Exports transactions of the external ecosystem, normalized. Share. Compiled by the authors.

- (iv) To build and to visualize the supply as a function to normalized platform produce/selling transactions $\check{z}'(t) \in [0; 1]$ from a domain of the observation $z'(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$ (see Figure 2, histogram with a round marker with a gray fill);
- Step 2: Create the regression equations for the supply function of the platform produce/selling transactions $\check{z}'(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$.
- (i) Calculate the slope between the dependent $\check{z}'(t)$ and the independent variable $z'(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$;
- (ii) Calculate the intercept between the dependent $\check{z}'(t)$ and the independent variable $z'(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$;
- (iii) Calculate the R-square for the regression equation between the dependent $\check{z}'(t)$ and the independent variable $z'(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$;
- (iv) Calculate the p-value of parameters for the regression equation between the dependent $\check{z}'(t)$ and the independent variable $z'(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$;
- (v) Calculate the standard errors of parameters for the regression equation between the dependent $\check{z}'(t)$ and the independent variable $z'(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$;
- (vi) To build the regression equations for the supply function of the platform produce/selling transactions $\check{z}'(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$ [35]:

$$\check{z}'(t) = \begin{matrix} \text{Intercept}' \\ \text{R - square} \end{matrix} + \begin{matrix} \text{Slope}' \\ (\text{Std. Error}) \end{matrix} \times z'(t), \quad t = \overline{1995}; \overline{1995 + (T - 1)},$$

$$T = 1, 2, \dots, 24,$$

(4)

where unknown parameters Slope', Intercept', R-square, p-value, and Standard errors will be estimated by the least squares in the above sub steps (i)-(v);

The figure is a scatter plot with two data series: 'Produce/selling' (represented by gray circles) and 'Purchase/buying' (represented by white squares with black outlines). The x-axis is labeled 'Price, Billion U.S. dollars' and ranges from 0.076 to 8.353 with major ticks at 0.076, 1.110, 2.145, 3.180, 4.214, 5.249, 6.283, 7.318, and 8.353. The y-axis is labeled 'Normalize, Share' and ranges from 0.000 to 1.000 with major ticks every 0.125. A dashed line represents the 'Supply function', starting near (0.076, 0.000) and rising to (3.180, 1.000). A dotted line represents the 'Demand function', starting near (0.076, 1.000) and falling to (8.353, 0.000). A vertical dashed line at Price = 3.180 intersects the supply and demand curves at a Normalized Share of 0.750, which is labeled as the 'Equilibrium' point in the legend.

Figure 2. Observation, regression equations, and equilibrium of the platform produce/selling and purchase/buying transactions in the financial and insurance activities industry.

(vii) Visualize the regression equations for the supply function of the platform produce/selling transactions $\bar{z}'(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$ (see Figure 2, a dotted line with one dot, Table 5, column (a)).

Table 5. Results of the intelligent analysis of equilibrium growth in the platform industry.

Year	(a)	(b)	(c)	(d)	(e)	(f)	Year	(a)	(b)	(c)	(d)	(e)	(f)
$\overline{1995}$	0.114	-0.038	UV	10.794	-2.442	UV	$\overline{2007}$	0.470	0.038	OV	2.006	1.887	OV
$\overline{1996}$	0.127	-0.037	UV	9.802	-1.552	UV	$\overline{2008}$	0.554	0.014	OV	1.750	0.375	OV
$\overline{1997}$	0.140	-0.049	UV	8.865	-1.078	UV	$\overline{2009}$	0.663	0.070	OV	1.573	-0.108	UV
$\overline{1998}$	0.154	-0.062	UV	8.006	-0.867	UV	$\overline{2010}$	0.781	0.020	OV	1.447	-0.394	UV
$\overline{1999}$	0.168	-0.071	UV	7.194	-0.449	UV	$\overline{2011}$	1.008	0.526	OV	1.342	-0.475	UV
$\overline{2000}$	0.185	-0.072	UV	6.445	-0.216	UV	$\overline{2012}$	1.263	0.462	OV	1.253	-0.512	UV
$\overline{2001}$	0.202	-0.088	UV	5.698	0.511	OV	$\overline{2013}$	1.527	0.257	OV	1.180	-0.568	UV
$\overline{2002}$	0.221	-0.093	UV	5.004	0.760	OV	$\overline{2014}$	1.823	0.179	OV	1.114	-0.566	UV
$\overline{2003}$	0.245	-0.083	UV	4.319	1.379	OV	$\overline{2015}$	2.146	0.040	OV	1.049	-0.513	UV
$\overline{2004}$	0.280	-0.043	UV	3.635	2.052	OV	$\overline{2016}$	2.470	-0.279	UV	0.989	-0.492	UV
$\overline{2005}$	0.327	-0.007	UV	3.052	1.792	OV	$\overline{2017}$	2.817	-0.466	UV	0.931	-0.442	UV
$\overline{2006}$	0.395	0.066	OV	2.474	2.331	OV	$\overline{2018}$	3.256	-0.286	UV	0.875	-0.413	UV

Note. (a) Supply function values for the produce/selling transactions. (b) Nominal estimate of the equilibrium of the produce/selling transactions. (c) Linguistic variables: Undervalue and Overvalue of the equilibrium of the produce/selling transactions. (d) Demand function values for the purchase/buying transactions. (e) Nominal estimate of the equilibrium the purchase/buying transactions. (f) Linguistic variables: Undervalue and Overvalue of the equilibrium of the purchase/buying transactions. A Billion U.S. dollars. Compiled by the authors.

Step 3: To create the demand function as a data set on the normalized platform purchase/buying transactions $[0;1]$ from the domain of the observation $z(t)$,

$t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$.

(i) Descending sorted of data $z(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$, i.e. rearrange the elements of observation data $z(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$, into a sequence such that the following chains of inequalities hold: $z(\overline{1995}) \geq z(\overline{1995 + 1}) \geq \dots \geq z(\overline{1995 + 23})$, and denote by $z(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$ (see Table 3, column (b)), where

$$z(\overline{1995d}) = \max_{t=\overline{1995}; \overline{1995+(T-1)}} \{z(t)\}, \quad T = \overline{1}; \overline{24},$$

and

$$z(\overline{1995 + (T - 1)}) = \min_{t=\overline{1995}; \overline{1995+(T-1)}} \{z(t)\}, \quad T = \overline{1}; \overline{24};$$

(ii) Calculate the cumulative sum of sorted data $z(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$:

$$\text{SUM}_{T=\overline{1}; \overline{24}} \left(z(t = \overline{1995}) : z(t = \overline{1995}; \overline{1995 + (T - 1)}) \right);$$

(iii) To normal the cumulative sum of sorted data $z(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$:

$$\frac{\text{SUM}_{T=\overline{1}; \overline{24}} \left(z(t = \overline{1995}) : z(t = \overline{1995}; \overline{1995 + (T - 1)}) \right)}{z(\overline{1995})},$$

and denote by $\bar{z}(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$ (see Table 4, column (b));

(iv) To build and visualize the demand function to normalized platform purchase/buying transactions $\check{z}(t)$ from the domain of the observation $z(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}, T = \overline{1}; \overline{24}$ (see Figure 2, histogram with a square marker with white fill);

Step 4: Create the regression equations for the demand function of the platform purchase/buying transactions: $\check{z}(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}, T = \overline{1}; \overline{24}$.

(i) Calculate the slope between the dependent $\check{z}(t)$ and the independent variable $z(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}, T = \overline{1}; \overline{24}$;

(ii) Calculate the intercept between the dependent $\check{z}(t)$ and the independent variable $z(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}, T = \overline{1}; \overline{24}$;

(iii) Calculate the R-square for the regression equation between the dependent $\check{z}(t)$ and the independent variable $z(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}, T = \overline{1}; \overline{24}$;

(iv) Calculate the p-value of parameters for the regression equation between the dependent $\check{z}(t)$ and the independent variable $z(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}, T = \overline{1}; \overline{24}$;

(v) Calculate the standard errors of parameters for the regression equation between the dependent $\check{z}(t)$ and the independent variable $z(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}, T = \overline{1}; \overline{24}$;

(vi) To build the regression equations for the demand function of the platform purchase/buying transactions $\check{z}(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}, T = \overline{1}; \overline{24}$ [30]:

$$\begin{array}{llll} \check{z}(t) = & \text{Intercept} + & \text{Slope} \times z(t), & t = \overline{1995}; \overline{1995 + (T - 1)}, \\ \text{R - square} & (\text{Std. Error}) & (\text{Std. Error}) & T = 1, 2, \dots, 24, \end{array} \quad (5)$$

where unknown parameters Slope, Intercept, R-square, p-value, and Standard errors will be estimated by the least squares in the above sub-steps (i)-(v);

(vii) Visualize the regression equations for the demand function of the platform purchase/buying transactions $\check{z}(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}, T = \overline{1}; \overline{24}$ (see Figure 2, the dotted line with two dots, Table 5, column (d)).

Step 5: Find the equilibrium transactions $z'(t^*)$ of the platform produce/selling for the financial and insurance activities industry, i.e. prove that

$\exists! t^* = \overline{1995}; \overline{1995 + (T - 1)}, T = \overline{1}; \overline{24} | z'(t^*) = z(t^*)$.

(i) Construct equations for the equilibrium transactions of the platform produce/selling $\check{z}'(t)$ and the purchase/buying $\check{z}(t)$ from the equality condition of equations (4) and (5), i.e. $\check{z}'(t) = \check{z}(t)$.

Indeed, from (4) and (5) we obtain:

$$\begin{array}{ll} \text{Intercept}' + \text{Slope}' \times z'(t) = \text{Intercept} + \text{Slope} \times z(t), \\ t = \overline{1995}; \overline{1995 + (T - 1)}, T = \overline{1}; \overline{24}; \end{array} \quad (6)$$

(ii) Find the normalized sequences $\check{z}'(t)$, $t \in \overline{1995}; \overline{1995 + (T - 1)}, T = \overline{1}; \overline{24}$, such that these functions satisfied conditions (6):

(iia) If for $\{z'(t)\}$, $t = \overline{1995}; \overline{1995 + (T - 1)}, T = \overline{1}; \overline{24}$ the following holds:

$$\min_{t \in \overline{1995}; \overline{1995 + (T - 1)}} \{z'(t)\} < \{z'(t)\} < \max_{t \in \overline{1995}; \overline{1995 + (T - 1)}} \{z'(t)\},$$

then we use linear interpolation and ensure convergence of the iteration using the gradient method [31]:

$$\check{z}' = \check{z}'[j] + \frac{\check{z}'[j+1] - \check{z}'[j]}{z'[j+1] - z'[j]} \cdot (z' - z'[j]), \quad j = 1, 2, \dots; \quad (7)$$

(iib) If for $\{z'(t)\}$, $t = \overline{1995}; \overline{1995 + (T - 1)}, T = \overline{1}; \overline{24}$ the following holds:

$$\min_{t \in \overline{1995}; \overline{1995 + (T - 1)}} \{z'(t)\} > \{z'(t)\},$$

or

$$\{z'(t)\} > \max_{t \in \overline{1995}; \overline{1995 + (T - 1)}} \{z'(t)\}.$$

Then, respectively, we use linear extrapolation and ensure convergence of the iteration by the gradient method [31]:

$$\check{z}' = \check{z}'[\min] + \frac{\check{z}'[\min + 1] - \check{z}'[\min]}{z'[\min + 1] - z'[\min]} \cdot (z' - z'[\min]), \quad \min, \min + 1, \dots; \quad (8)$$

or

$$\check{z}' = \check{z}'[\max] + \frac{\check{z}'[\max] - \check{z}'[\max - 1]}{z'[\max] - z'[\max - 1]} \cdot (z' - z'[\max]), \quad \max, \max - 1, \dots; \quad (9)$$

Step 6: Find the equilibrium transactions $z(t^*)$ of the platform purchase/buying for the financial and insurance activities industry, i.e. prove that

$\exists! t^* = \overline{1995; 1995 + (T - 1)}, T = \overline{1; 24} \mid z(t^*) = z'(t^*)$.

(i) Construct equations for the equilibrium transactions of the platform purchase/buying $\check{z}(t)$ and the produce/selling $\check{z}'(t)$ from the equality condition of equations (4) and (5), i.e. $\check{z}(t) = \check{z}'(t)$.

Indeed, from (4) and (5) we obtain:

$$\begin{aligned} \text{Intercept} + \text{Slope} \times z(t) &= \text{Intercept}' + \text{Slope}' \times z'(t), \\ t &= \overline{1995; 1995 + (T - 1)}, \quad T = \overline{1; 24}; \end{aligned} \quad (10)$$

(ii) Find the normalized sequences $\check{z}(t)$, $t = \overline{1995; 1995 + (T - 1)}, T = \overline{1; 24}$, such that these functions satisfied conditions (10):

(iia) If for $\{z(t)\}$, $t = \overline{1995; 1995 + (T - 1)}, T = \overline{1; 24}$ the following holds:

$$\max_{t \in \overline{1995; 1995 + (T - 1)}} \{z(t)\} > \{z(t)\} > \min_{t \in \overline{1995; 1995 + (T - 1)}} \{z(t)\},$$

then we use linear interpolation and ensure convergence of the iteration using the gradient method [31]:

$$\check{z} = \check{z}[j] + \frac{\check{z}[j + 1] - \check{z}[j]}{z[j + 1] - z[j]} \cdot (z - z[j]), \quad j = 1, 2, \dots; \quad (11)$$

(iib) If for $\{z(t)\}$, $t = \overline{1995; 1995 + (T - 1)}, T = \overline{1; 24}$ the following holds:

$$\max_{t \in \overline{1995; 1995 + (T - 1)}} \{z(t)\} < \{z(t)\},$$

or

$$\{z(t)\} < \min_{t \in \overline{1995; 1995 + (T - 1)}} \{z(t)\}.$$

Then, respectively, we use linear extrapolation and ensure convergence of the iteration by the gradient method [31]:

$$\check{z} = \check{z}[\max] + \frac{\check{z}[\max] - \check{z}[\max - 1]}{z[\max] - z[\max - 1]} \cdot (z - z[\max]), \quad [\cdot] = \max, \max - 1, \dots; \quad (12)$$

or

$$\check{z} = \check{z}[\min] + \frac{\check{z}[\min + 1] - \check{z}[\min]}{z[\min + 1] - z[\min]} \cdot (z - z[\min]), \quad [\cdot] = \min, \min + 1, \dots; \quad (13)$$

3.1.2. Simulation for the Intelligent Analysis of Equilibrium Growth of the Platform Industry

In Section 3.1, the behavior of platform production/selling transactions is evaluated using the supply function, while the behavior of platform purchase/buying transactions is evaluated using the demand function.

First, the regression equation (4) is created for platform produce/selling agent behavior, where the dependent variable is normalized produce/selling transactions, and the independent variable is observed produce/selling transactions.

The regression equation, using the Slope' and Intercept' parameters and the normalized produce/selling transaction dependent variable values estimated through the least squares, provides the estimated supply function values:

$$\frac{\bar{z}'(t) - \text{Intercept}'}{\text{Slope}'}, \quad t = \overline{1995; 1995 + (T - 1)}, \quad T = \overline{1; 24}.$$

Also, the values obtained by subtracting the observed produce/selling transactions from the calculated produce/selling transactions represent the estimates of the platform produce/selling behavior.

Thus, we use computational model to detect the equilibrium to identify time phases of undervalued and overvalued nominal estimate and linguistic variables in the platform produce/selling of the financial and insurance activities industry we get (see Table 5, column (b)-(c)):

- The first phase of undervalued of the platform produce/selling of the financial and insurance activities industry is characterized by a flow of transactions with the following attributes: an entry point of 0.038, a peak deviation of 0.093, and an exit point of 0.007 billion U.S. dollars in undervalued transactions;
- The phase of overvalued of the platform produce/selling of the financial and insurance activities industry is characterized by a flow of transactions with the following attributes: an entry point of 0.066, a peak deviation of 0.526, and an exit point of 0.040 billion U.S. dollars in overvalued transactions;
- The second phase of undervalued of the platform produce/selling of the financial and insurance activities industry is characterized by a flow of transactions with the following attributes: an entry point of 0.279, a peak deviation of 0.466, and an exit point of 0.286 billion U.S. dollars in undervalued transactions.

Next, for the platform purchase/buying behavior, a regression equation (5) is created, where the dependent variable is the normalized purchase/buying transactions and the independent variable is the observed purchase/buying transactions. Using Slope, Intercept parameters, values of normalized purchase/buying transaction dependent variable and least squares were estimated the parameters of regression equation and the demand function values are calculated:

$$\frac{\bar{z}(t) - \text{Intercept}}{\text{Slope}}, \quad t = \overline{1995; 1995 + (T - 1)}, \quad T = \overline{1; 24},$$

Also, the values obtained by subtracting the observed purchase/buying transactions from the calculated purchase/buying transactions represent the estimates of the platform purchase/buying behavior.

We now apply computational model to establish equilibrium, determine time phases of undervaluation and overvaluation of nominal estimate and linguistic variables within the platform purchase/buying in the financial and insurance activities industry we get (see Table 5, column (e)-(f)):

- The first phase of undervalued of the platform purchase/buying of the financial and insurance activities industry is characterized by a flow of transactions with the following attributes: an entry point of 2.442, a peak deviation of 1.552, and an exit point of 0.216 billion U.S. dollars in undervalued transactions;
- The phase of overvalued of the platform purchase/buying of the financial and insurance activities industry is characterized by a flow of transactions with the following attributes: an entry point of 0.511, a peak deviation of 2.331, and an exit point of 0.375 billion U.S. dollars in overvalued transactions;
- The second phase of undervalued of the platform purchase/buying of the financial and insurance activities industry is characterized by a flow of transactions with the following attributes: an entry point of 0.108, a peak deviation of 0.568, and an exit point of 0.413 billion U.S. dollars in undervalued transactions.

Also in Section 3.1, based on studies of the behavior of produce/selling and purchase/buying agents, work is carried out to detect the equilibrium points of the stochastic dynamic state of the

platform industry. Indeed, regression equations (4) and (5) are constructed respectively by applying the least squares method to the supply function of the produce/selling transactions data and the demand function of the purchase/buying transactions. This, in turn, the problem of determining the equilibrium points in the behavior of the mentioned produce/selling and purchase/buying agents leads to the problem of calculating the intersection points of the linear equations (4) of supply and (5) of the demand function.

First, for a platform produce/selling agent, if the equilibrium point lies in the feasible domain of solution, then the desired point is detected using the linear interpolation and the gradient method defined by equation (7). The stopping criterion for iterative calculations is obtained from equality (6). Also for the produce/selling of the platform industry, if the equilibrium point does not belong to the feasible domain of solution, then the desired point is detected by equation (8) for the left side, and equation (9) for the right side and It is determining by linear extrapolation and gradient method. And the stopping criterion for iterative calculations is obtained from equality (6).

Second, for a purchase/buying of a platform industry, if the equilibrium point lies in the feasible domain of solution, then the desired point is detected by linear interpolation and gradient method, defined by equation (11). The criterion for stopping the iterative calculations is obtained from equality (10). Also for the purchase/buying of the platform industry, if the equilibrium point does not belong to the feasible domain of solution, then the desired point is detected by equation (12) for the left part, and (13) for the right part and It is determining by linear extrapolation and gradient method. The criterion for stopping the iterative calculations is obtained from equilibrium (10).

As a result, the equilibrium transaction behavior of the produce/selling and the purchase/buying agents of the platform industry was completely detected by the above computational model and distributed into the following time phases (see Figure 3, the histogram with round marker with gray fill and the histogram with square marker with white fill, Table 6, column (a)-(b)):

- The first time phases cover the period from 1995 to 2004. This period is distinguished by the fact that it does not belong to the feasible domain of solutions for the equilibrium transactions of platform industry produce/selling and purchase/buying agents. That is, for first-time phases the financial and insurance industry has an entry point of 0.159, a peak deviation of 0.228, and an exit point of 0.221 billion U.S. dollars;
- The initial median average was 0.198 and the final median average of the first time phases was 0.174 billion U.S. dollars. That is, in the first time phases, the median average absolute value of equilibrium transactions in the financial and insurance sector decreased by 0.025 billion U.S. dollars, and the median average relative value of equilibrium transactions decreased by 87.52%;
- The second time phases cover the period from 2005 to 2018, this period is in the feasible domain of solution of equilibrium transactions of produce/selling and purchase/buying agents of the platform industry. That is, for the second time phases the financial and insurance industry has an entry point of 0.279, a peak deviation of 2.470, and an exit point of 2.723 billion U.S. dollars;

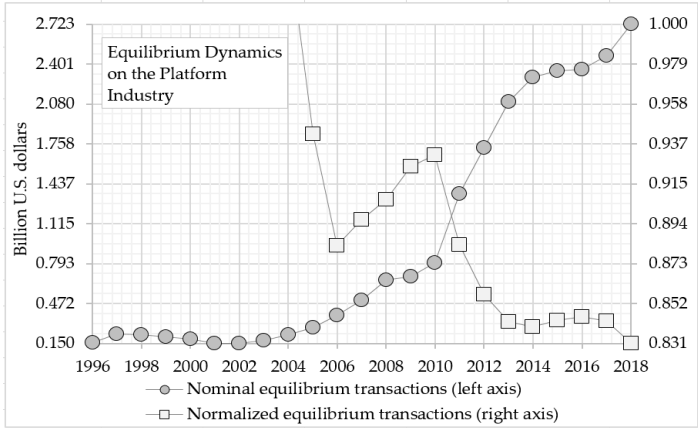


Figure 3. Nominal and normalized equilibrium dynamics of the platform produce/selling and purchase/buying transactions in the financial and insurance activities industry.

- The initial median average was 0.666 and the final median average for the second time phase was 2.288 billion U.S. dollars. That is, in the second time phase, the median average absolute value of equilibrium transactions in the financial and insurance sector increased by 1.622 billion U.S. dollars, and the median average relative value of equilibrium transactions increased by 343.36%.

Thus, analyzing the entry points, peak deviations, exit points, time phases, and increase or decrease of median average values of these transactions enables a deeper insight into the fundamental patterns of inter-industry linkages, which help address theoretical and practical issues related to platform agent’s behavior.

Table 6. Dynamics of nominal and normalized equilibrium transactions of the platform industry and its internal and external ecosystem for Kazakhstan’s financial and insurance activities.

Year	(a)	(b)	(c)	(d)	(e)	(f)	Year	(a)	(b)	(c)	(d)	(e)	(f)
1995	NaN	NaN	NaN	NaN	NaN	NaN	2007	0.501	0.896	0.861	0.233	0.146	0.921
1996	0.159	5.209	0.681	-1.279	0.019	4.433	2008	0.658	0.907	1.012	0.215	0.314	0.877
1997	0.228	4.191	0.645	-0.670	0.023	1.295	2009	0.689	0.925	1.096	0.195	0.359	0.875
1998	0.220	3.773	0.677	-0.515	0.024	1.351	2010	0.802	0.931	1.164	0.173	0.360	0.884
1999	0.200	3.260	0.570	-0.047	0.026	1.366	2011	1.358	0.883	1.185	0.160	0.362	0.891
2000	0.186	2.470	0.568	-0.047	0.026	1.063	2012	1.728	0.857	1.236	0.151	0.373	0.893
2001	0.150	1.759	0.564	-0.104	0.027	1.061	2013	2.097	0.842	1.340	0.144	0.369	0.898
2002	0.151	1.454	0.561	-0.119	0.029	1.032	2014	2.296	0.840	1.427	0.136	0.377	0.893
2003	0.173	1.244	0.551	0.035	0.033	1.041	2015	2.348	0.843	1.583	0.141	0.392	0.883
2004	0.221	1.043	0.596	0.219	0.041	1.034	2016	2.356	0.845	1.699	0.148	0.393	0.889
2005	0.279	0.942	0.705	0.279	0.042	0.996	2017	2.470	0.843	1.784	0.147	0.395	0.890
2006	0.378	0.883	0.766	0.258	0.051	0.936	2018	2.723	0.831	1.783	0.137	0.400	0.888

Note. (a) Nominal equilibrium transactions of the platform industry. (b) Normalized equilibrium transactions of the platform industry. (c) Nominal equilibrium transactions of the internal ecosystem. (d) Normalized equilibrium transactions of the internal ecosystem. (e) Nominal equilibrium transactions of the external ecosystem. (f) Normalized equilibrium transactions of the external ecosystem. A Billion U.S. dollars. Compiled by the authors.

As a result, in Section 3.1 we created, substantiated, and implemented of the computational model on the determine equilibrium states by aligning supply and demand functions of the produce/selling and purchase/buying transactions. The novelty of these results are definition of equilibrium transactions; analysis of time phases of undervalued and overvalued transactions; classification of time phases of equilibrium growth within the area of admissible solutions of the produce/selling and purchase/buying and the significance may be to use resources efficiently and ensure sustainable growth in the financial and insurance activities of Kazakhstan.

3.2. An Algorithm for Determine the Equilibrium of the Internal Ecosystem and Its Application

In Section 3.2 we focus on developing and applying computational model to detect equilibrium transactions within the internal ecosystem of Kazakhstan's financial and insurance activities industry. The usage of normalized data, regression equations, iterative techniques, operations research, mathematical programming and computational model to detect equilibrium transactions allows us to get information on the equilibrium state of internal ecosystem flows and their role in achieving equilibrium growth.

3.2.1. Creating an Algorithm to Determine the Equilibrium in the Internal Ecosystem

Entry: $p(t)$ – the internal ecosystem payment transactions of the total input of financial and insurance activities industry, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$, a billion U.S. dollars (see Table 1, column (c)); $f(t)$ – the internal ecosystem final demand transactions of the total output of the financial and insurance activities industry, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$, a billion U.S. dollars (see Table 1, column (d)).

Outcome: Equilibrium transactions of the internal ecosystem payment and final demand, respectively, of the total input and the total output of financial and insurance activities industry.

Step 1: To create the supply function as a data set on the normalized internal ecosystem payment transactions $[0;1]$ from the domain of the observation $p(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$.

(i) Sorting by the growth of data $p(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$, i.e. rearrange the elements of observation data $z'(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$, into a sequence such that the following chains of inequalities hold: $p(\overline{1995}) \leq p(\overline{1995} + 1) \leq \dots \leq p(\overline{1995} + 23)$, and denote by $p(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$ (see Table 3, column (c)), where

$$p(\overline{1995}) = \min_{t=\overline{1995}; \overline{1995 + (T - 1)}} \{p(t)\}, \quad T = \overline{1}; \overline{24},$$

and

$$p(\overline{1995} + (T - 1)) = \max_{t=\overline{1995}; \overline{1995 + (T - 1)}} \{p(t)\}, \quad T = \overline{1}; \overline{24};$$

(ii) Calculate the cumulative sum of sorted data $p(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$:

$$\text{SUM}_{T=\overline{1}; \overline{24}} \left(p(t = \overline{1995}) : p(t = \overline{1995}; \overline{1995 + (T - 1)}) \right);$$

(iii) To normal the cumulative sum of sorted data $p(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$:

$$\frac{\text{SUM}_{T=\overline{1}; \overline{24}} \left(p(t = \overline{1995}) : p(t = \overline{1995}; \overline{1995 + (T - 1)}) \right)}{p(\overline{1995} + (T - 1))},$$

and denote by $\check{p}(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$ (see Table 4, column (c));

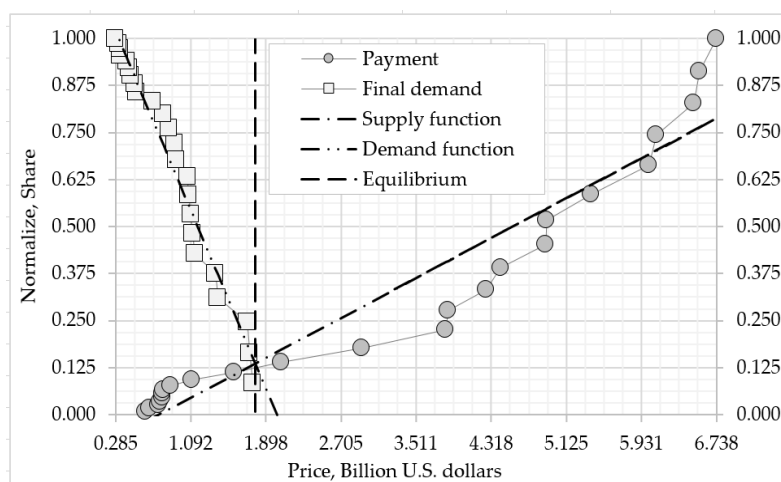


Figure 4. Observation, regression equations, and equilibrium of the internal ecosystem payment and final demand transactions in the financial and insurance activities industry.

(iv) To build and to visualize the supply as a function of normalized internal ecosystem payment transactions $\check{p}(t) \in [0; 1]$ from the domain of the observation $p(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$ (see Figure 4, histogram with a round marker with a gray fill);

- Step 2: Create the regression equations for the supply function of the internal ecosystem payment transactions $p(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$.
- (i) Calculate the slope between the dependent $\check{p}(t)$ and the independent variable $p(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$;
 - (ii) Calculate the intercept between the dependent $\check{p}(t)$ and the independent variable $p(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$;
 - (iii) Calculate the R-square for the regression equation between the dependent $\check{p}(t)$ and the independent variable $p(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$;
 - (iv) Calculate the p-value of parameters for the regression equation between the dependent $\check{p}(t)$ and the independent variable $p(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$;
 - (v) Calculate the standard errors of parameters for the regression equation between the dependent $\check{p}(t)$ and the independent variable $p(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$;

Table 7. Results of the intelligent analysis of equilibrium growth in the internal ecosystem.

Year	(a)	(b)	(c)	(d)	(e)	(f)	Year	(a)	(b)	(c)	(d)	(e)	(f)
$\overline{1995}$	0.803	-0.198	UV	1.874	-0.121	UV	$\overline{2007}$	2.469	1.360	OV	0.721	0.141	OV
$\overline{1996}$	0.867	-0.218	UV	1.735	-0.009	UV	$\overline{2008}$	2.850	1.005	OV	0.657	0.140	OV
$\overline{1997}$	0.940	-0.199	UV	1.599	0.102	UV	$\overline{2009}$	3.272	0.996	OV	0.602	0.077	OV
$\overline{1998}$	1.015	-0.257	UV	1.488	-0.106	UV	$\overline{2010}$	3.708	0.710	OV	0.562	-0.056	UV
$\overline{1999}$	1.093	-0.307	UV	1.378	-0.019	UV	$\overline{2011}$	4.192	0.709	OV	0.522	-0.032	UV
$\overline{2000}$	1.170	-0.382	UV	1.287	-0.153	UV	$\overline{2012}$	4.678	0.232	OV	0.486	-0.040	UV
$\overline{2001}$	1.249	-0.450	UV	1.198	-0.088	OV	$\overline{2013}$	5.210	0.180	OV	0.452	-0.026	UV
$\overline{2002}$	1.336	-0.462	UV	1.110	-0.021	OV	$\overline{2014}$	5.804	0.209	OV	0.420	-0.015	UV
$\overline{2003}$	1.445	-0.344	UV	1.024	0.045	OV	$\overline{2015}$	6.406	-0.315	UV	0.392	-0.054	UV
$\overline{2004}$	1.598	-0.042	UV	0.939	0.117	OV	$\overline{2016}$	7.048	-0.554	UV	0.365	-0.030	UV
$\overline{2005}$	1.802	0.258	OV	0.864	0.072	OV	$\overline{2017}$	7.695	-1.141	UV	0.340	-0.023	UV
$\overline{2006}$	2.091	0.836	OV	0.790	0.131	OV	$\overline{2018}$	8.361	-1.623	UV	0.317	-0.032	UV

Note. (a) Supply function values for the payment transactions. (b) Nominal estimate of the equilibrium of the payment transactions. (c) Linguistic variables: Undervalue and Overvalue of the equilibrium of the payment transactions. (d) Demand function values for the final demand transactions. (e) Nominal estimate of the equilibrium the final demand transactions. (f) Linguistic variables: Undervalue and Overvalue of the equilibrium of the final demand transactions. A Billion U.S. dollars. Compiled by the authors.

- (vi) To build the regression equations for the supply function of the normalized data of the internal ecosystem payment transactions $\check{p}(t)$ on the domain of the observation data $p(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$ [30]:

$$\begin{matrix} \check{p}(t) = & \text{Intercept}' & + & \text{Slope}' \times p(t), & t = \overline{1995}; \overline{1995 + (T - 1)}, \\ \text{R-square} & (\text{Std. Error}) & & (\text{Std. Error}) & T = 1, 2, \dots, 24, \end{matrix} \tag{14}$$

where unknown parameters Slope', Intercept', R-square, p-value, and Standard errors will be estimated by the least squares in the above sub steps (i)-(v);

- (vii) Visualize the regression equations for the supply function of the normalized data of the internal ecosystem payment transactions $\check{p}(t)$ on the domain of the observation data $p(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$ (see Figure 4, a dotted line with one dot, Table 7, column (a)).

Step 3: Create the demand function for the normalized data set of the internal ecosystem final demand transactions $\check{f}(t)$ on the domain of the observation data set $f(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$.

(i) Descending sorted of data $f(t)$, $t = \overline{1995}; \overline{1995 + T}$, i.e. rearrange the elements of observation data $f(t)$, $t = \overline{1995}; \overline{1995 + T}$ into a sequence such that the following chains of inequalities hold: $f(\overline{1995}) \geq f(\overline{1995 + 1d}) \geq \dots \geq f(\overline{1995 + 23})$, and denote by $f(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$ (see Table 3, column (d)), where

$$f(\overline{1995}) = \max_{t=\overline{1995}; \overline{1995+(T-1)}} \{f(t)\}, \quad T = \overline{1}; \overline{24},$$

and

$$f(\overline{1995 + (T - 1)}) = \min_{t=\overline{1995}; \overline{1995+(T-1)}} \{f(t)\}, \quad T = \overline{1}; \overline{24};$$

(ii) Calculate the cumulative sum of sorted data $f(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$:

$$\text{SUM}_{T=\overline{1}; \overline{24}} \left(f(t = \overline{1995}): f(t = \overline{1995}; \overline{1995 + (T - 1)}) \right);$$

(iii) To normal the cumulative sum of sorted data $f(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$:

$$\frac{\text{SUM}_{T=\overline{1}; \overline{24}} \left(f(t = \overline{1995}): f(t = \overline{1995}; \overline{1995 + (T - 1)}) \right)}{f(1995d)},$$

and denote by $\check{f}(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$;

(iv) To build and visualize the demand function to normalized platform final demand transactions $\check{f}(t)$ from the domain of the observation $f(t)$,

$t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$ (see Figure 4, histogram with a square marker with a white fill);

Step 4: Create the regression equations for the demand function of the internal ecosystem final demand transactions: $\check{f}(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$.

(i) Calculate the slope between the dependent $\check{f}(t)$ and the independent variable $f(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$;

(ii) Calculate the intercept between the dependent $\check{f}(t)$ and the independent variable $f(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$;

(iii) Calculate the R-square for the regression equation between the dependent $\check{f}(t)$ and the independent variable $f(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$;

(iv) Calculate the p-value of parameters for the regression equation between the dependent $\check{f}(t)$ and the independent variable $f(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$;

(v) Calculate the standard errors of parameters for the regression equation between the dependent $\check{f}(t)$ and the independent variable $f(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$;

(vi) To build the regression equations for the demand function of the platform purchase/buying transactions $f(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$ [35]:

$$\check{f}(t) = \begin{matrix} \text{Intercept} \\ \text{R - square} \end{matrix} + \begin{matrix} \text{Slope} \\ (\text{Std. Error}) \end{matrix} \times f(t), \quad t \in \overline{1995}; \overline{1995 + (T - 1)}, \quad T = 1, 2, \dots, 24, \quad (15)$$

where unknown parameters Slope, Intercept, R-square, p-value, Standard errors will be estimated by the least squares in the above sub-steps (i)–(v);

(vii) Visualize the regression equations for the demand function of the internal ecosystem final demand transactions $\check{f}(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$ (see Figure 4, the dotted line with two dots, Table 7, column (d)).

Step 5: Find the equilibrium transactions $p(t^*)$ of the internal ecosystem payment for the financial and insurance activities industry, i.e. prove that $\exists! t^* \in \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$ | $p(t^*) = f(t^*)$.

(i) Construct equations for the equilibrium transactions of the internal ecosystem payment $\check{p}(t)$ and the final demand $\check{f}(t)$ from the equality condition of equations (14) and (15), i.e. $\check{p}(t) = \check{f}(t)$. Indeed, from (14) and (15) we obtain:

$$\begin{aligned} \text{Intercept}' + \text{Slope}' \times p(t) &= \text{Intercept} + \text{Slope} \times f(t), \\ t &= \overline{1995}; \overline{1995} + (T - 1), \quad T = \overline{1}; \overline{24}; \end{aligned} \quad (16)$$

(ii) Find the normalized sequences $\check{p}(t)$, $t \in \overline{1995}; \overline{1995} + (T - 1)$, $T = \overline{1}; \overline{24}$, such that these functions satisfied conditions (16):

(iia) If for $\{p(t)\}$, $t = \overline{1995}; \overline{1995} + (T - 1)$, $T = \overline{1}; \overline{24}$ the following holds:

$$\min_{t=\overline{1995}; \overline{1995}+(T-1)} \{p(t)\} < \{p(t)\} < \max_{t=\overline{1995}; \overline{1995}+(T-1)} \{p(t)\},$$

then we use linear interpolation and ensure convergence of the iteration using the gradient method [31]:

$$\check{p} = \check{p}[j] + \frac{\check{p}[j+1] - \check{p}[j]}{p[j+1] - p[j]} \cdot (p - p[j]), \quad j = 1, 2, \dots; \quad (17)$$

(iib) If for $\{p(t)\}$, $t \in \overline{1995}; \overline{1995} + (T - 1)$, $T = \overline{1}; \overline{24}$ the following holds:

$$\min_{t=\overline{1995}; \overline{1995}+(T-1)} \{p(t)\} > \{p(t)\},$$

or

$$\{p(t)\} > \max_{t=\overline{1995}; \overline{1995}+(T-1)} \{p(t)\}.$$

Then, respectively, we use linear extrapolation and ensure convergence of the iteration by the gradient method [31]:

$$\check{p} = \check{p}[\min] + \frac{\check{p}[\min+1] - \check{p}[\min]}{p[\min+1] - p[\min]} \cdot (p - p[\min]), \quad [\cdot] = \min, \min+1, \dots; \quad (18)$$

or

$$\check{p} = \check{p}[\max] + \frac{\check{p}[\max] - \check{p}[\max-1]}{p[\max] - p[\max-1]} \cdot (p - p[\max]), \quad [\cdot] = \max, \max-1, \dots; \quad (19)$$

Step 6: Find the equilibrium transactions $f(t^*)$ of the internal ecosystem final demand for the financial and insurance activities industry, i.e. prove that

$\exists! t^* \in \overline{1995}; \overline{1995} + (T - 1)$, $T = \overline{1}; \overline{24}$ | $z(t^*) = z'(t^*)$.

(i) Construct equations for the equilibrium transactions of the internal ecosystem final demand $\check{f}(t)$ and the internal ecosystem payment $\check{p}(t)$ from the equality condition of equations (14) and (15), i.e. $\check{f}(t) = \check{p}(t)$. Indeed, from (14) and (15) we obtain:

$$\begin{aligned} \text{Intercept} + \text{Slope} \times f(t) &= \text{Intercept}' + \text{Slope}' \times p(t), \\ t &= \overline{1995}; \overline{1995} + (T - 1), \quad T = \overline{1}; \overline{24}; \end{aligned} \quad (20)$$

(ii) Find the normalized sequences $\check{f}(t)$, $t = \overline{1995}; \overline{1995} + (T - 1)$, $T = \overline{1}; \overline{24}$, such that these functions satisfied conditions (20):

(iia) If for $\{f(t)\}$, $t = \overline{1995}; \overline{1995} + (T - 1)$, $T = \overline{1}; \overline{24}$ the following holds:

$$\max_{t=\overline{1995}; \overline{1995}+(T-1)} \{f(t)\} > \{f(t)\} > \min_{t=\overline{1995}; \overline{1995}+(T-1)} \{f(t)\},$$

then we use linear interpolation and ensure convergence of the iteration using the gradient method [31]:

$$\check{f} = \check{f}[j] + \frac{\check{f}[j+1] - \check{f}[j]}{f[j+1] - f[j]} \cdot (f - f[j]), \quad j = 1, 2, \dots; \quad (21)$$

(iib) If for $\{f(t)\}$, $t = \overline{1995}; \overline{1995} + (T - 1)$, $T = \overline{1}; \overline{24}$ the following holds:

$$\max_{t=1995;1995+(T-1)} \{f(t)\} < \{f(t)\},$$

or

$$\{f(t)\} < \min_{t=1995;1995+(T-1)} \{f(t)\}.$$

Then, respectively, we use linear extrapolation and ensure convergence of the iteration by the gradient method [31]:

$$\check{f} = \check{f}[\max] + \frac{\check{f}[\max] - \check{f}[\max - 1]}{f[\max] - f[\max - 1]} \cdot (f - f[\max]), \quad [\cdot] = \max, \max - 1, \dots; \quad (22)$$

or

$$\check{f} = \check{f}[\min] + \frac{\check{f}[\min + 1] - \check{f}[\min]}{f[\min + 1] - f[\min]} \cdot (f - f[\min]), \quad [\cdot] = \min, \min + 1, \dots; \quad (23)$$

3.2.2. Simulation and Its Application in Intelligent Analysis of Equilibrium Growth of the Internal Ecosystem

In Section 3.2, the behavior of internal ecosystem payment transactions is evaluated using the supply function, while the behavior of internal ecosystem final demand transactions is evaluated using the demand function.

First, the regression equation (14) is created for internal ecosystem payment agent behavior, where the dependent variable is normalized payment, and the independent variable is observed payment transactions.

The regression equation, using the Slope' and Intercept' parameters and the normalized payment transaction dependent variable values estimated through the least squares, provides the estimated supply function values:

$$\frac{\check{p}(t) - \text{Intercept}'}{\text{Slope}'}, \quad t = \overline{1995; 1995 + (T - 1)}, \quad T = \overline{1; 24}.$$

Also, the values obtained by subtracting the observed payment transactions from the calculated payment transactions represent the estimates of the internal ecosystem payment behavior.

Thus, we use computational model to detect the equilibrium to identify time phases of undervalued and overvalued nominal estimate and linguistic variables in the internal ecosystem payment of the financial and insurance activities industry we get (see Table 7, column (b)-(c)):

- The first phase of undervalued the internal ecosystem payment of the financial and insurance activities industry is characterized by a flow of transactions with the following attributes: an entry point of 0.198, a peak deviation of 0.462, and an exit point of 0.042 billion U.S. dollars in undervalued transactions;
- The phase of overvalued internal ecosystem payment of the financial and insurance activities industry is characterized by a flow of transactions with the following attributes: an entry point of 0.258, a peak deviation of 1.360, and an exit point of 0.209 billion U.S. dollars in overvalued transactions;
- The second phase of undervalued the internal ecosystem payment of the financial and insurance activities industry is characterized by a flow of transactions with the following attributes: an entry point of 0.315, a peak deviation of 1.141, and an exit point of 1.623 billion U.S. dollars in undervalued transactions.

Next, for the internal ecosystem final demand behavior, a regression equation (15) is created, where the dependent variable is the normalized final demand transactions and the independent variable is the observed final demand transactions. Using Slope, Intercept parameters, values of normalized final demand transaction dependent variable and least squares were estimated the parameters of the regression equation and the demand function values are calculated:

$$\frac{\check{f}(t) - \text{Intercept}}{\text{Slope}}, \quad t = \overline{1995}; \overline{1995 + (T - 1)}, \quad T = \overline{1}; \overline{24},$$

Also, the values obtained by subtracting the observed final demand transactions from the calculated final demand transactions represent the estimates of the internal ecosystem's final demand behavior.

We now apply computational model to establish equilibrium, determine time phases of undervaluation and overvaluation of nominal estimate and linguistic variables within the internal ecosystem final demand in the financial and insurance activities industry we get (see Table 7, column (e)-(f)):

- The first phase of undervalued of the internal ecosystem final demand of the financial and insurance activities industry is characterized by a flow of transactions with the following attributes: an entry point of 0.121, a peak deviation of 0.106, and an exit point of 0.021 billion U.S. dollars in undervalued transactions;
- The phase of overvalued of the internal ecosystem final demand of the financial and insurance activities industry is characterized by a flow of transactions with the following attributes: an entry point of 0.045, a peak deviation of 0.141, and an exit point of 0.077 billion U.S. dollars in overvalued transactions;
- The second phase of undervalued of the internal ecosystem final demand of the financial and insurance activities industry is characterized by a flow of transactions with the following attributes: an entry point of 0.056, a peak deviation of 0.054, and an exit point of 0.032 billion U.S. dollars in undervalued transactions.

Also, in Section 3.2, based on studies of the behavior of payment and final demand agents, work is carried out to detect the equilibrium points of the stochastic dynamic state of the internal ecosystem. Indeed, regression equations (14) and (15) are constructed respectively by applying the least squares method to the supply function of the payment transactions data and the demand function of the final demand transactions. This, in turn, the problem of determining the equilibrium points in the behavior of the mentioned payment and final demand agents leads to the problem of calculating the intersection points of the linear equations (14) of supply and (15) of demand function.

First, for an internal ecosystem payment agent, if the equilibrium point lies in the feasible domain of solution, then the desired point is detected using the linear interpolation and the gradient method defined by equation (17). The stopping criterion for iterative calculations is obtained from equality (16). Also for the internal ecosystem payment, if the equilibrium point does not belong to the feasible domain of solution, then the desired point is detected by equation (18) for the left side and equation (19) for the right side and It is determining by linear extrapolation and gradient method. The stopping criterion for iterative calculations is obtained from equality (16).

Second, for a final demand of an internal ecosystem, if the equilibrium point lies in the feasible domain of solution, then the desired point is detected by linear interpolation and gradient method, defined by equation (21). The criterion for stopping the iterative calculations is obtained from equality (20). Also for the final demand of the internal ecosystem, if the equilibrium point does not belong to the feasible domain of solution, then the desired point is detected by equation (22) for the left part, and (23) for the right part, and It is determining by linear extrapolation and gradient method. The criterion for stopping the iterative calculations is obtained from equilibrium (20).

As a result, the equilibrium transaction behavior of the payment and the final demand agents of the internal ecosystem was completely defined and distributed into the following time phases (see Figure 5, the histogram with round marker with gray fill and the histogram with a square marker with white fill, Table 6, column (c)-(d)):

- The first time phases cover the period from 1995 to 2002. This period is distinguished by the fact that it does not belong to the feasible domain of solution for the equilibrium transactions of internal ecosystem payment and final demand agents. That is, for first-time phases the financial and insurance industry has an entry point of 0.681, a peak deviation of 0.677, and an exit point of 0.570 billion U.S. dollars;

- The initial median average was 0.643 and the final median average of the first time phases was 0.565 billion U.S. dollars. That is, in the first time phases, the median average absolute value of equilibrium transactions in the financial and insurance sector decreased by 0.079 billion U.S. dollars, and the median average relative value of equilibrium transactions decreased by 87.74%;
- The second time phases cover the period from 2003 to 2018, this period is in the feasible domain of solution of equilibrium transactions of payment and the final demand agents of the internal ecosystem. That is, for the second time phases the financial and insurance industry has an entry point of 0.551, a peak deviation of 1.096, and an exit point of 1.164 billion U.S. dollars;
- The initial median average was 0.844 and the final median average for the second time phase was 1.505 billion U.S. dollars. That is, in the second time phase, the median average absolute value of equilibrium transactions in the financial and insurance sector increased by 0.661 billion U.S. dollars, and the median average relative value of equilibrium transactions increased by 178.31%.

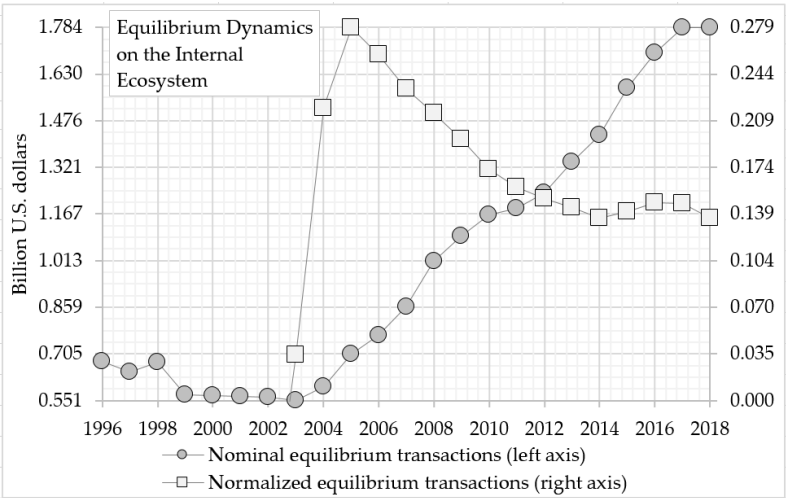


Figure 5. Nominal and normalized equilibrium dynamics of the internal ecosystem payment and final demand transactions in the financial and insurance activities industry.

Thus, analyzing the entry points, peak deviations, exit points, time phases, and increase or decrease of median average values of these transactions enables a deeper insight into the fundamental patterns of inter-industry linkages, which help address theoretical and practical issues related to the internal ecosystem agent’s behavior.

In Section 3.2 we created, substantiated, and implemented of the computational model on the determine equilibrium states by aligning supply and demand functions of the internal ecosystem transactions. The novelty of these results are definition of equilibrium transactions; analysis of time phases of undervalued and overvalued transactions; classification of time phases of equilibrium growth within the area of admissible solutions of the internal ecosystem payments and demand, classifying equilibrium transactions and the significance may be to use resources efficiently and ensure sustainable growth in the financial and insurance activities of Kazakhstan.

3.3. An Algorithm for Determine the Equilibrium on the External Ecosystem and Its Application

In Section 3.3 we offer on the development and application of computational model to detect equilibrium transactions within the external ecosystem of Kazakhstan's financial and insurance activities industry. By analyzing import (outflow and (or) demand for foreign currency) and export (inflow and (or) supply for foreign currency) transactions, the algorithm employs normalized data, regression modeling, operations research and mathematical programming to align supply and demand functions, providing a systematic approach to understanding external ecosystem interactions and achieving equilibrium growth.

3.3.1. An Algorithm for Determine the Equilibrium on the External Ecosystem

Entry: Let $e(t)$ – the external ecosystem export (inflow and (or) supply for foreign currency) transactions of the total output of financial and insurance activities industry, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$, a billion U.S. dollars (see Table 1, column (f));

$m(t)$ – the external ecosystem import (outflow and (or) demand for foreign currency) transactions of the total input of financial and insurance activities industry,

$t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$, a billion U.S. dollars (see Table 1, column (e)).

Outcome: Equilibrium transactions of the external ecosystem import and exports, respectively, of the total input and the total output of the financial and insurance activities industry.

Step 1: To create the supply function as a data set on the normalized external ecosystem export transactions $[0;1]$ from the domain of the observation $e(t)$,

$t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$.

(i) Sorting by growth of data $e(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, i.e. rearrange the elements of observation data $e(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$ into a sequence such that the following chains of inequalities hold: $e(\overline{1995}) \leq e(\overline{1995} + 1) \leq \dots \leq e(\overline{1995} + 23)$, and denote by $e(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$ (see Table 3, column (f)), where

$$e(\overline{1995}) = \min_{t=\overline{1995}; \overline{1995+(T-1)}} \{e(t)\}, \quad T = \overline{1}; \overline{24},$$

and

$$e(\overline{1995} + (T - 1)) = \max_{t \in \overline{1995}; \overline{1995+(T-1)}} \{e(t)\}, \quad T = \overline{1}; \overline{24};$$

(ii) Calculate the cumulative sum of sorted data $m(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$:

$$\text{SUM}_{T=\overline{1}; \overline{24}} \left(e(t \in \overline{1995}): e(t = \overline{1995}; \overline{1995 + (T - 1)}) \right);$$

(iii) To normal the cumulative sum of sorted data $e(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$:

$$\frac{\text{SUM}_{T=\overline{1}; \overline{24}} \left(e(t = \overline{1995}): e(t = \overline{1995}; \overline{1995 + (T - 1)}) \right)}{e(\overline{1995} + (T - 1))},$$

and denote by $\check{e}(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$ (see Table 4, column (f));

(iv) To build and to visualize the supply as function to normalized of external ecosystem export transactions $\check{e}(t) \in [0; 1]$ from domain of the observation $e(t)$,

$t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$ (see Figure 6, histogram with a round marker with a gray fill);

Step 2: Create the regression equations for the supply function of the external ecosystem export transactions $e(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$.

(i) Calculate the slope between the dependent $\check{e}(t)$ and the independent variable $e(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$;

(ii) Calculate the intercept between the dependent $\check{e}(t)$ and the independent variable $e(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$;

(iii) Calculate the R-square for the regression equation between the dependent $\check{e}(t)$ and the independent variable $e(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$;

(iv) Calculate the p-value of parameters for the regression equation between the dependent $\check{e}(t)$ and the independent variable $e(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$,

$T = \overline{1}; \overline{24}$;

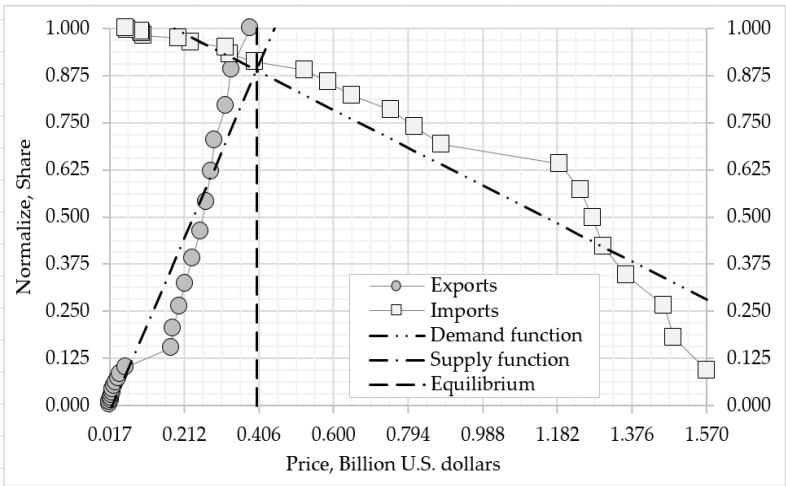


Figure 6. Observation, regression equations, and equilibrium of the external ecosystem import and export transactions in the financial and insurance activities industry.

- (v) Calculate the standard errors of parameters for the regression equation between the dependent $\check{e}(t)$ and the independent variable $e(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; 24$;
- (vi) To build the regression equations for the supply function of the normalized data of the internal ecosystem payment transactions $\check{e}(t)$ on domain of the observation data $e(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; 24$ [30]:

$$\check{e}(t) = \begin{matrix} \text{R-square} & \text{Intercept'} & \text{Slope'} \times e(t), & t = \overline{1995}; \overline{1995 + (T - 1)}, \\ & (\text{Std. Error}) & (\text{Std. Error}) & T = \overline{1}, 2, \dots, 24, \end{matrix} \tag{24}$$

where unknown parameters Slope', Intercept', R-square, p-value, and Standard errors will be estimated by the least squares in the above sub steps (i)–(v);

- (vii) Visualize the regression equations for the supply function of the normalized data of the external ecosystem export transactions $\check{e}(t)$ on the domain of the observation data $e(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; 24$ (see Figure 6, a dotted line with one dot, Table 8, column (a)).

Table 8. Results of the intelligent analysis of equilibrium growth in the external ecosystem.

Year	(a)	(b)	(c)	(d)	(e)	(f)	Year	(a)	(b)	(c)	(d)	(e)	(f)
$\overline{1995}$	0.026	−0.009	UV	1.933	−0.363	UV	$\overline{2007}$	0.089	0.089	OV	0.460	0.126	OV
$\overline{1996}$	0.029	−0.011	UV	1.765	−0.281	UV	$\overline{2008}$	0.111	0.070	OV	0.400	0.125	OV
$\overline{1997}$	0.031	−0.010	UV	1.599	−0.141	UV	$\overline{2009}$	0.135	0.065	OV	0.355	0.040	OV
$\overline{1998}$	0.034	−0.012	UV	1.445	−0.084	UV	$\overline{2010}$	0.161	0.052	OV	0.318	0.013	OV
$\overline{1999}$	0.036	−0.014	UV	1.297	0.004	OV	$\overline{2011}$	0.189	0.044	OV	0.282	0.038	OV
$\overline{2000}$	0.040	−0.014	UV	1.153	0.122	OV	$\overline{2012}$	0.220	0.033	OV	0.256	−0.027	UV
$\overline{2001}$	0.043	−0.016	UV	1.012	0.230	OV	$\overline{2013}$	0.252	0.016	OV	0.233	−0.036	UV
$\overline{2002}$	0.046	−0.017	UV	0.877	0.311	OV	$\overline{2014}$	0.286	−0.006	UV	0.221	−0.116	UV
$\overline{2003}$	0.050	−0.017	UV	0.777	0.105	OV	$\overline{2015}$	0.322	−0.032	UV	0.210	−0.108	UV
$\overline{2004}$	0.055	−0.016	UV	0.685	0.125	OV	$\overline{2016}$	0.360	−0.040	UV	0.198	−0.099	UV
$\overline{2005}$	0.060	−0.017	UV	0.600	0.149	OV	$\overline{2017}$	0.401	−0.067	UV	0.191	−0.127	UV
$\overline{2006}$	0.068	−0.007	UV	0.526	0.120	OV	$\overline{2018}$	0.447	−0.064	UV	0.184	−0.126	UV

Note. (a) Supply function values for the export transactions. (b) Nominal estimate of the equilibrium, of the export transactions. (c) Linguistic variables: Undervalue and Overvalue of the equilibrium of the export transactions. (d) Demand function values for the import transactions. (e) Nominal estimate of the equilibrium of

the import transactions. (f) Linguistic variables: Undervalue and Overvalue of the equilibrium the import transactions. A Billion U.S. dollars. Compiled by the authors.

Step 3: To create the demand function as a data set on the normalized of the external ecosystem import transactions $[0;1]$ from the domain of the observation $m(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1; 24}$.

(i) Descending sorted of data $m(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, i.e. rearrange the elements of observation data $m(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$ into a sequence such that the following chains of inequalities hold: $m(\overline{1995}) \geq m(\overline{1995 + 1}) \geq \dots \geq m(\overline{1995 + 23})$, and denote by $m(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1; 24}$ (see Table 3, column (e)), where

$$m(\overline{1995}) = \frac{\max}{t=\overline{1995}; \overline{1995+(T-1)}} \{m(t)\}, \quad T = \overline{1; 24},$$

and

$$m(\overline{1995 + (T - 1)}) = \frac{\min}{t=\overline{1995}; \overline{1995+(T-1)}} \{m(t)\}, \quad T = \overline{1; 24};$$

(ii) Calculate the cumulative sum of sorted data $m(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1; 24}$:

$$\text{SUM}_{T=\overline{1; 24}} \left(m(t = \overline{1995}): m(t = \overline{1995}; \overline{1995 + (T - 1)}) \right);$$

(iii) To normal the cumulative sum of sorted data $m(t)$, $t \in \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1; 24}$:

$$\frac{\text{SUM}_{T=\overline{1; 24}} \left(m(t = \overline{1995}): m(t = \overline{1995}; \overline{1995 + (T - 1)}) \right)}{m(\overline{1995})},$$

and denote by $\check{m}(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1; 24}$;

(iv) To build and visualize the demand function to normalized external ecosystem import transactions $\check{m}(t)$ from the domain of the observation $m(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1; 24}$ (see Figure 6, histogram with a square marker with a white fill);

Step 4: Create the regression equations for the demand function of the external ecosystem import transactions: $\check{m}(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1; 24}$.

(i) Calculate the slope between the dependent $\check{m}(t)$ and the independent variable $m(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1; 24}$;

(ii) Calculate the intercept between the dependent $\check{m}(t)$ and the independent variable $m(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1; 24}$;

(iii) Calculate the R-square for the regression equation between the dependent $\check{m}(t)$ and the independent variable $m(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1; 24}$;

(iv) Calculate the p-value of parameters for the regression equation between the dependent $\check{m}(t)$ and the independent variable $m(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1; 24}$;

(v) Calculate the standard errors of parameters for the regression equation between the dependent $\check{m}(t)$ and the independent variable $m(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1; 24}$;

(vi) To build the regression equations for the demand function of the external ecosystem import transactions $\check{m}(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1; 24}$ [35]:

$$\check{m}(t) = \begin{matrix} \text{Intercept} \\ \text{R - square} \end{matrix} + \begin{matrix} \text{Slope} \\ (\text{Std. Error}) \end{matrix} \times m(t), \quad t = \overline{1995}; \overline{1995 + (T - 1)}, \quad T = \overline{1, 2, \dots, 24}, \quad (25)$$

where unknown parameters Slope, Intercept, R-square, p-value, and Standard errors will be estimated by the least squares in the above sub-steps (i)–(v);

(vii) Visualize the regression equations for the demand function of the external ecosystem import transactions $\check{m}(t)$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1; 24}$ (see Figure 6, the dotted line with two dots, Table 8, column (d)).

Step 5: Find the equilibrium transactions $e(t^*)$ of the external ecosystem export for the financial and insurance activities industry, i.e. prove that

$\exists! t^* \in \overline{1995; 1995 + (T - 1)}, T = \overline{1; 24} | e(t^*) = m(t^*)$.

(i) Construct equations for the equilibrium transactions of the external ecosystem the exports $\check{e}(t)$ and import $\check{m}(t)$ from the equality condition of equations (24) and (25), i.e. $\check{e}(t) = \check{m}(t)$. Indeed, from (24) and (25) we obtain:

$$\begin{aligned} \text{Intercept}' + \text{Slope}' \times e(t) &= \text{Intercept} + \text{Slope} \times m(t), \\ t &= \overline{1995; 1995 + (T - 1)}, T = \overline{1; 24}; \end{aligned} \quad (26)$$

(ii) Find the normalized sequences $\check{e}(t)$, $t \in \overline{1995; 1995 + (T - 1)}, T = \overline{1; 24}$, such that these functions satisfied conditions (26):

(iia) If for $\{\check{e}(t)\}$, $t = \overline{1995; 1995 + (T - 1)}, T = \overline{1; 24}$ the following holds:

$$\min_{t=\overline{1995; 1995+(T-1)}} \{e(t)\} < \{e(t)\} < \max_{t=\overline{1995; 1995+(T-1)}} \{e(t)\},$$

then we use linear interpolation and ensure convergence of the iteration using the gradient method [31]:

$$\check{e} = \check{e}[j] + \frac{\check{e}[j+1] - \check{m}[j]}{e[j+1] - e[j]} \cdot (e - e[j]), \quad j = 1, 2, \dots; \quad (27)$$

(iib) If for $\{e(t)\}$, $t = \overline{1995; 1995 + (T - 1)}, T = \overline{1; 24}$ the following holds:

$$\min_{t=\overline{1995; 1995+(T-1)}} \{e(t)\} > \{e(t)\},$$

or

$$\{e(t)\} > \max_{t=\overline{1995g; 1995g+(T-1)g}} \{e(t)\}.$$

Then, respectively, we use linear extrapolation and ensure convergence of the iteration by the gradient method [31]:

$$\check{e} = \check{e}[\min] + \frac{\check{e}[\min+1] - \check{e}[\min]}{e[\min+1] - e[\min]} \cdot (e - e[\min]), \quad [\cdot] = \min, \min+1, \dots; \quad (28)$$

or

$$\check{e} = \check{e}[\max] + \frac{\check{e}[\max] - \check{e}[\max-1]}{e[\max] - e[\max-1]} \cdot (e - e[\max]), \quad [\cdot] = \max, \max-1, \dots; \quad (29)$$

Step 6: Find the equilibrium transactions $m(t^*)$ of the external ecosystem imports for the financial and insurance activities industry, i.e. prove that

$\exists! t^* \in \overline{1995; 1995 + (T - 1)}, T = \overline{1; 24} | m(t^*) = e(t^*)$.

(i) Construct equations for the equilibrium transactions of the external ecosystem exports $\check{e}(t)$ and the external ecosystem import $\check{m}(t)$ from the equality condition of equations (24) and (25), i.e. $\check{m}(t) = \check{e}(t)$. Indeed, from (24) and (25) we obtain:

$$\begin{aligned} \text{Intercept} + \text{Slope} \times m(t) &= \text{Intercept}' + \text{Slope}' \times e(t), \\ t &= \overline{1995; 1995 + (T - 1)}, T = \overline{1; 24}; \end{aligned} \quad (30)$$

(ii) Find the normalized sequences $\check{m}(t)$, $t = \overline{1995; 1995 + (T - 1)}, T = \overline{1; 24}$, such that these functions satisfied conditions (30):

(iia) If for $\{m(t)\}$, $t = \overline{1995; 1995 + (T - 1)}, T = \overline{1; 24}$ the following holds:

$$\max_{t=\overline{1995; 1995+(T-1)}} \{m(t)\} > \{m(t)\} > \min_{t=\overline{1995; 1995+(T-1)}} \{m(t)\},$$

then we use linear interpolation and ensure convergence of the iteration using the gradient method [36]:

$$\tilde{m} = \tilde{m}[j] + \frac{\tilde{m}[j+1] - \tilde{m}[j]}{m[j+1] - m[j]} \cdot (m - m[j]), \quad j = 1, 2, \dots; \quad (31)$$

(iib) If for $\{m(t)\}$, $t = \overline{1995}; \overline{1995 + (T - 1)}$, $T = \overline{1}; \overline{24}$ the following holds:

$$\max_{t=\overline{1995}; \overline{1995 + (T - 1)}} \{m(t)\} < \{m(t)\},$$

or

$$\{m(t)\} < \min_{t=\overline{1995}; \overline{1995 + (T - 1)}} \{m(t)\}.$$

Then, respectively, we use linear extrapolation and ensure convergence of the iteration by the gradient method [36]:

$$\tilde{m} = \tilde{m}[\max] + \frac{\tilde{m}[\max] - \tilde{m}[\max - 1]}{m[\max] - m[\max - 1]} \cdot (m - m[\max]), \quad [\cdot] = \max, \max - 1, \dots; \quad (32)$$

or

$$\tilde{m} = \tilde{m}[\min] + \frac{\tilde{m}[\min + 1] - \tilde{m}[\min]}{m[\min + 1] - m[\min]} \cdot (m - m[\min]), \quad [\cdot] = \min, \min + 1, \dots; \quad (33)$$

3.3.2. Simulation and Its Application in Intelligent Analysis of Equilibrium Growth of the External Ecosystem

In Section 3.3, the behavior of external ecosystem export (inflow and (or) supply for foreign currency) transactions is evaluated using the supply function, while the behavior of external ecosystem imports (outflow and (or) demand for foreign currency) transactions is evaluated using the demand function.

First, the regression equation (24) is created for external ecosystem export agent behavior, where the dependent variable is normalized export transactions, and the independent variable is observed export transactions.

The regression equation, using the Slope' and Intercept' parameters and the normalized external ecosystem exports transaction dependent variable values estimated through the least squares, provides the estimated supply function values:

$$\frac{\check{e}(t) - \text{Intercept}'}{\text{Slope}'}, \quad t = \overline{1995}; \overline{1995 + (T - 1)}, \quad T = \overline{1}; \overline{24}.$$

Also, the values obtained by subtracting the observed export transactions from the calculated export transactions represent the estimates of the external ecosystem export behavior.

Thus, we use computational model to detect the equilibrium to identify time phases of undervalued and overvalued nominal estimate and linguistic variables in the external ecosystem export of the financial and insurance activities industry we get (see Table 8, column (b)-(c)):

- The first phase of undervalued the external ecosystem export of the financial and insurance activities industry is characterized by a flow of transactions with the following attributes: an entry point of 0.009, a peak deviation of 0.017, and an exit point of 0.007 billion U.S. dollars in undervalued transactions;
- The phase of overvalued external ecosystem export of the financial and insurance activities industry is characterized by a flow of transactions with the following attributes: an entry point of 0.089, a peak deviation of 0.070, and an exit point of 0.016 billion U.S. dollars in overvalued transactions;
- The second phase of undervalued the external ecosystem export of the financial and insurance activities industry is characterized by a flow of transactions with the following attributes: an entry point of 0.006, a peak deviation of 0.067, and an exit point of 0.064 billion U.S. dollars in undervalued transactions.

Next, for the external ecosystem import behavior, a regression equation (25) is created, where the dependent variable is the normalized export transactions and the independent variable is the observed import transactions. Using Slope, Intercept parameters, values of normalized import transaction dependent variable, and least squares were estimated the parameters of the regression equation and the demand function values are calculated:

$$\frac{\tilde{m}(t) - \text{Intercept}}{\text{Slope}}, \quad t = \overline{1995}; \overline{1995 + (T - 1)}, \quad T = \overline{1}; \overline{24},$$

Also, the values obtained by subtracting the observed import transactions from the calculated import transactions represent the estimates of the external ecosystem import behavior.

We now apply computational model to establish equilibrium, determine time phases of undervaluation and overvaluation of nominal estimate and linguistic variables within the external ecosystem import in the financial and insurance activities industry (see Table 8, column (e)-(f)):

- The first phase of undervalued of the external ecosystem import of the financial and insurance activities industry is characterized by a flow of transactions with the following attributes: an entry point of 0.363, a peak deviation of 0.281, and an exit point of 0.084 billion U.S. dollars in undervalued transactions;
- The phase of overvalued external ecosystem import of the financial and insurance activities industry is characterized by a flow of transactions with the following attributes: an entry point of 0.004, a peak deviation of 0.149, and an exit point of 0.038 billion U.S. dollars in overvalued transactions;
- The second phase of undervalued the external ecosystem import of the financial and insurance activities industry is characterized by a flow of transactions with the following attributes: an entry point of 0.027, a peak deviation of 0.127, and an exit point of 0.126 billion U.S. dollars in undervalued transactions.

Also, in Section 3.3, based on studies of the behavior of import and export agents, work is carried out to detect the equilibrium points of the stochastic dynamic state of the external ecosystem. Indeed, regression equations (24) and (25) are constructed respectively by applying the least squares method to the supply function of the import transactions data and the demand function of the export transactions. This, in turn, the problem of determining the equilibrium points in the behavior of the mentioned import and export agents leads to the problem of calculating the intersection points of the linear equations (24) of supply and (25) of demand function.

First, for the external ecosystem import agent, if the equilibrium point lies in the feasible domain of the solution, then the desired point is detected using the linear interpolation and the gradient method defined by equation (27). The stopping criterion for iterative calculations is obtained from equality (26). Also for the import of the external ecosystem, if the equilibrium point does not belong to the feasible domain of solution, then the desired point is detected by equation (28) for the left side, and equation (29) for the right side and It is determining by linear extrapolation and gradient method. The stopping criterion for iterative calculations is obtained from equality (26).

Second, for an export of an external ecosystem, if the equilibrium point lies in the feasible domain of solution, then the desired point is detected by linear interpolation and gradient method, defined by equation (31). The criterion for stopping the iterative calculations is obtained from equality (30). Also, for the export of the external ecosystem, if the equilibrium point does not belong to the feasible domain of solution, then the desired point is detected by equation (32) for the left part and (33) for the right part, and It is determining by linear extrapolation and gradient method. The criterion for stopping the iterative calculations is obtained from equilibrium (30).

As a result, the equilibrium transaction behavior of the export and the import agents of the external ecosystem industry was completely determining by the above model and distributed into the following time phases (see Figure 7, the histogram with round marker with gray fill and the histogram with square marker with white fill, Table 6, column (e)-(f)):

- The first time phases cover the period from 1995 to 2004. This period is distinguished by the fact that it does not belong to the feasible domain of solution for the equilibrium transactions of

external ecosystem import and export agents. That is, for first time phases the financial and insurance industry has an entry point of 0.019, a peak deviation of 0.033, and an exit point of 0.041 billion U.S. dollars;

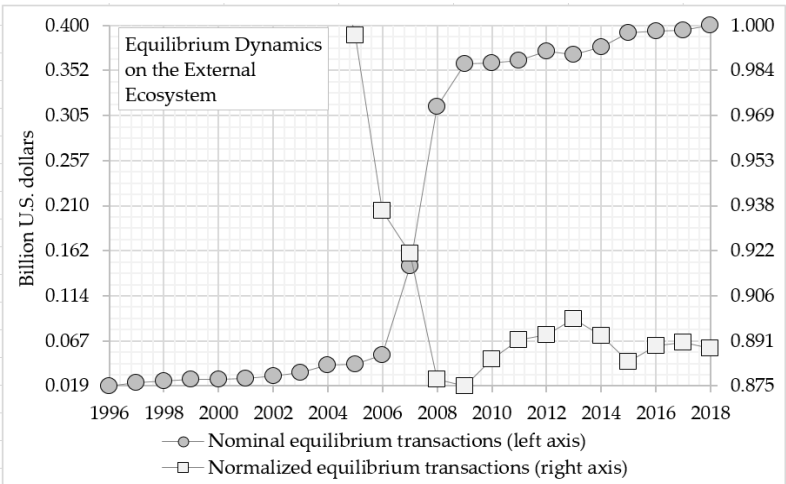


Figure 7. Nominal and normalized equilibrium dynamics of the external ecosystem import and export transactions in the financial and insurance activities industry.

- The initial median average was 0.024 and the final median average of the first-time phases was 0.033 billion U.S. dollars. That is, in the first time phase, the median average absolute value of equilibrium transactions in the financial and insurance sector increased by 0.009 billion U.S. dollars, and the median average relative value of equilibrium transactions decreased by 138.41%;
- The second time phases cover the period from 2005 to 2018, this period is in the feasible domain of solution of equilibrium transactions of import and export agents of the external ecosystem. That is, for the second time phase the financial and insurance industry has an entry point of 0.042, a peak deviation of 0.395, and an exit point of 0.400 billion U.S. dollars;
- The initial median average was 0.234 and the final median average for the second time phase was 0.386 billion U.S. dollars. That is, in the second time phase, the median average absolute value of equilibrium transactions in the financial and insurance sector increased by 0.152 billion U.S. dollars, and the median average relative value of equilibrium transactions increased by 165.07%.

Thus, analyzing the entry points, peak deviations, exit points, time phases, and increase or decrease of median average values of these transactions enables a deeper insight into the fundamental patterns of inter-industry linkages, which help address theoretical and practical issues related to external ecosystem agent’s behavior.

Based on the results of Section 3.3, we created substantiated and implemented of the computational model on the determine equilibrium states for external ecosystem transactions by alignment import (outflow and (or) demand for foreign currency) and export (inflow and (or) supply for foreign currency) flows. The novelty of these results are determine equilibrium transactions; analysis of time phases of undervalued and overvalued transactions; classification of time phases of equilibrium growth within the area of admissible solutions of the external ecosystem imports and exports, classifying equilibrium transactions and the significance may be to use resources efficiently and ensure sustainable growth in the financial and insurance activities of Kazakhstan.

4. Discussion

The application of computational model to the investigation of equilibrium growth in Kazakhstan's insurance and financial sectors presents important opportunities and serious challenges. The diverse lessons that recent studies of platform economies and digital infrastructures have to offer can be used to develop such systems, but they also suggest the challenges in such change-oriented strategies.

The integration of distributed artificial intelligence, as emphasized by Guerreiro Augusto et al [32], and the call for self-determination rights in digital economies by Pisani [33] provide a strong foundation for creating robust, ethically aligned intelligent systems. These studies emphasize that while platform economies have the potential to streamline operations and support autonomous decision-making, they must also adhere to regulatory frameworks that respect user autonomy and data privacy.

Ferrari et al. [34] and Demir [35] describe the risk of marginalization and exploitation of labor with regard to platform economies. The implications are of greatest relevance in Kazakhstan, where the movement toward labor in intelligent systems would improve the efficiency of financial markets but risk precipitating precariat labor unless addressed carefully. Similarly, Gorissen [36] and McKnight et al [37] write of the convergence between platform governance and worker autonomy and conclude that while digital systems are capable of opening up economic participation, they also can place restrictions that cut off the agency and fair remuneration, especially in sectors like insurance, where data on the individual and trans-transactional openness are critical.

The socioeconomic effects of the platform economy are sufficiently covered by Hao and Ji [38], who talk about urban-rural income inequality, and Meng et al [39], who write about reducing carbon emissions. The two papers point to the possibility of platform ecosystems leading to inclusive growth but caution against unequal growth due to unregulated market expansion. The result of their analysis confirms the arguments of You [40] and Fuster Morell et al [41], who consider the sustainability of the governance of the platform and stress the intelligent system demands that combine sustainable development indicators with long-term socioeconomic impacts on the insurance and financial industries.

Apart from this, recent models like Suresh and Jagatheeswari [24] and Zhang et al [25] illustrate techniques whereby machine learning together with econometric and optimization techniques improve the predictive power as well as economic system sustainability. As mentioned previously, these innovations are important to the financial sector of Kazakhstan in that they promote optimization of resource utilization, effective risk management, and accurate time series econometric prediction. Deshkar [26] and He [27] illustrate the application of the economic region's hybrid algorithm in economic inequality understanding, which is central to the development of financial systems that support balanced demographic growth diversity, thus building upon the ideas.

The studies unveil severe restrictions, even when examining the possibilities these technological solutions provide. In focus, Ferrari et al [34] and Demir [35] discuss the risks associated with exploitation of labor that platform economies are characteristically susceptible to, and argue how there is a significant gap within systems intelligence in the context of necessary protective measures for adequate system fairness. Also, similar to You [40], Hao and Ji [38] show that the gaps in data systems and administratively controlled information about people and commerce put the effectiveness of intelligent systems towards the goal of equilibrium sustainable growth to be less practical than they want. If these regulatory gaps are not attended to, as highlighted by McKnight et al [37,38], the adoption of platform based systems into the economy and insurance serves of Kazakhstan may end up reproducing the same problems of injustice and exploitation that are observed in other countries. Therefore, a realization of the scientific research, development, and implementation of the system is as follows:

- Detailed analytical models, – studies such as Wang [21] and Suresh and Jagatheeswari [24] provide thoughtful frameworks for smart decision-making that can be applied to the financial and insurance sectors in Kazakhstan;
- Enhanced forecasting models, – Advanced forecasting characteristics typified by Zhang et al [25] and Deshkar [26] demonstrate the ability of sound forecasting and risk assessment, essential for balanced growth;
- Policy and sustainability perspectives, – the policy and regulatory perspectives delivered by McKnight et al [37] and You [40] support the formation of platform economies that conform to sustainable development objectives;

- Precocity and exploitation of labor, – Ferrari et al [34] and Demir [35] identify the frailties of labor exploitation, highlighting the need for strong labor protections in virtual financial platforms;
- Regulatory gap studies by You [40] and Hao and Ji [38] reveal that existing data governance models are insufficient to address the complexities of platform economies and require stronger adaptive and resilient regulations.

Thus, while the research provides valuable insights into Kazakhstan's financial and insurance industries' equilibrium growth analysis development of a computational model, it also indicates the necessity of responsible regulation and a harmonious strategy prioritizing both technological advancement and socioeconomic equity.

5. Conclusions

Using the conceptual principles of system solutions, the interaction of supply and demand functions, and gradient methods for finding the equilibrium state, we created three computational modelling for analyzing the equilibrium growth of transactions in the platform industry and its ecosystems.

In this study, firstly, we created and justified computational model for determine equilibrium states by aligning supply and demand functions for produce/selling and purchasing/buying transactions and its application for the financial and insurance activities industry of Kazakhstan's statistics. The efficiency of the modelling to detect equilibrium transactions is substantiated based on:

- the time phases of undervalued and overvalued of the platform produce/selling and purchase/buying transactions on the relation equilibrium structure to the supply and demand functions;
- the classification of time phases by belonging to equilibrium transactions on the domain of feasible solutions of the platform produce/selling and purchase/buying;
- the time phases of dynamics of the equilibrium growth of the platform produce/selling and purchase/buying transactions.

Secondly, we created and justified computational model for determine equilibrium states by aligning supply and demand functions for internal ecosystem payment and final demand transactions and its application for the financial and insurance activities industry of Kazakhstan's statistics. The efficiency of the modelling to detect equilibrium transactions is substantiated based on:

- the time phases of undervalued and overvalued of the internal ecosystem payment and final demand transactions on the relation equilibrium structure to the supply and demand functions, respectively, for internal producers and internal consumers of the ecosystem;
- the classification of time phases by belonging to equilibrium transactions on the domain of feasible solutions of the internal ecosystem payment and final demand;
- the time phases of dynamics of the equilibrium growth of the internal ecosystem payment and final demand transactions.

Thirdly, we created and justified computational model for determine equilibrium states by aligning demand and supply for foreign currency functions for external ecosystem import and export transactions and its application for the financial and insurance activities industry of Kazakhstan's statistics. The efficiency of the modelling to detect equilibrium transactions is substantiated based on:

- the time phases of undervalued and overvalued of the external ecosystem import and export transactions on the relation equilibrium structure to the demand and supply for foreign currency functions, respectively, for external producers and external consumers of the ecosystem;
- the classification of time phases by belonging to equilibrium transactions on the domain of feasible solutions of the external ecosystem import and export;
- the time phases of dynamics of the equilibrium growth of the external ecosystem import and export transactions.

Thus, based on data analysis, mathematical modeling, operations research and mathematical programming, computational model for determine equilibrium states by aligning supply and

demand functions for produce/selling and purchasing/buying, internal ecosystem payment, and final demand and demand and supply for foreign currency functions for external ecosystem import and export transactions which allows for more efficient resource allocation and promotes sustainable growth of industry and its ecosystem of the financial and insurance internal of the financial and insurance activities of Kazakhstan.

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