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Econometric Analysis of the Sustainability and Development of an Alternative Strategy to Gross Value Added in Kazakhstan's Agricultural Sector

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Citation: Tleubayev, Azat, Seyit Kerimkhulle, Manatshan Tleuzhanova, Aigul Uchkampirova, Zhanat Bulakbay, Raikhan Mugauina, Zhumagul Tazhibayeva, Alibek Adalbek, Yerassyl Iskakov, and Daniyar Toleubay. 2024. Econometric Analysis of the Sustainability and Development of an Alternative Strategy to Gross Value Added in Kazakhstan's Agricultural Sector. *Econometrics* 12: 29. <https://doi.org/10.3390/econometrics12040029>

Academic Editor: Xinzheng Shi

Received: 29 July 2024

Revised: 29 September 2024

Accepted: 9 October 2024

Published: 17 October 2024



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Abstract: Based on the systematization of relevant problems in the agricultural sector of Kazakhstan and other countries, the purpose of the research is to aid in the development and implementation of a methodology for the econometric analysis of sustainability, the classification of economic growth, and an alternative strategy for gross value added depending on time phases with time lags of 0, 1, and 2 years, and on the gross fixed capital formation in the agricultural sector of Kazakhstan. The research has used a variety of quantitative techniques, including the logistic growth difference equation, applied statistics, econometric models, operations research, nonlinear mathematical programming models, economic modeling simulations, and sustainability analysis. In the work on three criteria: equilibrium, balanced and optimal growth, we have defined the main trends of growth of Gross added value of agriculture, hunting and forestry. The first, depending on the time phases, the second, depending on the Gross fixed capital formation transactions for equilibrium growth, for the growth of an alternative strategy, for the endogenous growth rate and the growth of exogenous flows. And we also received a classification of the trend of Productive, Moderate and Critical growth for the agricultural industry depending on the correlated linked industry of the national economy of Kazakhstan. The results of this work can be used in data analytics and artificial intelligence, digital transformation and technology in agriculture, as well as in the areas of sustainability and environmental impact.

Keywords: Kazakhstan; sustainability in agriculture; econometric analysis; alternative strategy; gross value added; gross fixed capital formation

1. Introduction

Agriculture plays a critical role in the systemic provision of food security, economic growth, and environmental sustainability, especially in the context of continued growth in global demand for agricultural products (De Leo et al. 2023). In recent years, the

sustainability of agricultural industries has attracted increasing attention due to its potential to maintain social and environmental balance given the growth in production needs. The development of agricultural sectors must now take into account not only the needs of a growing population but also the environmental and social impacts of agricultural practices (Banhangi et al. 2024). Traditional agricultural production systems, which rely heavily on chemical inputs, have often been criticized for contributing to environmental degradation and resource depletion (Babu 2024; Karasoy 2024). For example, in regions such as India and Greece, agricultural expansion has been associated with biodiversity loss, soil degradation, and water pollution, requiring urgent strategies to achieve environmental sustainability (Karasoy 2024; Babu 2024).

In response to global challenges of uncertainty, a systems decision-making approach has been used to develop and implement multiple framework interventions such as agroecological analysis, life cycle assessment, and contingency analysis to assess and improve the environmental sustainability of agricultural practices (Piastrellini et al. 2024; Meng et al. 2023). These methods aim to quantify the ecological footprint of agricultural production and identify opportunities to improve resource efficiency and reduce emissions. For example, in Northern China, economic analysis has demonstrated the potential to balance agricultural production with environmental conservation by optimizing resource use (Shi and Umair 2024). Similarly, in Argentina, resilience assessment in tomato production highlights the importance of integrating contingency analysis to ensure sustainable resource management (Piastrellini et al. 2024).

Despite the various ways in which sustainability issues in the agricultural sector have been systematized, there are still unidentified issues in the implementation of strategies. This requires a comprehensive econometric analysis of sustainability in the agricultural sector to understand the interactions among agricultural productivity, ecological health, and social well-being (Nascimento et al. 2024). Such an approach is crucial to identify the determinants of sustainability and to development support systems that contribute to the long-term sustainability in the agricultural sector (Maji and Selin 2024). Furthermore, the integration of microbial applications has been proposed as a method to improve soil health and increase crop yields, potentially reducing the environmental burden of agriculture (Tensi et al. 2024).

Further, in this work, we advance the methodology of systemic research and econometric analysis of the sustainable development of the agricultural industry of Kazakhstan using OECD statistical data (IOTs Data 2021). The methodology we recommend has been sufficiently tested in many research works, identifying hidden links between economic growth and the Sustainable Development Goals (SDGs) of the national economy, in particular, in the study of macroeconomic decision-making and sustainable supply chain management (Jakubik et al. 2017; Kerimkhulle et al. 2022, 2023a). In addition, we include in the methodology systems of applied statistics, econometrics, and nonlinear programming models, as well as fuzzy logic systems for assessing the creditworthiness of trade and enterprises and the methodology of modeling economic models (Makhazhanova et al. 2022; Kerimkhulle et al. 2023b). This study also involves the methodology of assessing regional and sectoral parameters of energy supply and energy consumption, which are crucial for the implementation of agricultural policy in Kazakhstan, in the broader context of environmental, social, and corporate governance and risk management of the agricultural sector in the country (Niyazbekova et al. 2022). By integrating all of the above methodologies, this work will aim to provide a comprehensive econometric analysis of agricultural sustainability and propose by classifications of economic growth recommendations to promote sustainable development in the agricultural sector of Kazakhstan.

The above methods of systematizing the problems of the agricultural sector enable us to formulate the purpose of this research—the development and implementation of a methodology for the econometric analysis of sustainability, the classification of economic growth, and an alternative strategy for gross value added depending on the time phases

with time lags of 0, 1, and 2 years and on the gross fixed capital formation in the agricultural sector of Kazakhstan.

To achieve the purpose of the research, it is necessary to study the following three groups of tasks for the agriculture, hunting, and forestry industries transactions of Kazakhstan.

The first group of tasks:

- to create an econometric model which has the specification of the Verhulst logistic growth quasilinear first order difference equation for the Gross value added transactions depending on time phases;
- to give a classification equilibrium growth of the Gross value added by Increased, Balanced and Decreased transactions depending on the time phases;
- to determine the time phases of overvalue and (or) undervalue imbalances in which convergence to and (or) divergence from equilibrium growth for an alternative strategy of the Gross value added transactions;
- to determine the time phases of overvalue and (or) undervalue imbalances in which convergence to and (or) divergence from steady state for the endogenous factor growth rate and for the exogenous flows of the Gross value added transactions.

The second group of tasks:

- to create an econometric model which has the specification of the Verhulst logistic growth quasilinear first order difference equation for Gross value added transaction depending on an upper limit on the time of the Gross fixed capital formation;
- to give a classification equilibrium growth of the Gross value added by Increased, Balanced and Decreased transactions depending on an upper limit on the time of the Gross fixed capital formation;
- to determine the time phases of overvalue and (or) undervalue imbalances, in which convergence to and (or) divergence from steady state for the endogenous growth rate factor and for the exogenous flows of the Gross value added transactions depending on the Gross fixed capital formation are held.

The third group of tasks:

- to create an econometric linear regression model of the alternative strategy—Gross value added transactions with a one-year lag depending on the Gross fixed capital formation and to assess the statistical significance to also give an economic interpretation of the growth of Gross value added transactions from its level last year and the level of the Gross fixed capital formation in the current year;
- to create an econometric multiple linear regression model with distributed lags of the first and second order to solve the problems of classifying the economic growth of the Gross value added depending on the Gross fixed capital formation.

Thus, for the econometric analysis of sustainability and the development of an alternative strategy for Gross value added (GVA) depending on capital formation in Kazakhstan's agricultural industry, we plan to present the research in the following sequence: Introduction (Section 1); Literature review (Section 2); Materials and methods: Mathematical models for analysis of sustainability (Section 3.1); Data, Indicators, and Models for gross value added depending on gross fixed capital formation transactions (Section 3.2); Results: An econometric and sustainability analysis of GVA transactions over time phases (Section 4.1); An econometric and sustainability analysis of GVA based on Gross fixed capital formation (GFCF) transactions (Section 4.2); An analysis of GVA depending on the sum by the upper limit on GFCF transactions (Section 4.2.1); An econometric analysis of an alternative strategy for GVA based on GFCF transactions (Section 4.2.2); An econometric analysis and classification of GVA productivity by independent factors (Section 4.3); Discussion (Section 5); and Conclusions (Section 6).

2. Literature Review

To reveal the economic nature of the influence of Gross fixed capital formation transactions to Gross value added of the agricultural industry we focus on the modernization

of agricultural machinery and equipment. In this regard, our research should focus on advanced technologies such as robotics and intelligent systems to improve agricultural productivity. Also relevant are the prospects for machine and tractor fleet renewal, user-centered design for small-scale agriculture, as well as the challenges and future prospects of robotic weapons in precision agriculture, highlighting the significant benefits of technological improvements in technology:

- One of the necessary conditions for the accelerated growth of agricultural production is the renewal of the machine and tractor fleet, for which it is important to develop effective methods of government regulation that facilitate the acquisition of new equipment by agricultural producers. Here we note that the work of [Zhichkin et al. \(2022\)](#) proposed one of the effective approaches—the introduction of a commodity lending mechanism adapted to the characteristics of the lending object. This method will allow the use of money or products to repay a loan, including grain equivalent, which can become a significant incentive for agricultural producers;
- [Starostin et al. \(2023\)](#) examine the significance of digital technologies in agriculture, particularly focusing on the agricultural tractor fleet. They argue that digital transformation is crucial for enhancing the technical and economic performance of agricultural production. The study evaluates the current state of technical support, emphasizing the tractor fleet, and utilizes statistical extrapolation methods to forecast its development under various scenarios. This approach aims to identify strategic directions for the advancement of agricultural engineering;
- [Izmailov \(2019\)](#) discuss the introduction of digital intelligent technologies to improve production efficiency and crop yields in the article. For this purpose, a main goal has been identified that can optimize production processes and enterprise management. The main areas of use of digital technologies in agriculture are described, including monitoring, data transmission and storage, artificial intelligence and cloud technologies. In particular, monitoring includes analysis of soil, plant, animal and weather conditions in real time;
- An article by [Jin and Han \(2024\)](#) reviews the use of robotic manipulators in precision agriculture and analyzes their hardware and software aspects. In particular, the article highlights the key benefits of this approach, such as increased efficiency and reduced labor costs, and discusses the current status of application in various agricultural settings. Most attention is paid to problems of practical application and comparison of innovative technologies with traditional models. Application examples include greenhouse, field and fruit crops, demonstrating broad applicability and effectiveness in a variety of scenarios. It also highlights the importance of integrating different disciplines to achieve more efficient and sustainable agricultural practices;
- [Tiewtoy et al. \(2024\)](#) explore the economic valuation of agricultural innovation. They propose a framework that integrates design thinking and quality feature deployment, with a focus on community engagement and co-creation of sustainable solutions.

The study of agricultural sustainability and the development of Gross value added transactions depending on specific regions, such as Kazakhstan, Mongolia and the North Caucasus, is an urgent task for both academic scientists and public administration institutions. So, the goal of research is to understand how regional factors and innovations contribute to the overall growth and sustainability of the agricultural sector. The results of the study can be used to ensure an increase in agricultural productivity for the development of regions, the technical equipment necessary for the restoration of agriculture, and the resource potential of regional agro-industrial complexes:

- [Zhichkin et al. \(2024\)](#) focus on optimizing agricultural development through targeted breeding of dairy cattle, emphasizing the genetic potential of livestock. The study shows that a significant part of milk production is genetically determined and that increased breeding efforts can rapidly increase productivity, and offers valuable insights into optimizing agricultural productivity through genetic improvement and targeted livestock breeding. This approach is closely aligned with the goals of analyz-

ing sustainability and developing alternative strategies to increase GVA and capital formation in Kazakhstan's agricultural industry;

- An article by [Tokenova et al. \(2020\)](#), the authors describe the significant contribution of medium-sized commodity producers and farms to agricultural production in the Republic of Kazakhstan, where agriculture plays a key role in the socio-economic sphere of the region. In addition, they raise the problem of low reliability of agricultural machinery and the lag behind foreign analogues. The current state of the technological infrastructure of agricultural organizations in Kazakhstan and Mongolia is assessed, and the structure of fixed production assets and the level of wear and tear highlighted. Based on the analysis, the authors conclude that it is necessary to strengthen state support for updating agricultural equipment as a key condition for overcoming the agrarian crisis;
- An article by [Lukhmanova et al. \(2019\)](#) examines aspects of agricultural development in the Republic of Kazakhstan and describes the key directions of this development. The article also emphasizes the role of agriculture in the country's economy, and identifies the main directions of innovative development of agriculture, taking into account the sustainability of farms. The authors offer main directions and recommendations for the innovative development of the agro-industrial complex of the Republic of Kazakhstan;
- An economic analysis of spring wheat production in Northern Kazakhstan ([Mukhamet-zhanov and Zholaman 2023](#)) shows the high costs but profitability of producing expensive seeds compared to commercial grains. They highlight energy efficiency requirements and provide valuable information for investment decisions in the region's agricultural sector.

Today, in ensuring the sustainability of the agricultural industry, in-depth research and determination of the most important aspects of water resource management and irrigation in agriculture play an equally important role. In particular, this paper provides a scientific overview of advanced techniques such as reverse osmosis desalination for greenhouse irrigation, integration of IoT sensors into smart irrigation systems, and assessment of virtual water use in agriculture. The review also focuses on innovative solutions and technologies that optimize water use, providing efficient and sustainable agricultural practices:

- [Gil et al. \(2024\)](#) highlight that water shortages threaten agriculture, especially in dry regions such as the Spanish province of Almeria. One promising solution is the use of desalination, particularly reverse osmosis desalinated water, to irrigate greenhouses. An economic model based on the energy hub methodology estimates this by considering variable electricity production and water demand. The study shows that the leveled cost of water ranges from 2.51 to 3.69 euros/m³, and investments in reverse osmosis systems can pay for themselves in fewer than three years. This approach is particularly attractive to farmers and small associations promoting distributed desalination in agriculture;
- A study by [Ferreira Gonzaga et al. \(2019\)](#) aims to identify factors influencing the adoption of higher levels of technological practices by smallholder farmers in the Midwestern region of Brazil. Questionnaires administered to 1162 settlers were used. Education, technical assistance, and sharing experiences with neighbors have a positive effect on technology use, but not on technology package use. Investment financing has a greater impact on technology adoption than production cost financing, indicating the need to reconsider financing priorities;
- [Kumar et al. \(2024\)](#) highlight the urgent need for modern irrigation systems due to the increasing global demand for fresh water and population growth. They offer an IoT-based smart irrigation system that uses moisture and soil sensors and processes the data using a hybrid K-means SVM classifier, achieving 98.5% accuracy and significantly saving freshwater resources;
- [Ding et al. \(2020\)](#) developed the fuzzy-vertex-based virtual water analysis method (FVAM) to estimate the virtual water content of agriculture in Kazakhstan, finding

that wheat is the main consumer and the Kostanay region has the highest virtual water content. Kazakhstan is becoming a net virtual exporter of water, mainly to neighboring countries. The study highlights the need to reduce virtual water exports to address water scarcity and promote sustainable development.

It is known that economic, investment and public policies can stimulate economic growth and ensure sustainable development of the agricultural sector in order to comprehensively understand the economic drivers, risks and policy frameworks that determine the development and sustainability of the agricultural sector. To achieve this goal, a review of scientific works was carried out on the following topics: risk analysis in grain production, the relationship between energy consumption and agricultural growth, innovation management and the economic impact of digital tools in agriculture:

- [Kussaiynov et al. \(2023\)](#) propose a method to quantify the systemic and individual risks of agricultural production volatility using grain data from Kazakhstan. They propose methods for calculating losses due to systemic risks, aiming to reduce subjectivity in compensating farmers for losses. This study is the first to examine these dynamics in emerging grain markets;
- A study by [Sartbayeva et al. \(2023\)](#) sheds light on the relationships among renewable energy consumption, economic growth and agricultural development in Kazakhstan. Through rigorous analysis spanning three decades, the study highlights the potential of agricultural innovation to influence energy use patterns, highlighting the importance of sustainability in shaping the future of the sector;
- According to [Taishykov et al. \(2024\)](#), managing innovative processes in agriculture, which are important for the economy of the Republic of Kazakhstan, requires careful consideration of models and methods for increasing efficiency;
- A study of extension in agriculture began in the 1950s and has evolved through various models, including participatory research. A contemporary perspective on innovation systems recognizes the complex interactions of different actors and their contributions to technical, social and institutional change. This has led to a reorientation of knowledge diffusion towards innovation brokering, where priority is placed not only on knowledge dissemination, but also on creating an enabling context for the development of innovation ([Klerkx et al. 2012](#)). The importance of innovation brokering is emphasized not only in agriculture, but also in other sectors, where it can contribute to the wider use of research results and the development of innovation;
- [Ryskeldi et al. \(2024\)](#) examine the economic potential of digital technologies in Kazakh agriculture and find that their adoption increases profitability and influences future policy decisions.

Econometric analysis and classification of productivity of Gross value added transactions by independent factors as a tool of advanced data analytics and machine learning can change agricultural practices. It can be used in the field of data and Artificial Intelligence (AI) in agriculture, and can be used to improve the efficiency of animal feeding, precision agriculture using multi-modal image analysis, classification of soil salinity and predictive models of concrete strength and to improve the efficiency of agriculture and management decision-making. In the following works, separate attempts have been made to undertake this research:

- [Monteiro et al. \(2024\)](#) explore the role of the rumen microbiome in improving feed and milk production efficiency in dairy cows using artificial intelligence. They highlight its potential impact on the long-term sustainability of the dairy industry;
- An innovative approach to optimize crop water use using machine learning techniques discussed by [Munaganuri and Rao \(2024\)](#) highlights the importance of advanced technologies in making agriculture more sustainable;
- In their study on the justification and economic evaluation of innovative approaches in agricultural infrastructure, [Merembayev et al. \(2022\)](#) used satellite data and machine

learning algorithms to predict soil salinity in the Turkestan region of Kazakhstan, achieving the best results using a Gaussian process model;

- [Alyami et al. \(2024\)](#) conducted a study on the economic evaluation and justification of innovative approaches in agricultural infrastructure, focusing on the use of recycled materials in the production of sustainable concrete.

The results of this work, namely econometric analysis and sustainability analysis of Gross value added depending on the Gross fixed capital formation transactions, can be used in the field of digital transformation and technologies in agriculture. In particular, a review of the scientific literature shows that the introduction of key digital tools, Agriculture 4.0 and the development of modern farming practices can improve efficiency, sustainability and innovation in agricultural processes, with a particular focus on Kazakhstan and the wider trends affecting the agricultural industry:

- [Usenko et al. \(2024\)](#) talk about digital transformation in agriculture, which is carried out through the introduction of a set of digital technologies combined within the framework of smart agriculture and precision agriculture. This process requires widespread adoption of integrated solutions in sustainable crop production, including sensor devices, unmanned and automated technology, robotic production systems and platform technologies. The main task of digital transformation is to collect important information about the state of the environment using big data, which requires cloud platforms and solutions;
- Research by [Mendes et al. \(2022\)](#) on aspects of digital transformation in agriculture represents an important step in optimizing agribusiness in response to growing societal concerns and sustainability concerns about the use of natural resources. α methods and latent Dirichlet allocation models were used to identify and analyze the main aspects of digital transformation. The results allow us to identify eight dimensions, each with its own key pillars and barriers, and to develop recommendations and suggestions for practical and academic fields in addition to developing policies aimed at promoting sustainable agricultural development. This work represents a valuable contribution to the understanding and application of digital technologies to achieve sustainable agricultural development;
- The Fourth Agricultural Revolution must adhere to the three principles of sustainable intensification: people, production and planet. Currently, Agriculture 4.0 focuses mainly on increasing productivity and caring for the environment, but pays little attention to social sustainability. However, Agriculture 4.0 has a significant social impact and this aspect needs to take into account in development of business. The work of [Rose et al. \(2021\)](#) calls for the inclusion of social sustainability in technology strategies and proposes a framework for stakeholder co-innovation. Through the broad participation of people in innovative processes in agriculture, based on the principles of innovation, it is possible to increase the likelihood of achieving social sustainability, as well as improve production processes and environmental protection;
- A study by [Aydoğan et al. \(2022\)](#) aims to identify the factors influencing the innovativeness and sustainability of rice farmers. Data were obtained from questionnaires administered to 70 farmers in Turkey. Using cluster analysis, farmers were divided into groups with low, medium and high levels of innovation. Socio-economic and agricultural characteristics were compared using analysis of variance, and factors influencing innovativeness and sustainability were analyzed using accelerated failure time models. The results showed that education, experience, household size, participation in farmer organizations and other factors influence innovativeness and sustainability;
- [Cricelli et al. \(2024\)](#) analyze how Industry 4.0 technologies can help agro-food supply chains innovate post-COVID-19. They identify four technology clusters and three types of supply chains, emphasizing that successful technology adoption depends on its alignment with supply chain characteristics and strategic objectives;
- [Arthur et al. \(2024\)](#) provide an overview of digital innovation in agribusiness, particularly in Africa, and aim to provide recommendations for practice and further

research. The results of the work indicate significant interest in digital innovation in agribusiness, especially in the areas of digital finance and digital precision innovation. The main drivers and challenges of introducing digital innovation in the African agro-industrial sector are social, economic, and political factors. The authors recommend the active participation of governments and other stakeholders for the successful digitalization of agribusiness in Africa;

- Among the challenges associated with the digitalization of agricultural systems, [Moreno et al. \(2024\)](#) highlight the urgent need for a unified technology classification system. Their vision is the Agriculture Technology Navigator (ATN), a dynamic tool that allows stakeholders to effectively navigate and share digital solutions across the agricultural landscape;
- [Dibbern et al. \(2024\)](#) highlight the complexity of the transition from traditional to digital agriculture, highlighting factors such as economic conditions, technological infrastructure, and farmer demographics. They also highlight a gap in the literature regarding objective indicators to measure digital agriculture adoption, and suggest that policymakers use these insights to develop targeted policies;
- The study by [Bilal and Jaghdani \(2024\)](#) examines barriers to the adoption of innovative technologies such as genetically engineered seeds and herbicides and finds that factors such as agricultural machinery, non-farm income and education influence adoption rates.

A review of the scientific literature shows that the results of econometric analysis of alternative strategy of Gross value added depending on the Gross fixed capital formation transactions can be used to study the linkages of agriculture to sustainability and to the condition of a positive impact on the environment, as well as the effects of climate change on crop production; to reduce damage from forest fires and on general strategies to improve agricultural sustainability; and to balance productivity with environmental protection to ensure the long-term viability of agriculture:

- [Li et al. \(2024\)](#) analyzed the distribution and direction of the implementation of agricultural technology patents during the period 1970 and 2022 and identified trends in the context of Sustainable Intensification (SI). Despite the increase in the number of patents in recent decades, only a small proportion of them are related to SI objectives. The most cited patents related to SI included digital, machine and agro-environmental technologies. These results point to promising directions for technology development that can play an important role in achieving sustainable intensification goals. Also, [Li et al. \(2024\)](#) highlight the importance of not only technological innovation but also non-technological changes in farm management and institutional support;
- [Lecina-Diaz et al. \(2023\)](#) found that combining high nature value agricultural land with fire management strategies was the most effective approach to reducing wildfire risk and associated damage to ecosystem services such as timber and recreational benefits in the Gerês-Xurés Transboundary Biosphere Reserve (RBTGX). They highlight the importance of incentivizing farmers and landowners for their role in preventing wildfires through payment for ecosystem service policies;
- [Glotko et al. \(2020\)](#) assess the current state of the resource base and suggests directions for development. In addition, it proposes strategies for government support for antler reindeer husbandry, covering institutional, material, technical, infrastructural and resource aspects;
- The impact of climate change on wheat yields in Central Asia, especially in the North Kazakhstan region, has been assessed ([Teleubay et al. 2024](#)). Key research using CRAFT (Regional Agricultural Forecasting Toolbox) and DSSAT (Decision Support System for Agrotechnology Transfer) shows the sensitivity of agricultural productivity to greenhouse gas emissions. They highlight the urgent need to develop resilient crop varieties and diversify agricultural management practices to ensure food security in the face of climate change.

3. Materials and Methods

3.1. Mathematical Models for Analysis of Sustainability

We consider the first order linear as the logistic growth difference equation (Tsoularis and Wallace 2002):

$$-y(t + 1) + (1 + r(t))y(t) = x(t + 1), \quad t = 0, \pm 1, \pm 2, \dots, \tag{1}$$

where $y = \{y(t)\}_{t=0, \pm 1, \pm 2, \dots}$ is stock values of the system of logistic growth—an endogenous factor; the desired solution of the Equation (1) and $x = \{x(t)\}_{t=0, \pm 1, \pm 2, \dots}$ is values of flows of the system of logistic growth—an exogenous factor; and the right side of the Equation (1), $r = \{r(t) \geq 0\}_{t=0, \pm 1, \pm 2, \dots}$ is the logistic growth rate,

$$\forall d = 1, 2, \dots < \infty \mid \prod_{j=t}^{t+d-1} (1 + r(j)) < \infty, \quad t = 0, \pm 1, \pm 2, \dots, \tag{2}$$

and

$$x \in \ell_\infty \Leftrightarrow \|x\|_{\ell_\infty} = \sup_{t=0, \pm 1, \pm 2, \dots} |x(t)| < \infty,$$

is the space of bounded numerical sequences x . It is recognized that the functional-spatial mathematical formulation (1)–(2) of the problem under investigation—namely, the equilibrium, balanced, and productive growth of the agricultural sector’s Gross value added in Kazakhstan—constitutes the fundamental hypothesis for addressing applied economic challenges.

As a solution of Equation (1) we assume any absolutely bounded sequences y that satisfy (1) everywhere on $t = 0, \pm 1, \pm 2, \dots$. We need the following definitions:

Definition 1. We call the Equation (1) correctly solvable in the given space ℓ_∞ if the following two assertions hold:

- (a) for any $x \in \ell_\infty$, the Equation (1) has a unique solution $y \in \ell_\infty$,
- (b) the solution $y \in \ell_\infty$ of the Equation (1) satisfies the inequality

$$\|y\|_{\ell_\infty} \leq c \|x\|_{\ell_\infty}, \quad \text{for all } x \in \ell_\infty, \tag{3}$$

where c is an absolute positive constant.

Definition 2. Let $y(t)$, $t = 0, \pm 1, \pm 2, \dots$ be the solution of Equation (1) and for a given $\varepsilon > 0$ there is $\delta > 0$ such that if you change the function $x(t)$ by less than δ : $|x_0(t) - x_1(t)| < \delta$, then the solution $y(t)$ will change at $t = 0, \pm 1, \pm 2, \dots$ less than by ε : $|y_0(t) - y_1(t)| < \varepsilon$, then the solution $y(t)$ is called of sustainable.

Theorem 1. The first order linear the logistic growth difference Equation (1) is correctly solvable in space ℓ_∞ if and only if there is a finite $d = 1, 2, \dots$ such that (Kerimkhulle and Aitkozha 2017)

$$r_*(d) > 1, \quad r_*(d) \stackrel{\text{def}}{=} \inf_{t=0, \pm 1, \pm 2, \dots} \left\{ \prod_{j=t}^{t+d-1} (1 + r(j)) \right\}, r(t) \geq 0. \tag{4}$$

For any given $t = 0, \pm 1, \pm 2, \dots$, we define a function

$$d(t) = \inf_{d=1, 2, \dots} \left\{ d \mid \prod_{j=t}^{t+d-1} (1 + r(j)) \geq 2 \right\} \tag{5}$$

It is clear that the function $d(t)$ is defined correctly. The function $d(t)$ was first used in (Otelbaev 1974).

Corollary 1. *Let y be the solution of Equation (1) and $t + d \geq t, t = 0, \pm 1, \pm 2, \dots, d = 1, 2, \dots$. Then (Kerimkhulle and Aitkozha 2017)*

$$y(t) = \frac{y(t + d - 1)}{\prod_{j=t}^{t+d-1} (1 + r(j))} + \sum_{i=t}^{t+d-1} \frac{x(i)}{\prod_{j=t}^i (1 + r(j))}, \tag{6}$$

or for d tending to infinity

$$y(t) = \sum_{i=t}^{\infty} \frac{x(i)}{\prod_{j=t}^i (1 + r(j))}. \tag{7}$$

The application of Equations (4)–(7), specifically the results of Theorem 1 and Corollary 1, enables the construction of mathematical support for the development of a system of computable models in this work. For instance, condition (4) can serve as a criterion, providing a necessary and sufficient condition for the stability of the stochastic dynamics within the economic system. Also, the applied significance of Equation (5) lies in the finiteness of the doubling lags for Gross Value Added (GVA), where $d(t)$ is determined as the sum of lag periods in which $(r(j) = 0)$ and there are consecutive zeros. Additionally, $(r(j) = 1)$ only when a doubling of GVA occurs. Formula (6) represents the current solution $y(t)$ of Equation (1) in terms of future values $y(t + d - 1)$, while formula (7) expresses the current solution $y(t)$ over the entire temporal space.

Corollary 2. *Let y be the solution of Equation (1) and denote $d_* \stackrel{\text{def}}{=} \sup_{t=0, \pm 1, \pm 2, \dots} d(t)$. Then*

$\forall \varepsilon > 0 \exists \delta > 0$ is such that if the sequence x is changed by less than $\delta > 0 : |x_0(i) - x_1(i)| < \delta$, then the solution y will change by less than $\varepsilon > 0 : |y_0(t) - y_1(t)| < \varepsilon$.

Proof. Based on formula (6) and the conditions of Corollary 2, we have

$$y_0(t) = \sum_{i=t}^{\infty} \frac{x_0(i)}{\prod_{j=t}^i (1 + r(j))}. \tag{8}$$

and

$$y_1(t) = \sum_{i=t}^{\infty} \frac{x_1(i)}{\prod_{j=t}^i (1 + r(j))}. \tag{9}$$

Subtracting equality (9) term by term from (8), we obtain the estimate

$$|y_0(t) - y_1(t)| \leq \sum_{i=t}^{\infty} \frac{|x_0(i) - x_1(i)|}{\prod_{j=t}^i (1 + r(j))}. \tag{10}$$

Because

$$\begin{aligned} |x_0(i) - x_1(i)| < \delta, \\ \sum_{i=t+md(t)}^{t+(m+1)d(t)-1} \frac{1}{\prod_{j=t}^i (1 + r(j))} \\ \leq \sum_{i=t+md_*}^{t+(m+1)d_*-1} \frac{1}{\prod_{j=t}^i (1 + r(j))} \leq \frac{d_* - 1}{2^{md_*}}, \end{aligned}$$

then from (9) it follows that

$$\begin{aligned} |y_0(t) - y_1(t)| &\leq \delta \sum_{i=t}^{\infty} \frac{1}{\prod_{j=t}^i (1 + r(j))} = \delta \sum_{m=0}^{\infty} \sum_{i=t+md(t)}^{t+(m+1)d(t)-1} \frac{1}{\prod_{j=t}^i (1 + r(j))} \\ &\leq \delta \sum_{m=0}^{\infty} \sum_{i=t+md_*}^{t+(m+1)d_*-1} \frac{1}{\prod_{j=t}^i (1 + r(j))} \leq \delta \sum_{m=0}^{\infty} \frac{d_* - 1}{2^{md_*}} = \delta \left(d_* - 1 + \frac{d_* - 1}{2^{d_*}} \sum_{m=1}^{\infty} \frac{1}{2^m} \right) < \delta \left(d_* - 1 + \frac{d_* - 1}{2^{d_*-1}} \right). \end{aligned}$$

Thus, if for a given $\varepsilon > 0$ we choose $\delta = \varepsilon 2^{d_*-1} / (d_* - 1 + (d_* - 1)2^{d_*-1})$, then for $t = 0, \pm 1, \pm 2, \dots$ the inequality holds

$$|y_0(t) - y_1(t)| < \varepsilon,$$

indicating, according to Definition 2, the sustainability of the solution $y_0(t)$ under constantly acting disturbances. Thus, it is established that the definition of stable solutions (see Corollary 2) to Equation (1) is equivalent to the concept of correctly solvability (see Definition 1). \square

In this work we will also use the first order quasilinear the Verhulst logistic growth difference equation (Tsoularis and Wallace 2002):

$$\frac{1 - y(t+j+1)/k}{y(t+j+1)} - (1+r(t)) \frac{1 - y(t+j)/k}{y(t+j)} = 0, \quad (11)$$

and

$$\frac{1 - y(x(t+j+1))/k}{y(x(t+j+1))} - (1+r(t)\Delta x(t+j)) \frac{1 - y(x(t+j))/k}{y(x(t+j))} = 0, \quad (12)$$

where k is a capacity of growth size; $\Delta x(t+j) = x(t+j+1) - x(t+j)$ is difference operator of the first order, $j = 0, 1, 2, \dots, T-1$. The choice of the equation of Verhulst (11) produced based on the adequacy of the evolution of the distribution of Gross value added (GVA) under conditions of the constancy of its growth rate as a difference equation. In Equation (12) implements the case of the evolution of distribution with condition of a variable rate of growth of Gross value added (GVA).

Then, the solutions to Equations (11) and (12) are reduced to the solution, respectively, in the form of the following functional equations:

$$\ln \frac{1 - y(t+T-1)/k}{y(t+T-1)} = \ln \frac{1 - y(t)/k}{y(t)} + r(t) \times (T-1), \quad (13)$$

and

$$\ln \frac{1 - y(\sum_{j=t}^{t+T-1} \Delta x(j))/k}{y(\sum_{j=t}^{t+T-1} \Delta x(j))} = \ln \frac{1 - y(x(t))/k}{y(x(t))} + r(t) \times \sum_{j=t}^{t+T-1} \Delta x(j), \quad (14)$$

Here, we note that the number sequence $x(t+j)$, $j = 0, 1, 2, \dots, T-1$ is ranked in ascending order $x(t) < x(t+1) < \dots < x(t+T)$ not violating the generality of the value of the sequence $x(t+j)$ at which the growth increment is a constant value: $x(t+j+1) - x(t+j) = \text{constant}$; $\sum_{j=t}^{t+T-1} \Delta x(j)$ is the sum with a variable upper limit from $(T-1)$.

3.2. Data, Indicators, and Models for Gross Value Added Depending on Gross Fixed Capital Formation Transactions

This research is based on statistical data obtained from the official website of the Organization for Economic Cooperation and Development for the Republic of Kazakhstan (IOIs Data 2021). It has the following format: name of industry and indicator, unit, period, frequency, denote and characteristics of the variable with time lags for the following indicators:

- Agriculture, hunting and forestry industry, Gross value added transactions, Billion U.S. dollars, 1995–2018, Annually, $y(t)$ —dependent variables and $y_{(-1)}(t-1)$, $y_{(-2)}(t-2)$ —its, respectively, one and two-year time lags (see Table 1, column (a));
- Agriculture, hunting and forestry industry, Gross fixed capital formation transactions, Billion U.S. dollars, 1995–2018, Annually, $x_{(i)}(t)$ —independent variables and $x_{(i-1)}(t-1)$, $x_{(i-2)}(t-2)$ —its, respectively, one and two-year time lags ((see Table 1, column (d)));

- Food products, beverages and tobacco industry, Gross fixed capital formation transactions, Billion U.S. dollars, 1995–2018, Annually, $x_{(ii)}(t)$ —independent variables and $x_{(ii-1)}(t-1)$, $x_{(ii-2)}(t-2)$ —its, respectively, one and two-year time lags ((see Table 1, column (e)));
- Wholesale and retail trade industry, Gross fixed capital formation transactions, Billion U.S. dollars, 1995–2018, Annually, $x_{(iii)}(t)$ —independent variables and $x_{(iii-1)}(t-1)$, $x_{(iii-2)}(t-2)$ —its, respectively, one and two-year time lags ((see Table 1, column (f))).

Then, the econometric models with the following specification are used:

$$\begin{aligned}
 y(t) = & \beta_{(0)} + \beta_{(-1)} \times y_{(-1)}(t-1) + \beta_{(-2)} \times y_{(-2)}(t-2) + \beta_{(i)} \times x_{(i)}(t) \\
 & + \beta_{(i-1)} \times x_{(i-1)}(t-1) + \beta_{(i-2)} \times x_{(i-2)}(t-2) + \beta_{(ii)} \times x_{(ii)}(t) \\
 & + \beta_{(ii-1)} \times x_{(ii-1)}(t-1) + \beta_{(ii-2)} \times x_{(ii-2)}(t-2) + \beta_{(iii)} \times x_{(iii)}(t) \\
 & + \beta_{(iii-1)} \times x_{(iii-1)}(t-1) + \beta_{(iii-2)} \times x_{(iii-2)}(t-2) + \varepsilon(t),
 \end{aligned}
 \tag{15}$$

where $y_{(-1)}(t-1)$, $y_{(-2)}(t-2)$, $x_{(i)}(t)$, $x_{(i-1)}(t-1)$, $x_{(i-2)}(t-2)$, $x_{(ii)}(t)$, $x_{(ii-1)}(t-1)$, $x_{(ii-2)}(t-2)$, $x_{(iii)}(t)$, $x_{(iii-1)}(t-1)$, $x_{(iii-2)}(t-2)$ are the independent variables of the model; $\beta_{(0)}$, $\beta_{(-1)}$, $\beta_{(i)}$, $\beta_{(i-1)}$, $\beta_{(i-2)}$, $\beta_{(ii)}$, $\beta_{(ii-1)}$, $\beta_{(ii-2)}$, $\beta_{(iii)}$, $\beta_{(iii-1)}$, $\beta_{(iii-2)}$ are the unknown parameters; $\varepsilon(t)$ is an independent identically distributed (i.i.d.) normal random errors with variance σ^2 such that for all $t \neq s \in 1997-2018$ satisfy the following conditions (Greene 2018):

$$\begin{aligned}
 E[\varepsilon|X] &= 0, \\
 \text{Var}[\varepsilon|X] &= \sigma^2 I, \\
 \text{Cov}[\varepsilon(t), \varepsilon(s)|X] &= 0, \\
 \varepsilon|X &\sim N[0, \sigma^2 I],
 \end{aligned}
 \tag{16}$$

where X is a matrix of the observations compiled by data of indicators $y_{(-1)}$, $y_{(-2)}$, $x_{(i)}$, $x_{(i-1)}$, $x_{(i-2)}$, $x_{(ii)}$, $x_{(ii-1)}$, $x_{(ii-2)}$, $x_{(iii)}$, $x_{(iii-1)}$, $x_{(iii-2)}$; $E[\cdot]$ is an expectation; $\text{Cov}[\cdot]$ is a covariance; $\text{Var}[\cdot]$ is a variance; I is an identity matrix.

Table 1. Produce/selling data for the Gross value added and Purchase/buying data for the Gross fixed capital formation transactions of Kazakhstan’s economic statistics.

Year	(a)	(b)	(c)	(d)	(e)	(f)	Year	(a)	(b)	(c)	(d)	(e)	(f)
1995	0.915	0.405	0.061	0.031	−0.354	0.533	2007	4.751	2.102	0.315	0.541	−0.440	4.946
1996	0.936	0.414	0.062	0.020	0.144	0.412	2008	6.050	2.676	0.401	0.704	−0.096	4.344
1997	0.987	0.436	0.066	0.021	0.161	0.419	2009	5.276	2.334	0.350	1.820	0.047	4.100
1998	0.972	0.430	0.065	0.019	0.211	0.411	2010	6.651	2.943	0.441	1.100	0.216	4.569
1999	0.746	0.330	0.050	0.014	−0.237	0.295	2011	9.577	3.750	0.562	2.608	1.003	5.297
2000	0.800	0.354	0.053	0.017	0.074	0.373	2012	8.831	4.007	0.626	1.113	0.287	5.633
2001	0.969	0.429	0.064	0.050	0.337	0.713	2013	10.300	5.703	0.671	1.437	0.417	8.460
2002	1.078	0.477	0.072	0.070	0.595	0.902	2014	9.251	5.512	0.704	0.618	0.475	8.648
2003	1.356	0.600	0.090	0.065	−0.072	1.068	2015	8.438	4.792	0.642	1.433	0.839	7.418
2004	1.920	0.849	0.127	0.300	−0.113	1.323	2016	6.057	3.651	0.480	1.036	0.241	5.136
2005	2.546	1.126	0.169	0.425	−0.052	2.113	2017	7.113	4.261	0.569	0.417	4.678	6.481
2006	3.628	1.605	0.241	0.542	−0.049	3.599	2018	7.562	4.517	0.685	2.616	0.749	6.271

Note. (a) Gross value added transactions by the agriculture, hunting, and forestry industries; (b) Gross value added transactions by the food products, beverages, and tobacco industries; (c) Gross value added transactions by the chemical and chemical products industry; (d) Gross fixed capital formation transactions by the agriculture, hunting, and forestry industries; (e) Gross fixed capital formation transactions by the Food products, beverages, and tobacco industries; (f) Gross fixed capital formation transactions by the Wholesale and retail trade industry; Billion U.S. dollars. Compiled by the author based on the Input–Output Tables data (IOTs Data 2021).

Thus, the methodology of this work is created in the following sequence:

- create a result-oriented intermediate database to solve problems of econometric analysis of sustainability, and an alternative strategy of gross added value in the agricultural sector of Kazakhstan;

- the choice and use of econometric analysis models and Gross value added transactions depending on time phases (11), (13), (17)–(20) for the classification of equilibrium growth transactions: Increased, Balanced and Decreased;
- the choice and use of computable mathematical optimization models (21)–(23) to determine the time phases of overvalue and (or) undervalue of imbalances in two scenarios, the first, in which convergence and (or) divergence from equilibrium growth is observed for an alternative strategy of Gross value added transactions; the second, in which convergence to a steady state and (or) divergence from it is observed for the endogenous growth rate of factors and for exogenous flows of Gross value added transactions;
- the choice and use of models of econometric analysis and analysis of Gross value added transactions depending on a variable upper limit of gross fixed capital formation (12), (14)–(16), (24)–(25) for the classification of equilibrium growth: Increased, Balanced and Decreased;
- the choice and use of computable mathematical optimization models (26)–(27) to determine the time phases of overestimation and (or) underestimation of imbalances in which convergence to the steady state and (or) divergence from it is observed for endogenous growth rates of factors and for exogenous flows of Gross value added transactions depending on Gross fixed capital formation;
- the choice and use of an econometric model of linear regression with distributed lags of the first and second order (28)–(29) to solve the problems of classifying economic growth of Gross value added depending on Gross fixed capital formation.

4. Results

4.1. Gross Value Added Transactions by Time Phases

For econometric analysis of Gross value added transactions of the agriculture, hunting, and forestry industries (see Table 1, column (a); Figure 1a) depending on the time phases, we will use the first order quasilinear of the Verhulst logistic growth difference Equation (11) in the form of functional Equation (13). Then, the least squares give the following estimates (see Table 2) for equilibrium growth \hat{y} of the Gross value added transactions (see Table 3, column (a); Figure 1a):

$$\ln \frac{1 - \hat{y}(1995+T-1)/248.4}{\hat{y}(1995+T-1)} = -5.0150 + 0.2183 \times (T - 1), \quad T = 1, 2, \dots, 24, \quad (17)$$

$R^2 = 0.9881 \qquad (0.068) \qquad (0.005)$

Further, we will build an alternative strategy \tilde{y} for Gross value added transactions of the agriculture, hunting, and forestry industries (see Table 3, column (b); Figure 1a) as the product of the average weighted observation value y (see Table 1, column (a); Figure 1a) and deflator D by forecasting time $T = 1, 2, \dots, 24$:

$$\tilde{y}(1995 + T - 1) = D^{T-1} \times \frac{\text{SUMPRODUCT}(\text{array}(T), [\text{array}(y)])}{\text{SUMPRODUCT}(\text{array}(T), [\text{array}(1)])}. \quad (18)$$

for which we impose an optimality criterion on the distribution of the Gross value added transactions (see Table 3, column (a); Figure 1a), which is achieved on the forecasting time boundary:

$$\max_{j=1,2,\dots,23} \hat{y}(1995 + j) = \hat{y}(2018), \quad \text{and} \quad \Delta^2 \hat{y}(2018) = 0, \quad (19)$$

We also require the fulfillment of the criterion of balancing the value of the observation and the alternative strategy \tilde{y} of the Gross value added transactions (see Table 3, column (b); Figure 1a):

$$\sum_{j=t}^{t+T} y(j) = \sum_{j=t}^{t+T} \tilde{y}(j) \quad (20)$$

where $\Delta^2\hat{y}(t + j) = \hat{y}(t + j + 1) - 2\hat{y}(t + j) + \hat{y}(t + j - 1)$ is the difference operator of the second order.

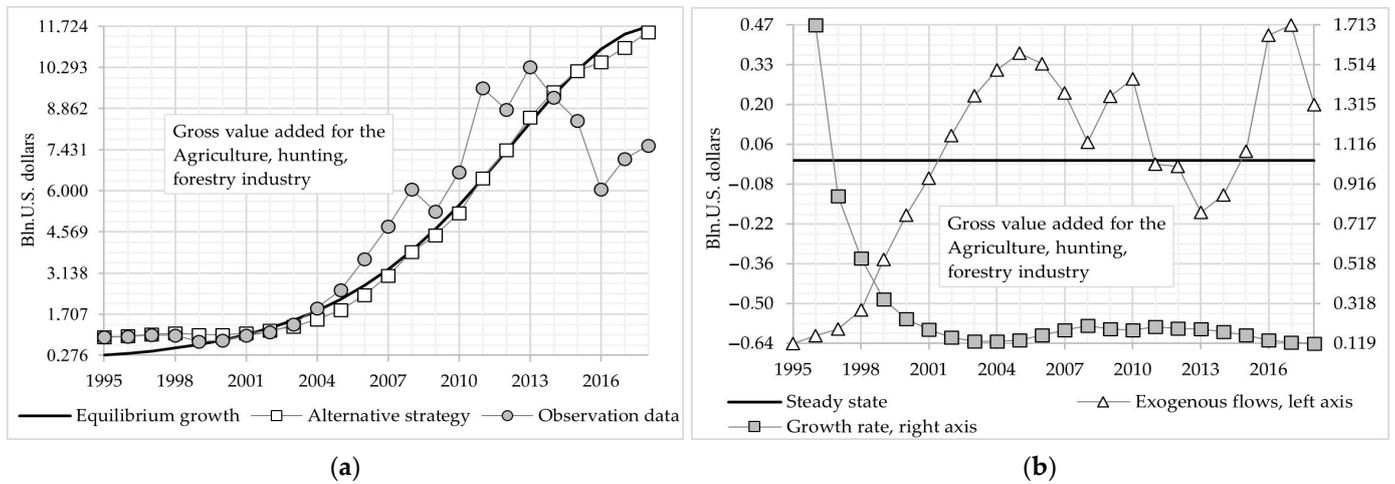


Figure 1. Gross value added transactions of the Agriculture, hunting, and forestry industries depending on the time phases: (a) Observation data; Equilibrium growth; Alternative strategy and (b) Growth rate, right axis; Exogenous flows, left axis; Steady state.

Table 2. The estimated least squares of parameters of a Verhulst logistic growth model for the Gross value added transactions depending on the time phases.

Parameters	$\ln \frac{1 - \hat{y}(1995 + T - 1)/248.4}{\hat{y}(1995 + T - 1)}$
$\hat{r}_{\hat{y}}$	0.2183 *** (0.005)
Constant	-5.0150 *** (0.068)
Num of obs.	24
R-square	0.9881

Note. The dependent variable is $\ln(1 - \hat{y}(1995 + T - 1)/248.4) / \hat{y}(1995 + T - 1)$ —a stock value of Gross value added of the Agriculture, hunting, and forestry industries’ transactions depending on the time phases, $T = 1, 2, \dots, 24$. In parentheses are standard errors. *, **, ***—estimate is significant at 10%, 5%, 1% level.

Table 3. Produce/selling data for the Gross value added transactions of the Agriculture, hunting, and forestry industries depending on the time phases.

Year	(a)	(b)	(c)	(d)	Year	(a)	(b)	(c)	(d)
1995	0.276	0.915		-0.639	2007	3.276	3.040	0.185	0.236
1996	0.342	0.955	1.713	-0.613	2008	3.929	3.866	0.209	0.063
1997	0.424	1.012	0.856	-0.588	2009	4.675	4.451	0.192	0.224
1998	0.526	1.047	0.544	-0.522	2010	5.510	5.224	0.186	0.286
1999	0.650	0.996	0.341	-0.345	2011	6.421	6.433	0.203	-0.012
2000	0.803	0.994	0.241	-0.191	2012	7.387	7.408	0.195	-0.021
2001	0.991	1.053	0.188	-0.062	2013	8.372	8.553	0.192	-0.181
2002	1.219	1.133	0.150	0.087	2014	9.328	9.449	0.177	-0.120
2003	1.497	1.270	0.129	0.227	2015	10.200	10.168	0.159	0.033
2004	1.833	1.517	0.128	0.316	2016	10.927	10.488	0.136	0.438
2005	2.235	1.860	0.136	0.376	2017	11.449	10.976	0.125	0.473
2006	2.714	2.375	0.160	0.338	2018	11.723	11.528	0.119	0.195

Note. (a) Equilibrium growth for the Gross value added transactions; (b) Alternative strategy for the Gross value added transactions; (c) Growth rate for the Gross value added transactions, share; (d) Exogenous flows for the Gross value added transactions; Billion U.S. dollars. Compiled by the author.

For analysis of the sustainability of Gross value added transactions of the Agriculture, hunting, and forestry industries (see Table 1, column (a); Figure 1a) depending on the time phases, we will use the first order linear of the logistic growth difference, Equations (1) and (2). Then, we obtain exogenous flows \check{y} for the Agriculture, hunting, and forestry industries (see Table 1, column (a); Figure 1a) as the difference between the equilibrium growth \hat{y} and the alternative strategy \tilde{y} :

$$\check{y} = \hat{y} - \tilde{y}. \quad (21)$$

Next, we build the endogenous Growth rate of the Agriculture, hunting, and forestry industries' transactions (see Table 1, column (a); Figure 1a) depending on the time phases as the optimal solution to the following mathematical programming problem:

Find Growth rate values $r(1995 + j - 1)$, $j = 1, 2, \dots, 24$, minimizing functionality

$$\min_{Y \in \ell_\infty} \|\tilde{Y} - Y\|_{\ell_\infty} \quad (22)$$

and satisfying constraint conditions as the first order linear of the logistic growth difference Equation (1):

$$Y(t + j + 1) = (1 + r(t + j))Y(t + j) - \check{y}(t + j + 1) \quad (23)$$

where $\tilde{Y}(t + j) = \sum_{j=t}^{t+j} \tilde{y}(j)$ is a stock made up of the values of the alternative strategy.

Then, implementing models (20)–(21) we will obtain predicted values of the following indicators for the Gross value added transactions:

- Equilibrium growth, billion U.S. dollars (see Table 3, column (a); Figure 1a). For the Equilibrium growth observed from 1995 to 2004—Increased phases of Equilibrium growth by $1.833 - 0.276 = 1.557$ billion U.S. dollars; from 2004 to 2012—Balanced phases of Equilibrium growth on $7.387 - 1.833 = 5.554$ billion U.S. dollars; from 2012 to 2018—Decreased phases of Equilibrium growth by $11.723 - 7.387 = 4.336$ billion U.S. dollars, which corresponds to the condition for sustainable growth Gross value added transactions of the Agriculture, hunting, and forestry industries depending on the factor Equilibrium growth, billion U.S. dollars (see Table 3, column (a); Figure 1a);
- Alternative strategy, billion U.S. dollars. For the Alternative strategy observed from 1995 to 2003—the first phase of convergence from overvalue by $0.915 - 0.276 = 0.639$ billion U.S. dollars to Equilibrium growth; from 2004 to 2015—the second phase of convergence from undervalue to $1.517 - 1.833 = -0.316$ billion U.S. dollars to Equilibrium growth; from 2016 to 2018—the third phase of convergence from undervalue to $10.488 - 10.927 = -0.439$ billion U.S. dollars to Equilibrium growth, which corresponds to the condition for sustainable growth Gross value added transactions of the Agriculture, hunting, and forestry industries depending on the factor Alternative strategy, billion U.S. dollars (see Table 3, column (b); Figure 1a);
- Growth rate, share. For the Growth rate observed from 1995 to 2004—the first phase of convergence with a growth rate of 1.713 to 0.128; from 2005 to 2008—the first phase of divergence with a growth rate of 0.136 to 0.209; from 2009 to 2018—the second phase of convergence with a growth rate of 0.192 to 0.119, which corresponds to the condition of sustainable growth Gross value added transactions of the Agriculture, hunting, and forestry industries depending on the endogenous factor Growth rate, share (see Table 3, column (c); Figure 1b);
- Exogenous flows, billion U.S. dollars. For the Exogenous flows are observed from 1995 to 2005—the first phase of convergence from an undervalue of 0.639 billion U.S. dollars to Steady state; from 2006 to 2013—the second phase of convergence from the overvalue to 0.338 billion U.S. dollars to Steady state; from 2014 to 2018—the third phase of convergence from undervalue by 0.120 billion U.S. dollars to Steady state, which corresponds to the condition of sustainable growth Gross value added transactions of the Agriculture, hunting, and forestry industries depending on the factor Exogenous flows, billion U.S. dollars (see Table 3, column (d); Figure 1b).

4.2. Gross Value Added Transactions Depending on the Factor Variables

4.2.1. Gross Value Added Transactions Depending on Sum by Upper Limit

For econometric analysis of the Gross value added (see Table 1, column (a)) of the Agriculture, hunting, and forestry industries depending on the sum by forecasting time, an upper limit on the Gross fixed capital formation $\sum_{j=t}^{t+T-1} \Delta x(j)$ transactions (see Table 4, column (a)), we will use the first order quasilinear the Verhulst logistic growth difference Equation (12) in the form of functional Equation (14).

$$\ln \frac{1-\hat{y} \left(\sum_{j=1995}^{1995+T-1} \Delta x(j) \right) / 251.1}{\hat{y} \left(\sum_{j=1995}^{1995+T-1} \Delta x(j) \right)} = \begin{matrix} -5.0929 \\ (0.093) \end{matrix} + 1.9656 \times \begin{matrix} \left(\sum_{j=1995}^{1995+T-1} \Delta x(j) \right) \\ (0.061) \end{matrix}, \quad (24)$$

$R^2 = 0.9795$ $T = 1, 2, \dots, 24,$

Further, we will build an alternative strategy \tilde{y} for the Gross value added (see Table 1, column (a)) of the Agriculture, hunting, and forestry industries depending on the sum, an upper limit on the Gross fixed capital formation $\sum_{j=1995}^{1995+T-1} \Delta x(j)$ transactions (see Table 5, column (a)) as the product of the average weighted observation value y (see Table 3, column (a)) on the sum by forecasting time $T = 1, 2, \dots, 24$ an upper limit on the Gross fixed capital formation transactions and deflator D :

$$\tilde{y}(1995 + T - 1) = D^{T-1} \times \frac{\text{SUMPRODUCT} \left(\text{array} \left(\sum_{j=t}^{t+T-1} \Delta x(j) \right), [\text{array}(y)] \right)}{\text{SUMPRODUCT} \left(\text{array} \left(\sum_{j=t}^{t+T-1} \Delta x(j) \right), [\text{array}(1)] \right)}. \quad (25)$$

Table 4. Produce/selling data for the Gross value added transactions depending on the Gross fixed capital formation phases of Kazakhstan’s economic statistics.

(a)	(b)	(c)	(d)	(e)	(a)	(b)	(c)	(d)	(e)
0.014	0.255	0.746		0.491	1.371	3.203	3.672	0.190	0.469
0.127	0.318	0.816	0.426	0.498	1.484	3.860	3.953	0.188	0.092
0.240	0.396	0.955	0.254	0.559	1.597	4.616	5.274	0.188	0.658
0.353	0.493	0.995	0.196	0.502	1.711	5.466	5.845	0.184	0.379
0.466	0.612	1.049	0.174	0.437	1.824	6.401	6.366	0.180	−0.035
0.579	0.760	1.065	0.167	0.305	1.937	7.397	6.949	0.176	−0.448
0.692	0.941	1.103	0.167	0.162	2.050	8.418	7.853	0.172	−0.564
0.806	1.164	1.253	0.173	0.089	2.163	9.415	8.626	0.166	−0.789
0.919	1.436	1.294	0.180	−0.141	2.276	10.327	9.646	0.158	−0.682
1.032	1.766	1.544	0.190	−0.222	2.389	11.090	9.823	0.148	−1.268
1.145	2.164	2.953	0.200	0.789	2.503	11.641	10.668	0.137	−0.973
1.258	2.640	3.088	0.192	0.448	2.616	11.930	11.173	0.125	−0.757

Note. (a) Uniform distribution of Gross fixed capital formation phases; (b) Equilibrium growth of Gross value added transactions depending on the Gross fixed capital formation phases; (c) Alternative strategy of Gross value added transactions depending on the Gross fixed capital formation phases; (d) Growth rate of Gross value added transactions depending on the Gross fixed capital formation phases, share; (e) Exogenous flows for the Gross value added transactions depending on the Gross fixed capital formation phases; Billion U.S. dollars. Compiled by the author.

Next, we build the endogenous factor Growth rate of the Gross value added (see Table 3, column (c)) of the Agriculture, hunting, and forestry industries depending on the sum of an upper limit on the Gross fixed capital formation transactions as the optimal solution to the following mathematical programming problem:

- Find Growth rate values $r \left(\sum_{j=1995}^{1995+T-1} \Delta x(j) \right), T = 1, 2, \dots, 24,$ minimizing functionality

$$\min_{Y \in \ell_\infty} \|\tilde{Y} - Y\|_{\ell_\infty} \quad (26)$$

and satisfying constraint conditions as the first order linear of the logistic growth difference Equation (1):

$$Y\left(\sum_{j=1995}^{1995+T-1} \Delta x(j)\right) = \left(1 + r\left(\sum_{j=1995}^{1995+T-1} \Delta x(j)\right)\right) \times Y\left(\sum_{j=1995}^{1995+T-1} \Delta x(j)\right) - \check{y}\left(\sum_{j=1995}^{1995+T-1} \Delta x(j)\right) \tag{27}$$

where $\check{Y}(t + T) = \sum_{j=t}^{t+T} \check{y}(j)$, $T = 1, 2, \dots, 24$ is a stock depending on sum by upper limit of the flows of the alternative strategy.

Table 5. The estimated least squares of parameters of a Verhulst logistic growth model for the Gross value added depending on the sum of an upper limit on Gross fixed capital formation transactions.

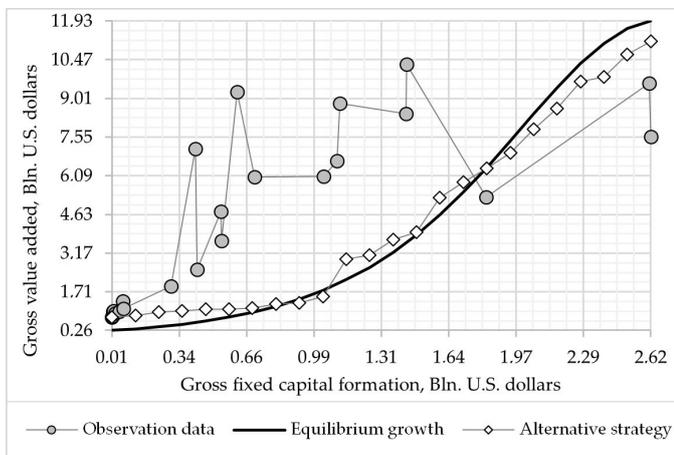
Parameters	$\ln \frac{1 - y\left(\sum_{j=1995}^{1995+T-1} \Delta x(j)\right)/251.1}{y\left(\sum_{j=1995}^{1995+T-1} \Delta x(j)\right)}$
\hat{r}_y	1.9656 *** (0.061)
Constant	-5.0929 *** (0.093)
Num of obs.	24
R-square	0.9795

Note. The dependent variable is $\ln\left(1 - y\left(\sum_{j=1995}^{1995+T-1} \Delta x(j)\right)/251.1\right) / y\left(\sum_{j=1995}^{1995+T-1} \Delta x(j)\right)$ —a stock value of Gross value added depending on sum an upper limit on Gross fixed capital formation transactions in the Agriculture, hunting, and forestry industries, $T = 1, 2, \dots, 24$. In parentheses are standard errors. *, **, ***—estimate is significant at 10%, 5%, 1% level.

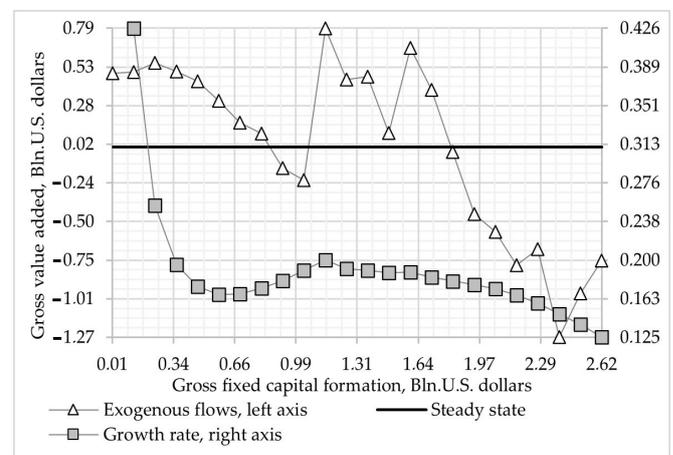
Then, implementing models (24)–(27) we will obtain predicted values of the following indicators for the Gross value added transactions:

- Equilibrium growth, billion U.S. dollars (see Table 6, column (b); Figure 2a). For the Equilibrium growth observed from 0.014 to 1.371 billion U.S. dollars the Gross fixed capital formation transactions—Increased phases of Equilibrium growth by $3.203 - 0.255 = 2.948$ billion U.S. dollars of the Gross value added transactions; from 1.371 to 1.937 billion U.S. dollars of the Gross fixed capital formation transactions—Balanced phases of Equilibrium growth on $7.397 - 3.203 = 4.194$ billion U.S. dollars of the Gross value added transactions; from 1.937 to 2.616 billion U.S. dollars the Gross fixed capital formation transactions—Decreased phases of Equilibrium growth by $11.930 - 7.397 = 4.534$ billion U.S. dollars of the Gross fixed capital formation transactions, which corresponds to the condition for sustainable growth Gross value added transactions of the Agriculture, hunting, and forestry industries depending on the factor Equilibrium growth, billion U.S. dollars (see Table 4, column (a), (b); Figure 2a);
- Alternative strategy growth, billion U.S. dollars. For the Alternative strategy growth observed from 0.014 to 0.806 billion U.S. dollars of the Gross fixed capital formation transactions—the Convergence phases of Alternative strategy growth, which allows the acquisition of $1.253 - 0.746 = 0.507$ billion U.S. dollars of the Gross value added transactions; from 0.919 to 1.824 billion U.S. dollars of the Gross fixed capital formation transactions—the Neutral phases of Alternative strategy growth, which allows the acquisition of $6.366 - 1.294 = 5.071$ billion U.S. dollars of the Gross value added transactions; from 1.937 to 2.616 billion U.S. dollars of the Gross fixed capital formation transactions—the Divergence phases of Alternative strategy growth, which allows the acquisition of $11.173 - 6.949 = 4.224$ billion U.S. dollars of the Gross value added transactions, which corresponds to the condition for sustainable growth Gross value added transactions of the Agriculture, hunting, and forestry industries depending

- on the factor on Alternative strategy, billion U.S. dollars (see Table 4, column (a), (c); Figure 2a);
- Growth rate, share. For the Growth rate observed from 0.127 to 0.692 billion U.S. dollars of the Gross fixed capital formation transactions—the first phase of Convergence with a growth rate from 0.426 to 0.167 share of the Gross value added transactions; from 0.806 to 1.597 billion U.S. dollars of the Gross fixed capital formation transactions—the Divergence phase with a growth rate from 0.173 to 0.188 share of the Gross value added transactions; from 1.711 to 2.616 billion U.S. dollars of the Gross fixed capital formation transactions—the second phase of Convergence with a growth rate from 0.184 to 0.125 share of the Gross value added transactions, which corresponds to the condition for sustainable growth Gross value added transactions of the Agriculture, hunting, and forestry industries depending on the endogenous factor Growth rate, share (see Table 4, column (a), (d); Figure 2b);
 - Exogenous flows, billion U.S. dollars. For the Exogenous flows observed from 0.014 to 0.806 billion U.S. dollars of the Gross fixed capital formation transactions—the Convergence phase of Exogenous flows, which allows the acquisition of $0.491 - 0.089 = 0.401$ billion U.S. dollars of the Gross value added transactions; from 0.919 to 1.824 billion U.S. dollars of the Gross fixed capital formation transactions—the Neutral phase of Exogenous flows, which allows the acquisition of $0.141 - 0.035 = 0.106$ billion U.S. dollars of the Gross value added transactions; from 1.937 to 2.616 billion U.S. dollars of the Gross fixed capital formation transactions—the Divergence phase of Exogenous flows, which allows the acquisition of $0.757 - 0.448 = 0.309$ billion U.S. dollars of the Gross value added transactions, which corresponds to the condition for sustainable growth Gross value added transactions of the Agriculture, hunting, and forestry industries depending on the factor on Exogenous flows, billion U.S. dollars (see Table 4, column (a), (f); Figure 2b).



(a)



(b)

Figure 2. Gross value added transactions depending on the Gross fixed capital formation phases in the Agriculture, hunting, and forestry industries: (a) Observation data; Equilibrium growth; Alternative strategy and (b) Growth rate, right axis; Exogenous flows, left axis; Steady state.

Table 6. The estimate least squares of parameters a logistic growth model for Gross value added depending on the variables of Gross fixed capital formation transactions by industries and their phase of time lags.

Parameters	y	Parameters	y
$\hat{\beta}_{(-1)}$	−0.2321 ** (0.112)	$\hat{\beta}_{(ii)}$	0.2895 *** (0.083)
$\hat{\beta}_{(i)}$	0.8836 *** (0.118)	$\hat{\beta}_{(ii-1)}$	−0.2408 *** (0.069)
$\hat{\beta}_{(i-1)}$	1.4610 *** (0.173)	$\hat{\beta}_{(iii-1)}$	1.0778 *** (0.107)
$\hat{\beta}_{(i-2)}$	2.0375 *** (0.188)	$\hat{\beta}_{(iii-2)}$	−0.5597 *** (0.070)
Constant	0.8884 *** (0.094)	Num of obs.	22
		R-square	0.9970

Note. The dependent variable *y* is a flow value of Gross value added of Agriculture, hunting, forestry produce/selling transactions. In parentheses are standard errors. *, **, ***—estimate is significant at 10%, 5%, 1% level.

4.2.2. Gross Value Added Transactions Depending on the Gross Fixed Capital Formation

For econometric analysis of the Alternative strategy of Gross value added (see Table 1, column (a)) of the Agriculture, hunting, and forestry industries depending on the Gross fixed capital formation transactions (see Table 1, column (d)), we will use the first order linear of the logistic growth difference Equation (1) in the specification (15) and condition (16). Then, the least squares give the following estimates (see Table 7):

$$y(t) = -0.1962 + 0.8690y_{(-1)}(t - 1) + 0.8706x_{(i)}(t). \tag{28}$$

$R^2 = 0.9920$ (0.188) (0.072) (0.319)

Table 7. The estimated least squares of the parameters of a logistic growth model for Alternative strategy of the Gross value added transactions depending on the Gross fixed capital formation variable.

Parameters	y	Parameters	y
$\hat{\beta}_{(-1)}$	0.8690 ** (0.072)	$\hat{\beta}_{(i)}$	0.8706 *** (0.319)
Constant	−0.1962 (0.188)	Num of obs.	23
		R-square	0.9920

Note. The dependent variable *y* is a flow value for the Alternative strategy of Gross value added of the Agriculture, hunting, and forestry produce/selling transactions. In parentheses are standard errors. *, **, ***—estimate is significant at 10%, 5%, 1% level.

Here we note that indeed productive growth in the stochastic dynamics of the depending variable for the Alternative strategy of Gross value added transactions *y*(*t*) of the Agriculture, hunting, and forestry industries will be ensured a growth of 0.8690 billion U.S. dollars at an increase of one billion U.S. dollars of the independent variable $y_{(-1)}(t - 1)$ with one-year time lags, and also will be provided a growth of 0.8706 Billion U.S. dollars at increase of one Billion U.S. dollars independent variable of the Gross fixed capital formation transactions $x_{(i)}(t)$ by Agriculture, hunting, and forestry industries.

4.3. Productivity Classification of Gross Value Added Transactions

For econometric analysis, we consider the Gross value added transactions *y*(*t*) of Agriculture, hunting, and forestry industries (see Table 1, column (a)) and its one-year time phases $y_{(-1)}(t - 1)$ depending on the statistically significant variables Gross fixed capital formation transactions $x_{(i)}(t)$ and its one-two-year time phases $x_{(i)}(t - 1)$, $x_{(i)}(t - 2)$ of Agriculture, hunting, and forestry industries (see Table 1, column (d)); Gross fixed capital formation transactions $x_{(ii)}(t)$ and its one-year time phases $x_{(ii)}(t - 1)$ of Food products, beverages and tobacco industries (see Table 1, column (e)); Gross fixed capital formation

transactions $x_{(iii)}(t)$ and its one-two-year time phases $x_{(iii)}(t - 1)$, $x_{(iii)}(t - 2)$ of Wholesale and retail trade industries (see Table 1, column (f)). Next we use the econometric models with (15)–(16) specification. Then the least squares give the following estimates (see Table 6):

$$\begin{aligned}
 y(t) = & \quad 0.8884 & \quad -0.2321y_{(-1)}(t - 1) & \quad +0.8836x_{(i)}(t) \\
 R^2 = 0.9970 & \quad (0.094) & \quad (0.112) & \quad (0.118) \\
 & +1.4610x_{(i)}(t - 1) & +2.0375x_{(i)}(t - 2) & +0.2895x_{(ii)}(t) \\
 & \quad (0.173) & \quad (0.188) & \quad (0.083) \\
 & -0.2408x_{(ii)}(t - 1) & +1.0778x_{(iii)}(t - 1) & -0.5597x_{(iii)}(t - 2), \\
 & \quad (0.069) & \quad (0.107) & \quad (0.070)
 \end{aligned} \tag{29}$$

Then we obtain a classification of the productivity of Gross value added transactions by depending on independent factors in the following groupings.

The first Productive growth group are:

- $x_{(i-2)}(t - 2)$, Gross fixed capital formation transactions by the Agriculture, hunting, and forestry industries with two-year time lags and productivity on 2.038 billion U.S. dollars (see Table 8), and
- $x_{(i-1)}(t - 1)$, Gross fixed capital formation transactions by the Agriculture, hunting, and forestry industries with one-year time lags and productivity on 1.461 Billion U.S. dollars (see Table 8), and
- $x_{(iii-1)}(t - 1)$, Gross fixed capital formation transactions by Wholesale and retail trade industries with one-year time lags and productivity on 1.078 Billion U.S. dollars (see Table 8).

Table 8. Classification of impact factors x to productivity of Gross value added transactions y .

Independent Variables	Slope Parameters	Classification of Growth
$x_{(i-2)}(t - 2)$	2.038	Productive growth
$x_{(i-1)}(t - 1)$	1.461	Productive growth
$x_{(iii-1)}(t - 1)$	1.078	Productive growth
$x_{(i)}(t)$	0.884	Moderate growth
$x_{(ii)}(t)$	0.290	Moderate growth
$y_{(-1)}(t - 1)$	-0.232	Critical growth
$x_{(ii-1)}(t - 1)$	-0.241	Critical growth
$x_{(iii-2)}(t - 2)$	-0.560	Critical growth

Note. $y_{(-1)}(t - 1)$ is the Gross value added transactions by the Agriculture, hunting, and forestry industries with one-year time lags; $x_{(i)}(t)$, $x_{(i-1)}(t - 1)$, $x_{(i-2)}(t - 2)$ is the Gross fixed capital formation transactions by the Agriculture, hunting, and forestry industries with current, respectively, one- and two-year time lags; $x_{(ii)}(t)$, $x_{(ii-1)}(t - 1)$ is the Gross fixed capital formation transactions by the Food products, beverages, and tobacco industries with current and one-year time lags; $x_{(iii-1)}(t - 1)$, $x_{(iii-2)}(t - 2)$ is the Gross fixed capital formation transactions by the Wholesale and retail trade industries with one- and two-year time lags; Billion U.S. dollars. Compiled by the authors.

The second Moderate growth group are:

- $x_{(i)}(t)$, Gross fixed capital formation transactions by the Agriculture, hunting, and forestry industries with productivity on 0.884 billion U.S. dollars (see Table 8), and
- $x_{(ii)}(t)$, Gross fixed capital formation transactions by the Food products, beverages and tobacco industries with productivity on 0.290 Billion U.S. dollars (see Table 8).

The third Critical growth group are:

- $y_{(-1)}(t - 1)$, Gross value added transactions by the Agriculture, hunting, and forestry industries with one year time lag and undervalue productivity on -0.232 billion U.S. dollars (see Table 8), and
- $x_{(ii-1)}(t - 1)$, Gross fixed capital formation transactions by the Food products, beverages and tobacco industries with one year time lag and undervalue productivity on -0.241 Billion U.S. dollars (see Table 8), and

- $x_{(iii-2)}(t-2)$, Gross fixed capital formation transactions by Wholesale and retail trade industries with two-year time lags and undervalue productivity on -0.560 Billion U.S. dollars (see Table 8).

5. Discussion

It should be noted that the expected results as a methodology can be implemented in the development of a multi-sided platform in the new economy. In this regard, we provide a definition of the platform. The agricultural industry is a structured system of complex objects, such as the Seller Block, the Consumer Block and the Online Digital Technology Platform. It integrates digital technologies and sustainable agricultural practices through ecosystems for all participants in the process, providing comprehensive standard solutions for interactions between users, including commercial transactions. Also, this system is aimed at increasing the efficiency and productivity of agricultural transactions by adopting platform approaches, where data, services and resources are interconnected within an integrated ecosystem in which innovations such as precision farming, IoT (Internet of Things) and data analytics are widely used. The agricultural industry platform promotes real-time decision-making, resource optimization and cost reduction.

Econometric analysis of sustainability and development strategies in the agricultural sector is critical to understanding the complex interactions of environmental, economic, and policy factors that shape agricultural systems. Here, we note that to ensure the sustainability of the economic system of the agricultural sector, the researcher and/or decision maker can use the results of Theorem 1 and Corollary 1, that is, the application of Equations (4)–(7) in constructing the equilibrium growth trajectory, an alternative strategy, and a more realistic trajectory of doubling the Gross Value Added. We also note that the results of Theorem 1 and Corollary 1 can be used for a more in-depth econometric analysis of the study by [Ahmadaali et al. \(2018\)](#) in the context of assessing the impact of water management strategies and climate change on the environmental and agricultural sustainability of the Lake Urmia Basin in Iran; it can also predict critical levels of unsustainable water use, levels of aggravated climate change, and the extent to which agricultural productivity and the country's ecological balance are disrupted ([Ahmadaali et al. 2018](#)).

Also, the econometric analysis and the analysis of the gross value added transaction depending on the time phases (11), (13), (17)–(20) for the classification of equilibrium growth: by increased, balanced and decreased operations of this study can be used in the assessment of the sustainability of agricultural systems with the application of multi-criteria analysis (MCA) in [Pashaei Kamali et al. \(2017\)](#) to examine the feasibility and sustainability of agricultural practices in different dimensions—economic, environmental and social processes—when checking sustainability indicators. In the case of assessing the heterogeneity and sustainability of agricultural production at the regional level, the results of computable mathematical optimization models (21)–(23) and (26)–(27) can be used in the new approach of multicriteria analysis of local environmental conditions, economic constraints and social factors in accordance with the requirements of regional development strategies ([Bartzas and Komnitsas 2020](#)).

The methodology of determining the time phases of overvalue and (or) undervalue of imbalances in which convergence to and (or) divergence from the equilibrium growth is observed for endogenous growth rates of factors and for exogenous flows of Gross value added transactions depending on Gross fixed capital formation can be applied in the implementation of the Data Envelopment Analysis (DEA) project on sustainability indicators of European agricultural systems at the regional level proposed by [Gerdessen and Pascucci \(2013\)](#) to generate new alternative valuable information on how different regions use their agricultural resources in relation to their environmental and economic constraints.

The methodology of determining the time phases of the overvalue and (or) undervalue of imbalances in which convergence and (or) divergence from equilibrium growth is observed for an alternative strategy of operations with Gross value added can be applied in the development new alternative of a robust Analysis and Design of Agricultural Sus-

tainability Indicators System that integrates several indicators—economic, environmental and social—to assess the long-term sustainability of agricultural systems (Qiu et al. 2007).

6. Conclusions

First of all, we studied econometric and sustainability analysis of Gross value added transactions depending on time phases. Using the first-order quasi-linear Verhulst logistic growth difference equation and the least squares method, we identified the main growth trends according to the following three criteria: equilibrium, balanced and optimal growth of Gross value added transactions.

For equilibrium growth:

- from 1995 to 2004, there was an Increased phase,
- from 2004 to 2012, a Balanced phase occurred,
- from 2012 to 2018, a Decreased phase was observed.

For alternative strategy growth:

- from 1995 to 2003, the first convergence phase was identified,
- from 2004 to 2015, the second convergence phase occurred,
- from 2016 to 2018, the third convergence phase was noted.

For Endogenous Growth Rate:

- from 1995 to 2004, the first phase of convergence to steady state was observed,
- from 2005 to 2008, there was a phase of divergence from steady state,
- from 2009 to 2018, a second convergence phase to steady state occurred.

For Exogenous Flows:

- from 1995 to 2005, there was a convergence to undervalue,
- from 2006 to 2013, there was convergence to overvalue,
- from 2014 to 2018, convergence to undervalue was observed again.

These assessments of depending on time phases describe the stochastic dynamics in agriculture, hunting, and forestry industries for Kazakhstan's economy. The first group of results allows us to conclude that a methodology has been developed for classifying the modeling of behavioral characteristics of a time series by time phases by the Increase, Balance and Decrease of a trend, by the Convergence and Divergence to a steady state, and by Undervalue and Overvalue of the state in relation to a trend.

Secondly, we studied econometric and sustainability analysis of Gross value added depending on sum by upper limit on Gross fixed capital formation transaction phases. Also, using the first-order quasi-linear Verhulst logistic growth difference equation and the least squares method, we identified the main growth trends according to the following three criteria: equilibrium, balanced and optimal growth of Gross value added.

For Equilibrium Growth:

- Increased Phase: Gross fixed capital formation transactions ranges from 0.014 to 1.371 billion U.S. dollars.
- Balanced Phase: It ranges from 1.371 to 1.937 billion U.S. dollars.
- Decreased Phase: It ranges from 1.937 to 2.616 billion U.S. dollars.

For Alternative Strategy Growth:

- Convergence Phase: Gross fixed capital formation transactions range from 0.014 to 0.806 billion U.S. dollars.
- Neutral Phase: It range from 0.919 to 1.824 billion U.S. dollars.
- Divergence Phase: It range from 1.937 to 2.616 billion U.S. dollars.

For Endogenous Growth Rate:

- First Convergence Phase: Gross fixed capital formation transactions ranges from 0.127 to 0.692 billion U.S. dollars.
- Divergence Phase: It ranges from 0.806 to 1.597 billion U.S. dollars.
- Second Convergence Phase: It ranges from 1.711 to 2.616 billion U.S. dollars.

For Exogenous Flows Growth:

- Convergence Phase: Gross fixed capital formation transactions ranges from 0.014 to 0.806 billion U.S. dollars.
- Neutral Phase: It ranges from 0.919 to 1.824 billion U.S. dollars.
- Divergence Phase: It ranges from 1.937 to 2.616 billion U.S. dollars.

These phases describe the growth patterns of Gross value added depending on Gross fixed capital formation transactions in Kazakhstan's agricultural, hunting, and forestry industries. Then the second group of results allows us to conclude that this work has developed a methodology for classifying the modeling of behavioral characteristics of the resulting indicator by a factor feature by an Increase, Balance and Decrease of the structure, by a Convergence and Divergence to a stable state, and by Undervalue and Overvalue of the state in relation to the structure.

Third, we have obtained a classification of the productivity of Gross value added transactions by depending on independent factors in the following groupings:

- the first Productive growth group are the Gross fixed capital formation transactions by the Agriculture, hunting, and forestry industries with one- or two-year time lags and the Gross fixed capital formation transactions by the Wholesale and retail trade industries with one-year time lags;
- the second Moderate growth group are the Gross fixed capital formation transactions by the Agriculture, hunting, and forestry industries and the Gross fixed capital formation transactions by the Food products, beverages and tobacco industries,
- the third Critical growth group are the Gross value added transactions by the Agriculture, hunting, and forestry industries with a one-year time lag and the Gross fixed capital formation transactions by the Food products, beverages and tobacco industries with a one-year time lag. Then, the third group of results allows us to conclude that this work has developed a methodology for classifying the modeling of behavioral characteristics of productivity growth by a factor indicator with 0, 1, and 2 years of time lags for the Productive, Moderate and Critical growth of the economic indicator.

Further, we note that the study of the econometric analysis of sustainability and alternative strategy of gross value added in the agricultural sector of Kazakhstan does not exclude a number of limitations, in particular the small size of the national economy of Kazakhstan, the presence of the "middle income trap", "resource curses", "Dutch disease", internal and external "challenges" in the energy sector, and technological shifts. The combination of economic theory with advanced mathematical methods and econometric simulation models to develop systematic classification structures for analyzing time series behavioral characteristics and agent productivity growth in the agricultural sector provides the originality of this research.

In conclusion, it should be noted that we see future research on the econometric analysis of sustainability and alternative strategy of gross added value in the agricultural sector of Kazakhstan in the development of the authors' methodology for classifying behavioral characteristics of a time series by time phases, the resulting indicator by a factor feature and productivity growth by factor indicator with time lags of 0, 1 and 2 years at a higher level of instrumental and mathematical methods of economics, such as fuzzy logic methods, genetic algorithms, neural networks and expert systems.

Author Contributions: Conceptualization, A.T. and S.K.; methodology, A.T. and S.K.; software, A.A., Y.I. and D.T.; validation, S.K. and A.A.; formal analysis, A.T., M.T., A.U., Z.B., R.M. and Z.T.; investigation, A.T., M.T., A.U., Z.B., R.M. and Z.T.; resources, A.A., Y.I. and D.T.; data curation, A.A., Y.I. and D.T.; writing—original draft preparation, S.K. and A.A.; writing—review and editing, S.K. and A.A.; visualization, S.K. and A.A.; supervision, S.K.; project administration, S.K.; funding acquisition, A.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. AP09259435).

Data Availability Statement: Data were obtained from the Organization for Economic Co-operation and Development Stat. Available online: <https://stats.oecd.org> (accessed on 15 April 2024).

Acknowledgments: We express gratitude to the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan for its support of the realization this research (Grant No. AP09259435).

Conflicts of Interest: The authors declare no conflicts of interest.

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