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The Impact of Agri-Food Supply Channels on the Efficiency and Links in Supply Chains

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Abstract: Improving the efficiency in the links in the supply chains of agri-food products is relevant in terms of the assessment methodology and practical aspects for ensuring and supporting sustainable supply chains of products not only in individual channels of product movement but also in the end-to-end supply chain of products, i.e., from the field to the end consumer. However, it is still unclear which supply chain opportunities in commodity distribution channels are more effective for creating end-to-end sustainable supply chains for agri-food products. The purpose of the study is to develop a methodology for assessing the impact of agri-food supply channels on the efficiency and link in supply chains, taking into account the factors affecting them and developing recommendations for their improvement. Quantitative methods based on correlation and regression analysis using the EViews program on the basis of Kazakh statistical data for 2008–2022 were used. A methodology is proposed for assessing the effectiveness of the functioning and links in commodity movement in the supply chains of agricultural products at the macroeconomic level based on the consideration and use of important factors affecting the efficiency and links: production and sales volumes, total costs, and profitability for each supply channel: "production–processing–industrial production–trade". The relationship between the efficiency and the links in supply chains and also the key factors that affect them have been established. The results showed that the increase in the efficiency in supply channels in the commodity distribution system leads to a decrease in the coefficient of the link in commodity movement and inventory availability. To reduce the link ratio in the supply chains of agri-food products, it is necessary to increase the efficiency in supply chains in each supply chain link and reduce the share of retail trade in the gross turnover. Recommendations are proposed to improve supply chain efficiency and reduce links to support and create end-to-end sustainable supply chains of agri-food products. The study makes an essential contribution to providing empirical evidence of the relationship between the effectiveness of agri-food supply channels and the link in the supply chain. Since few works describe the relationship between the links of product distribution and the efficiency in supply chains in the literature, in this work, it was possible to propose a methodology and identify factors and gaps in research to identify potential areas for future research.

Keywords: supply chain performance; agri-food supply chain; profitability; connectivity ratio; distribution channels; economic sustainability; goods flow; trade

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1. Introduction

In the domestic market of Kazakhstan, agricultural products pass through many channels in the supply chains before reaching the final consumer. At the same time, the number of intermediaries in supply chains increases, the price of products increases, and the quality of services decreases (Raimbekov et al. 2021). In recent years, the prices for products in the domestic market of Kazakhstan have been growing faster than in the foreign market, which could be explained by a significant number of intermediaries in retail trade, a low level of integration, and an undeveloped mechanism for the interaction of small producers (almost 80% of agricultural products in Kazakhstan are produced by small-scale farms and households) with vegetable and potato stores and warehouses for agricultural products, as well as with retail chains (National Trade Development 2021). All these facts lead to a considerable increase in the cost of goods for the end consumer (up to five to ten times), to an increase in the share of the shadow economy (24% in 2021), and to a decrease in the efficiency and sustainability of the commodity distribution network in Kazakhstan. The share of the non-observed (shadow) economy in wholesale and retail trade is 7.2% of GDP, and in agriculture is 2.0% of GDP[1].

Thus, the question arises of reducing the shadow economy by decreasing the number of intermediaries arising (reduction of the number of links in the movement of goods) while increasing the efficiency in supply chains not only through individual channels but throughout the entire supply chain: agricultural enterprises, processing enterprises in the agricultural industry, industrial production enterprises, and trade.

Improving the efficiency in each link in food supply chains (production, processing, delivery, and sale) is of great interest in terms of improving the sustainability and competitiveness of agri-food supply chains (McCullough et al. 2008). As world experience shows, it is possible to increase the efficiency in organizing the sale of agricultural products, processing, and food industries through the rational organization of supply chains and the development of a commodity distribution network and the system as a whole (Baibardina and Yakimik 2018; Closs et al. 2011; Ilyina 2013; Kireenko 2015; Touboulic and Walker 2015).

The process of bringing agricultural or agro-industrial products to end consumers includes a multi-link chain, and the overall effectiveness of this system depends on the efficiency in each link: production, sales, trade, and the entire system. Therefore, to identify reserves for improving the efficiency in supply channels, it is necessary to consider supply channels not only individually but also as a supply chain in general. Identification of crucial links in supply chains and formation of a system of indicators to assess their effectiveness are required.

The impact of agri-food supply chains on efficiency has been explored in papers from various perspectives: economic, environmental, and social (Despotovic et al. 2016). While the influence of supply channels on the linkage of supply chains is poorly understood, it has great practical importance. In our opinion, this could be explained by the lack of a developed assessment methodology. The repeated and unjustified increase in the number of links in supply chains negatively affects supply chains' efficiency, competitiveness, and sustainability (Bowersox et al. 2014) and the support of end-to-end supply chains (Closs et al. 2011). In this regard, there is a need to study them and determine the key factors influencing the coefficient of links in the distribution of agri-food products.

At the same time, when studying the production, sale, and consumption of agri-food products, the quantitative and qualitative methods for measuring efficiency are widely used, such as statistical and economic analysis. However, these methods are insufficient to assess agri-food supply chains' impact on supply chain efficiency and linkage. Meanwhile, the statistical and economic indicators, such as the volume of trade, total costs, profitability, link ratio for individual participants in supply chains, and others are used.

We propose a cross-cutting approach to determine the influence of factors on the efficiency and linkage of product distribution.

As the object of study for testing the methodology, Kazakhstan has been chosen for the following reasons. Firstly, this is due to the significant dispersion of producers (with an explicit regional specialization) of agricultural raw materials and their processing, food production enterprises, and trade from the main consumer markets due to the country's vast territories. Secondly, it is because of the need for a mechanism for coordinating and regulating the system of agricultural product distribution. Those circumstances led to an unjustified increase in the number of intermediaries, a decrease in the quality of services, an increase in prices for final products, and others.

Studying supply channels' influence on supply chains' efficiency and links will speed up the turnover process, reduce the number of intermediaries, reduce costs when promoting goods to the consumer, and ultimately find the best options for product supply channels.

The study aims to develop a methodology for assessing the impact of agri-food supply channels on the efficiency and chain links in supply chains and to assess the key factors affecting them. The study's objectives are the development of a methodology; analysis of trends and calculation of indicators of the link ratio and efficiency in supply chains; construction of regression dependencies between the studied factors; and development of recommendations.

The solution to this problem allows us to correctly build the logistics of supply and determine long-term investment in one or another type of channel in the supply chains of agri-food products.

2. Literature Review

Both foreign and domestic scientists are devoted to studying the issues of the formation and development of the supply chain in the activities of enterprises. Among foreign authors, the following should be noted: Barrett et al. (2019); Harrison and Van Hoek (2008); Ilyina (2013); Kireenko (2015); Kotler and Armstrong (2005); Zinovieva et al. (2020).

A complete schematic diagram of possible economic relations in the supply chain of agri-food products is considered (Callado and Jack 2017; Van der Vorst et al. 2007) as a commodity producer–processing enterprise–a wholesale buyer–retail chain–the consumer.

Each of these structures has a variety of activities: trade, production, advertising, information, scientific, etc., and all of them are combined into one system, which is the commodity distribution system.

The theoretical analysis of supply chain management is closely related to concepts such as the efficiency, sustainability, and competitiveness of supply chains. Theoretical aspects of supply chain management and its relationship with sustainability and competitiveness are reflected in the works of Constantin et al. (2023); Touboulic and Walker (2015). Improvement in the efficiency in supply chains is ensured by reduction in costs, which consequently has a positive effect on enhancing competitiveness and quality of services and on the stability of the supply chain.

According to the economic component, supply chain sustainability management makes the supply chain less costly and more efficient while not harming the environment and social groups (Pagell and Shevchenko. 2014). A highly efficient supply chain will provide significant benefits to the enterprise, such as integrated resources, reduced logistics costs, improved logistics efficiency, and high quality of the overall service level (Fan and Zhang 2016).

Of particular interest is the construction of a composite sustainable economic competitiveness index (SECI), which is aimed at direct use in value chains in the agri-food sector (Constantin et al. 2023), in particular for grain chains and a system for assessing sustainability performance with the use of an integrated triple profit (Kumar et al. 2022). These mentioned studies do not consider the coefficient of connectedness of supply chain participants. One of the critical vectors for building sustainable economic competitiveness is a reasonable supply. At the same time, the emphasis should be placed on exporting agri-food products with a high level of added value.

Improving the sustainability of the supply of agri-food products can occur by increasing the efficiency in organizing sales channels for agricultural products, processing, and food industries, as well as trade; improving the structure of supply chains is possible through the rational organization of supply chains with a decrease in the number of intermediaries on the way to selling agricultural products. We also link the efficiency and sustainability of supply chains with the links in the distribution of goods.

The link between efficiency and sustainability in the agri-food sector has shown that the best sustainable companies tend to improve future profitability (Cupertino et al. 2021).

Conversely, the worst of them should focus on the reasons (innovation, commitment of management, and management to sustainable development) that positively affect their profitability. In the short term, a study on the impact of economic sustainability of development on the company's profitability shows that companies have better stability with an increase in their future profitability (Cupertino et al. 2021).

The formation and development of the food supply chain is closely related to assessing the effectiveness of the functioning of food supply chains.

There are the following methods for assessing the effectiveness of supply chains: balanced scorecard (Kaplan and Norton 2005); functional cost analysis (Mouritsen et al. 2001); SCOR (Supply Chain Operations Reference) (Wang et al. 2009); and cost-benefit analysis (Ableeva et al. 2019; Grigoreva et al. 2019).

Further, van Hoek et al. (2001) propose methods for measuring flexible supply chains. In each case, one or another indicator is selected based on the economic, social, or environmental aspects of the supply chain and the type of industry. Knowledge management mechanisms (KMM) based on trust, reciprocity, and contracts positively impact product quality, efficiency, flexibility, agility, and quality of processes in the agri-food supply chain (AFSC).

Meanwhile, domestic businesses could already assess the efficiency in their supply chains using the average performance indicators (API) developed by Deloitte. According to Deloitte, the effect of supply chain management (SCM) optimization is sometimes measured by a significant increase in inventory turnover and a decrease in logistics costs (Harrison et al. 2005). To date, that area of SCM also needs to be studied further. For example, the issues of assessing sustainability, approaches to assessment, and indicators for such an assessment still need to be developed. This issue is further complicated by the fact that the overall composition of indicators will differ for each of the industries.

When assessing the economic efficiency in an enterprise's functioning in the food and trade market, the method of a balanced scorecard and the process of analyzing the economic effect based on Key Performance Indicators (KPIs) are used more often than the others, taking into account the specifics of the industry and the business model being implemented. The discussed methods are used by companies depending on the goals and objectives being solved, and they obtain excellent results. Nevertheless, without detracting from the advantages of each of the above methods of evaluating the effectiveness of supply chains, it should be noted that these methods require the use of very many indicators; therefore, collecting information is a time-consuming process, and sometimes complex, and it takes a long time to obtain the results.

Regarding the efficiency in the commodity movement system, the total costs of performing the commodity movement operation, the quality of logistics operations, labor productivity, and the duration of logistics operations are usually considered (Harrison and Van Hoek 2008; Tyapukhin and Ermakova 2022).

The analysis shows that the factors of supply management, transportation, and logistics positively influence the economic stability of the supply chain of agri-food products. At the same time, the impact of demand and production management on sustainable productivity are not considered significant (Ardekani et al. 2023; Alassane et al. 2020). The positive impact of the productivity and efficiency in the logistics infrastructure of various intermediaries (wholesale and retail trade, warehouses, transport, etc.) on the economic growth of developing countries has been established (Khadim et al. 2021).

The study results of the impact of economic sustainability on a company's short-term profitability (Cupertino et al. 2021) show that companies have better sustainability with an increase in their future profitability.

In the studies of various authors on the product supply chain, multiple indicators are proposed to measure the performance of supply chains (efficiency, flexibility, operational efficiency, and quality of products) (Aramyan et al. 2007); (cooperation, trust, and efficiency) (Gajdić et al. 2023).

Various models and methods are also used to quantify the efficiency and sustainability of the agri-food supply chain: fuzzy AHP method, fuzzy MICMAC analysis method (Ramos et al. 2022), and data coverage analysis method (Raimbekov et al. 2021).

Measuring the productivity and risks of the agri-food supply chain based on a survey and a system of indicators for dairy products (Kataike et al. 2019; Moazzam et al. 2018) and for rice (Chopra et al. 2017) has limitations associated with only one sector of agriculture.

Fan and Zhang (2016) proposed systems of performance indicators and methods for evaluating the effectiveness of the supply chain (SC). However, there are no generally accepted systems of indicators that could be practically used in the assessment of the activity of the SC activity because the indicators in different systems are defined without a common understanding of the values and relationships between them; they are non-linear and very complex.

The overall effectiveness for all partners in the agricultural supply chain (resource suppliers, farmers, distributors, and retailers) is customer satisfaction, that is, their ability to buy products (Callado and Jack 2017). The company's overall efficiency, among other factors, is negatively affected by the company's inventory (Woo and Suresh 2022).

Efficiency or inefficiency in the agri-food supply chain on short or long supply chains (Majewski et al. 2020); assessment of the managerial effectiveness of agricultural products in companies (Kim and Hyun 2017); and measurements of the sustainability of supply chains based on economic, social, and environmental indicators (To et al. 2021) show that they are all related to the links of commodity movement in supply chains, which plays a vital role in ensuring efficiency (Makarevich 2017; Tyapukhin and Ermakova 2022).

The study based on a survey of the company's employees showed that sales channels (variety of channels, integration to attract customers) and strategy factors (finance, innovation, personnel, etc.) have a positive impact on the company's productivity (growth, profit, market share) (Bui and Nguyen 2021).

It could be observed from the research that increasing the sustainability of the supply chain ensures profit at all levels, provides social benefits to society, and has a positive impact on the environment. At the same time, the existing methods of assessing sustainability and effectiveness are mainly associated with a survey in each specific area of research or an analytical assessment of existing data. This approach is limited to using only particular products or agricultural industries and does not consider the influence of sales channels in supply chains.

Considering the problems of functioning and trends in the development of relations between production in agriculture, industrial food production, marketing, and trade of food, we propose to use profitability and the coefficient of links of goods as indicators.

In the work of Makarevich (2017), a methodological development is presented for calculating the coefficient of the links of goods in the wholesale and retail trade system. However, this approach does not assess the links and effectiveness of other supply channels.

Reduction in the links in the movement of goods and also delivery directly to the retail trade network cause a decrease in transport costs, product losses, and other costs (Vlasova et al. 2012). However, the above approaches do not consider the evaluation of linkage and effectiveness in conjunction with other supply channels.

The analysis of methods for assessing the effectiveness of the process of commodity movement (Krasilnikova and Timiryanova 2013) using statistical (dispersion, variation, and cyclicality; link of commodity movement, turnover, and others) and economic (physical volume of sales, volume, and structure of turnover, and others) indicators was carried out.

At the same time, in our opinion, the assessment of the effectiveness of commodity circulation should be carried out, taking into account the specifics of the movement of goods and the links of commodity circulation.

Thus, the approaches considered are focused on evaluating the effectiveness or links of supply chains in individual links and do not imply the possibility of building a mutually interconnected efficiency or links typical of the entire system at all stages of sales channels in product supply chains. In addition, they do not provide a unified system of indicators for the supply of products interconnected with quantitative indicators of production, sales, and trade with economic indicators of efficiency, turnover, prices, and others.

According to this, we propose a methodological approach that allows us to determine the efficiency and links of work, both in separate units and in general in food supply chains, based on the proposed indicators.

Further development of tools for such an assessment will allow for a comprehensive analysis of the movement of goods, with subsequent recommendations to improve its effectiveness.

In this regard, in the study, we have comprehensively studied the influence of sales channels on the efficiency and links in commodity flows with an assessment of the impact of specific factors in supply chains of agri-food products.

3. Methodology and Data

The supply chain for the agro-industrial complex could be characterized as an activity carried out in relation to agricultural products from the state of production to distribution for consumption. Figure 1 shows the supply chain and distribution of agri-food products, where the manufacturer, processing enterprises, trade, and catering are represented according to the following typical scheme: "production–processing–distribution–sale–consumption" (Figure 1).

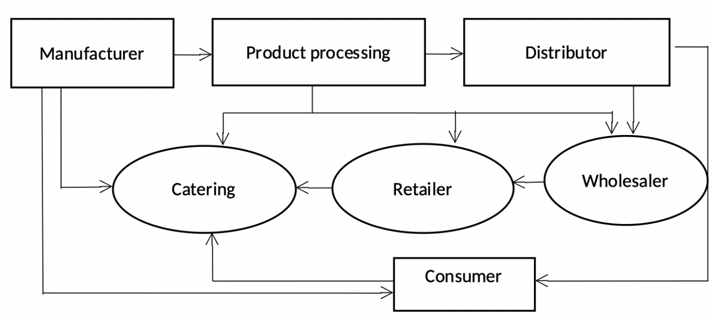

Figure 1. A typical scheme of the agri-food supply chain.

In accordance with Figure 1, the gross trade turnover may consist of the following elements: agricultural products; trade turnover of the food industry; trade turnover of wholesale trade in food products; retail trade in food products; trade turnover of catering services.

The main absolute indicator reflecting the size of the material flow based on its cost characteristics is the volume of gross turnover, the volume of food production.

The indicators characterizing the activities of participants in the commodity distribution chain include:

(1) The coefficient of efficiency (profitability) (CE) in supply chains of food products (SC FP), defined as the ratio of gross profit to revenue (income) or as the ratio of gross turnover to total costs.
The efficiency coefficient (profitability) is determined (Table 1) for (a) manufactured products; (b) sold products; (c) processed and manufactured products in industry; (d) sold food products in industry; (e) trade.

(2) The coefficient of product connectivity in supply chains (SCr) is an indicator that characterizes how many links on average products pass on their way from the sphere of production to the final consumer.
SCr is determined by the ratio of gross turnover and the product sold, or it can be determined through wholesale turnover to retail turnover. The SCr could be calculated both in the economy as a whole, and in the context of individual consumer goods or products, as well as for individual parts of the supply chain (SC).
SCr is defined for agricultural products sold, wholesale trade, FP producers, for trade and their average values (Table 2).

(3) Turnover characterizes inventories, which are determined by the level of availability of inventories (I_l), and is determined by the formula

$$I_l = [(I_{lb} + I_{le})/2] \times 360/Vtt \quad (1)$$

where I_{lb}, I_{le}—inventories at the beginning and end of the period, respectively, Vtt—gross turnover of FP.

(4) The purchasing power of monetary income on average per capita, the number of sets of subsistence minimum (SM), i.e., the ability to buy a living wage, times.

(5) Food price index compared to last year, %

The stability of the supply chain parameters (CS) is determined using the coefficient of variation (CV) according to the formula CS = 100 − CV. The closer the CV value is to 100%, the more stable the series is considered.

Table 1. Indicators used to assess the efficiency and connectivity in commodity movement in food supply chains.

No	Variable and Abbreviation	Formula
	The coefficient of product distribution links in supply chains:	
1	SCrag. Coefficient of links in the sale of agricultural products	Vr.t/Vs.ag.m
2	SCrwt. Coefficient of links of wholesale trade in agricultural food products	Vw.t/Vs.ag.m
3	SCrfm. The coefficient of linkage of food producers	Vt/Vs.ag.m
4	SCrft. The coefficient of linkage of trade in food products	Vtt/Vr.t
5	SCrav. Average link ratio of the food supply chain	(SCag. + SCwt. + SCfm. + SCft.)/4
	Efficiency (profitability) ratio:	
1	CPag. Agricultural production efficiency coefficient	1-Cag/Vag
2	CPi.p. Efficiency coefficient of industrial production of food products (FP)	1-Cin/Vin
3	CPs.ag. Ratio of efficiency in sales of agricultural food products	1-Cag/Vag
4	CPs.in. Efficiency ratio for the sale of industrial food products	1- Cs.in/Vs.in.
5	CPt. Trade efficiency ratio	1- Ct.t/(Vw.t + Vr.t + Vcat.)
6	CPav. Average Food Supply Chain Efficiency Ratio	(CPag. + CPi.p. + CPs.ag. + CPs.in. + CPt.)/5

The research algorithm includes the following stages:

(1) Selection of the scheme of movement (supply channels) of agri-food products according to Figure 1;
(2) Collection of statistical data on each supply channel of agri-food products for the industry according to Table 2: Vag, Vin, Vs.ag.m, Vs.in., and Vtt;
(3) Calculation of supply chain indicators for each channel and in the system as a whole, according to Table 1 and according to Il, PP, and PI, indicators that affect the efficiency and links of supply chains;
(4) Definition and description of statistical characteristics of variables (Table 3);
(5) Description of the dynamics of changes in indicators of production, processing, sales, and trade through supply channels (Table 4);
(6) Modeling and evaluation of the influence of factors on the efficiency and security of supply chains (Table 5). The following is a description of the methodology for evaluating efficiency and linkage in the production and sales supply chain (PS SC):
    1. Definition of variables: production and processing volumes, sales, and trade of agri-food products, their total costs, and profitability (Table 2):
    2. Determination of total costs (cost of products sold and services rendered) and profitability in each link and in the whole system for indicators 1–5 in Table 2.
    3. Calculation of the efficiency in supply chains in each link (Table 1).

4. Calculation of the connectivity ratio of supply chains in each link (Table 1).
5. Assessment of factors affecting the efficiency and connectivity in the supply chain.
6. Analysis, identification of problems.
7. Recommendations for improving distribution channels in agri-food supply chains.

Table 2. Initial indicators of agri-food supply channels, billion KZT.

Supply Chains	Variables	Notation
Production and processing	1. The volume of agricultural products produced	Vag
	The cost of production in agriculture	Cag
	2. The volume of industrial production of food products from raw materials and materials of agricultural products	Vin
	The cost of industrial production of food products	Cin
	Gross food production, (sum of lines 1 + 2)	Vg
Sales	3. Cost of sold agricultural products, billion KZT	Vs.ag.m
	Cost of sold agricultural products	Cs.ag
	4. The volume of sales of food products in the industry	Vs.in.
	The cost of selling food products in the industry	Cs.in
	Gross turnover of food producers (Sum of lines 3 + 4)	Vt
Trade	5.1. Volume of wholesale trade in food products, million KZT	Vw.t
	5.2. The volume of retail trade in food products, million KZT	Vr.t
	5.3. Provision of services for the provision of food and drinks (public catering), million KZT	Vcat.
	Total cost of food trade	Ct.t
	Gross turnover of food products (Sum of lines 5.1-5.3)	Vtt

Table 3. Descriptive statistics of variables.

Variable	Mean	SD	Skewness	Kurtosis	Jarque–Bera Test	*p*-Value	CS
1. The volume of gross food production (Vg)							
1.1. Vag	799.9	353.7	0.80	−0.67	1.88	0.39	65.8
1.2. Vin	1347.2	662.0	1.03	0.72	2.96	0.23	62.9
Vg, Total	2147.1	1009.0	0.94	0.18	2.23	0.33	73.1
2. The volume of gross turnover of food producers (Vt)							
2.1. Vs.ag.m	1326.0	869.8	1.01	0.07	2.56	0.28	69.4
2.2. Vs.in.	1279.8	628.9	1.03	0.72	2.96	0.23	67.9
Vt, Total	2605.9	1494.3	1.02	0.33	2.64	0.27	66.3
3. Gross turnover (Vtt)							
3.1. Vw.t	3715.3	1989.0	0.12	−1.36	1.20	0.51	66.5
3.2 Vr.t	2456.6	1494.1	0.91	−0.16	2.10	0.35	69.2
3.3. Vcat.	370.9	210.7	0.38	−1.16	1.20	0.49	73.2
Vtt, Total	6542.8	3650.8	0.44	−0.94	1.04	0.59 **	74.3

Table 3. *Cont.*

Variable	Mean	SD	Skewness	Kurtosis	Jarque–Bera Test	*p*-Value	CS
Variable factors that affect CPav and SCav							
GDP, billion KZT	47,967.9	25,321.0	0.66	−0.27	1.13	0.57 **	77.2
PP, once	3.2	0.3	−0.73	−1.05	1.04	0.36	90.0
Il	41.8	6.5	0.27	−1.21	1.10	0.51	84.4
PI, %	108.2	3.4	1.86	0.91	2.34	0.05	97.8

GDP—gross domestic product; SD—standard deviation; CS—stability coefficient; **—5% significance level.

Table 4. The cost of gross production, sales, and turnover, the dynamics of changes in variables, and their ratio to GDP and gross turnover, billion KZT.

	2008	2010	2012	2014	2016	2018	2020	2022
1. The volume of gross food production (VG FP) (Vg)								
Vag	452.1	465.2	594.3	563.8	708.1	951.7	1222.4	1495.7
Vin	623.5	695.2	865.6	1103.5	1448.4	1527.7	1957.2	2914.4
Vg, Total	1075.6	1160.4	1459.9	1667.3	2156.5	2479.4	3179.6	4410.1
2. The volume of gross turnover of food producers (Vt):								
Vs.ag.m	370.5	544.1	755.7	872.8	1182.0	1520.2	2304.1	3212.7
Vs.in.	592.3	660.5	822.3	1048.3	1376.0	1451.3	1859.4	2768.7
Vt, Total	962.8	1204.6	1578.0	1921.1	2557.9	2971.5	4163.5	5981.4
3. Gross turnover (Vtt)								
Vw.t	982.8	1548.2	2057.5	3029.9	4448.2	5216.9	5333.1	7043.8
Vr.t	819.7	1050.2	1417.7	1820.8	2204.3	3035.8	4102.1	5614.6
Vcat.	103.3	156.0	220.5	269.3	415.8	524.8	536.6	751.5
Vtt, Total	1905.7	2754.4	3695.7	5120.0	7068.4	8777.5	9971.8	13,409.9
Variables								
GDP	16,052.9	21,815.5	30,177.5	38451.4	45,622.7	61,819.5	70,649.0	101,523
Il	0.152	0.135	0.159	0.122	0.110	0.109	0.107	0.095
PP, once	2.67	2.89	3.08	3.27	3.54	3.44	3.52	3.53
PI,%	108.2	107.1	105.1	106.7	114.6	107.5	108.8	110.7
Calculation of the dynamics of changes in indicators								
Vt share in GDP	0.12	0.13	0.12	0.13	0.15	0.14	0.14	0.13
Vt/Vtt	0.51	0.44	0.43	0.38	0.36	0.34	0.42	0.45
Vtt/Vt	1.98	2.29	2.34	2.67	2.76	2.95	2.40	2.24
Vt/Vg	0.90	1.04	1.08	1.15	1.19	1.20	1.31	1.36
Vtt/Vg	1.77	2.37	2.53	3.07	3.28	3.54	3.14	3.04
Vr.t/Vtt (Srt)	0.43	0.42	0.38	0.36	0.31	0.35	0.41	0.42

Table 5. Indicators for a comprehensive assessment of efficiency and connectivity in supply chains.

	Model 1	Model 2	Model 3
Dependent variables	CPav	CPav	SCrav
Independent variables	SCrft.; CPag.; CPi.p.; CPt.; PP; I_1	SCrft.; PP	Srt; CPav.; PI

Quantitative research methods using data from the website of Bureau of National Statistics of the Republic of Kazakhstan for 2008–2022 were used for the analysis[2].

According to the indicators in Table 2, data collection was carried out.

As shown in Table 2, each supply chain has three components: (1) production and sales volume, (2) production and sales costs, and (3) gross turnover (commodity turnover). Their selection was based on a typical agri-food supply chain layout (Figure 1).

Once the statistics were retrieved from the relevant databases, the next step was to calculate the link ratio and supply chain efficiency in each supply chain link, following Figure 1, using the formula in the column of Table 1.

Thus, the research hypotheses are established as follows:

Hypothesis 1. *in the supply channels of agricultural products, trade has a great impact on the efficiency and connectivity in supply chains;*

Hypothesis 2. *the total efficiency in the supply chain depends on the efficiency in each sales channel, the connectivity in the movement of supply chains, inventory levels, and purchasing power;*

Hypothesis 3. *the connectivity in commodity movement in supply chains negatively affects the efficiency in channels in the supply chain of agricultural products.*

To test hypothesis H1, an analysis of the trend of variables was carried out in Section 4.1; hypotheses H2 and H3 were tested in Section 4.2: Models 1 and 2—to assess the impact of factors on the overall efficiency in supply chains, Model 3—to assess the impact of factors on the connectivity in commodity movement in supply chains.

The names of variables and their designations are presented in Table 5.

In models 1 and 2, the dependent variables are the supply chain efficiency coefficient (average value); in Model 3 is the supply chain connectivity coefficient (average value). Calculations were conducted via the EViews program.

4. Results And Discussion

4.1. Analysis of Efficiency and Connectivity in the Supply Chains of Agri-Food Products

The agro-industrial complex (AIC) is of strategic importance for the socio-economic development of the country and global food security. Unlike other countries, the Eurasian region (Kazakhstan, Russia, Belarus, Uzbekistan, Tajikistan, Kyrgyzstan, and Turkmenistan) ensures food security through its production. Self-sufficiency for most products in 2020 and 2021 exceeded 80–95% (Vinokurov et al. 2023). At the same time, the predominant part of the supply of agricultural goods to the domestic market falls on Russia, Belarus, and Kazakhstan, whose combined share in mutual exports in 2021 amounted to 90%. The share of Kazakhstan in the agri-food market in the Eurasian region ranges from 7.7 to 18.0%, depending on the type of product. The output of food products in monetary terms in 2021 amounted to USD 146.7 billion in prices of 2020. Production and export of food products in the Eurasian region in 2021 amounted to USD 39.8 billion (Russia—29.1, Belarus—6.0, Kazakhstan—3.2). Mutual food trade between the countries of the Eurasian region is growing steadily and reached USD 15.4 billion in 2021.

In terms of production and sales, Kazakhstan occupies a leading position in grain, vegetables, and melons. Table 3 presents statistical data on the volume of production and sale of food products in the supply chains of the Republic of Kazakhstan and the most important factors affecting efficiency and connectivity.

Table 3 shows descriptive statistics for all variables. The asymmetries and kurtosis coefficients are close to zero, which makes it possible to approximate a normal distribution. The hypothesis of normality could be accepted based on the Jarque–Bera statistics at the 5% level. Thus, all parameters studied in Table 3 can be used as methods of parametric statistics for further analysis and have a stable connection (where CS is more than 65%).

Table 4 presents data on the volume of production and sales of food products in the supply chains of the Republic of Kazakhstan.

Despite the slowdown in economic growth due to the pandemic, at the end of 2022, the volume of agricultural production in Kazakhstan at current prices increased by 22.3% and amounted to KZT 1495.7 billion; industrial food production increased by 27.4% or KZT 2914.4 billion. The volume of gross trade turnover of food products increased by KZT 5981.4 billion or 21.6%. Gross trade in food products increased to KZT 13409.9 billion or by 12.4% (Table 4).

In 2008–2022, there was a rapid increase in the volume of gross output (Vg), gross turnover in production (Vt), and gross trade (Vtt) in monetary terms by more than four, six, and seven times, respectively, with a simultaneous decrease in the physical volume index in some of its years (2015, 2016, 2010), which is determined mainly by the influence of the price factor.

There was a slight increase in the share of trade turnover in GDP from 0.12 to 0.13, while the share of production and processing of products (Vt) in the volume of trade turnover (Vtt) decreased from 0.51 to 0.45, and the share of trade turnover (Vtt) to the volume of production (Vg) increased (from 1.98 to 2.24 times). This indicates an increase in the role of trade in comparison with production and processing. That is, trade occupies a leading position in the supply chains of products.

The share of gross trade turnover in production (Vt) to the volume of gross production (Vg) also increased—from 0.90 to 1.36 times—and the Vt/Vg ratio from 1.77 to 3.04 times, which indicates a high growth rate of trade over the growth rate of products sold, as well as the growth rate of products sold over the growth rate of production. The share of retail trade in the total volume of food trade in 2008–2022 increased from 38.1 to 41.8%, catering from 5.4 to 5.6% and vice versa; the share of wholesale trade decreased from 56.5 to 52.5%.

The analysis of supply chain efficiency is presented in Table 6.

Table 6. Analysis of supply chain efficiency, billion KZT.

	2008	2010	2012	2014	2016	2018	2020	2022
1. Production of agricultural products (Vag)								
Vag	427.7	433.3	545.0	582.3	771.9	1031.8	1415.1	1759.7
Cag	337.2	396.4	463.9	504.7	625.9	837.6	1068.7	1318.3
CPag, %	14.37	−3.45	5.42	1.86	5.54	6.45	18.95	25.3
2. Sales of agricultural products (Vs.ag.m)								
Vs.ag.m	370.5	544.1	755.7	872.8	1182.0	1520.2	2304.1	3295.1
Cs.ag	281.6	408.1	553.4	631.5	855.1	1128.0	1639.2	2235.3
CPs.ag, %	24.0	25.0	26.8	27.7	27.7	25.8	28.9	27.1
3. Industrial food production (Vin)								
Vin	623.5	695.2	865.6	1103.5	1448.4	1527.7	1957.2	2914.4
Cin	621.2	697.5	840.9	1069.6	1408.3	1507.6	1831.3	2681.3
CPi.p., %	0.41	−0.33	2.91	3.24	2.81	1.35	6.96	8.72

Table 6. *Cont*.

	2008	2010	2012	2014	2016	2018	2020	2022
4. Sales of food products in the industry (Vs.in.)								
Vs.in.	592.3	660.4	822.3	1048.3	1375.9	1451.3	1859.3	2768.7
Cs.in	515.6	588.2	770.9	915.9	1152.2	1374.2	1655.3	2483.6
CPs.in, %	13.0	10.9	6.20	12.6	13.4	5.30	11.0	10.2
5. Trade in food products (Vtt)								
Vtt	1905.7	2754.4	3695.7	5120.0	7068.4	8777.5	9971.8	13409.9
Ct.t	1385.6	1796.6	2757.5	2757.5	3547.6	5259.5	5513.2	7120.9
CPt, %	27.3	34.8	25.4	46.1	49.8	40.1	44.7	41.6

Note: the full costs of the WTO CCI are obtained from the input–output data of the Bureau of National Statistics of the Republic of Kazakhstan: https://stat.gov.kz/official/industry/11/statistic/5 (accessed on 25 March 2023).

The analysis showed that, during the period under review, the average profitability in the production of agri-food products amounted to 7.83%, in its implementation (CPs.ag) 26.4%; the processing and production of agricultural products in the industry amounted to 2.77%, and in its implementation (CPs.in) 10.2%. The average gross margin of trade was 40.6%.

It is confirmed by the results of numerous studies that trade dominates and dictates the terms of delivery of products and affects the efficiency in other sales channels (Krasilnikova and Timiryanova 2013; Makarevich 2017). As a result, due to the economic efficiency in the enlarged trading business, food retail chains have a greater possibility of price pressure on suppliers (Baibardina and Yakimik 2018).

The shift in the balance of "market power" from producers towards retailers contributes to an increase in the dependence of agricultural producers on wholesale and retail trade (European Commission 2019).

The calculation of the parameters of supply chains is determined by two indicators: the efficiency in the supply chain and the coefficient of the connectivity in goods movement (Table 7).

Table 7. Calculation of parameters in supply chains of agri-food products.

	2008	2010	2012	2014	2016	2018	2020	2022	Mean	SD	CV	CS
Calculation of links in supply chains												
1.SCrag	2.21	1.93	1.88	2.09	1.86	2.00	1.78	1.70	1.90	0.15	7.90	92.1
2.SCrwt	2.65	2.85	2.72	3.47	3.76	3.43	2.31	2.14	2.92	0.53	18.1	81.8
3.SCrfm	5.14	5.06	4.89	5.87	5.98	5.77	4.33	4.07	5.12	0.64	12.5	87.5
4.SCrft	2.33	2.62	2.61	2.81	3.21	2.89	2.43	2.39	2.69	0.28	10.4	89.6
SCrav	3.08	3.12	3.02	3.56	3.78	3.52	2.71	2.57	3.16	0.37	11.7	88.3
Calculation of efficiency (profitability) in supply chains												
1.CPag	0.14	−0.03	0.05	0.02	0.06	0.06	0.19	0.25	0.08	0.10	10.4	89.6
2.CPs.ag	0.24	0.25	0.27	0.28	0.28	0.26	0.29	0.27	0.26	0.02	7.3	92.7
3.CPi.p	0.00	0.00	0.03	0.03	0.03	0.01	0.06	0.08	0.03	0.03	30.4	69.6
4.CPs.in	0.13	0.11	0.06	0.13	0.13	0.05	0.11	0.10	0.10	0.03	26.9	73.1
5.CPt	0.27	0.35	0.25	0.46	0.50	0.40	0.55	0.42	0.41	0.08	19.1	80.9
CPav	0.16	0.13	0.13	0.18	0.20	0.16	0.24	0.22	0.18	0.03	19.1	80.9

As can be seen from Table 7, SCrav increased to a value of 3.78 in general in 2016. Then, there is a decrease to a value of 2.57 in 2022, which indicates a reduction in the number of links through which goods pass on the way from the production sector to the retail network.

The dynamics of changes in trade efficiency correlates with the SCrav connectivity coefficient and purchasing power (PP). Reducing SCrav has a positive effect on reducing the number of resellers. An increase in PP leads to an increase in the volume of trade turnover and an increase in the efficiency in trade (Figure 2).

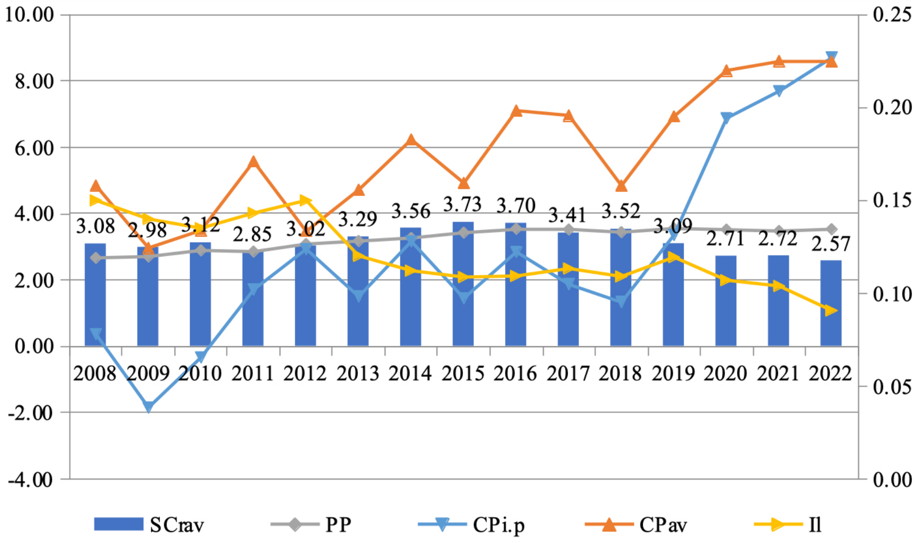

Figure 2. Dynamics of the main factors affecting efficiency in the supply chains of agri-food products in Kazakhstan.

However, the structure of the participants in the distribution chain is far from optimal. This is most likely due to a sharp increase in product prices and an increase in circulation costs, that is, an increase in the costs of intermediary structures, which is due to irrational interconnections and cargo transportation associated with a large number of mutually duplicating economic ties and insufficient development of the commodity market infrastructure.

The supply chain will be considered optimal when the connectivity ratio approaches one. That means that commodity producers (from the point of view of the distribution of proceeds from the sale of products between the participants of the commodity movement) and consumers (concerning the price level) are more profitable than the minimum number of intermediaries, i.e., the equality of the coefficient of the link unit. An increase in the link ratio leads to additional costs within the product distribution chain (Ilyina 2013). That means the company sold all its products through its retail network. Nevertheless, in practice, this does not happen. However, striving by changing structures, using organizational measures and new technologies, and others are necessary.

As discussed earlier, a more optimal structure of participants in the chain of distribution of the food complex is achieved by increasing the share of wholesale trade in the total volume of sales of food products, which helps to reduce the number of links between participants in the movement of goods and, consequently, reduce the SCr.

4.2. Assessment of Factors Affecting Efficiency and Connectivity in Food Supply Chains

After excluding multicollinear, insignificant variables, as well as after correcting heteroscedasticity, we obtain the regression results in Table 8.

Table 8. The main parameters of regression coefficients (n = 15).

Variables and Their Characteristics	Model 1	Model 2	Variables	Model 3
	Dependent Variable CPav		Dependent Variable SCav	
constant	0.0536 **	0.0207 **	SCav	4.5275 ***
Independent variable				
SCav	−0.0117 **	−0.0973 ***	CPav.	−3.3996 **
CPag	0.2018 ***	-	Srt	−8.5982 ***
CPi.p	0.2604 **	-	PI	0.0227 **
CPt.	0.2831 ***	-		
PP		0.0528 ***		
Il		−0.9189 **		
R-squared	0.9669	0.7690		0.8470
Adjusted R-squared	0.9537	0.7141		0.8053
F-statistic	73.21	7.4112		20.30
p-value for the F test	2.2904×10^{-7}	0.0054		0.00008

Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

It may be observed from the analysis of t-statistics that all coefficients are significant.

In Model 1 (R^2 = 0.96) is the greatest contribution to the dynamics of the aggregate efficiency indicator (CPavis created by the efficiency in industrial enterprises (CPi.p.) (r = 0.87) and the efficiency in trade (CPt.) (r = 0.59). An increase in their value by 1% increases CPav by 0.26% and 0.28%, respectively. An important contribution to CPav is shown by the averaged coefficient of product distribution connectivity (SCav) (r = −0.44). A decrease in its value from 3.0 to 2.0 (or by 50%) causes an increase in the overall efficiency in supply chains by 0.005% (50 × 0.0117). The Il factor is insignificant (r = −0.17) at a probability level of 90%, so it is not included in the model.

In Model 2 (R^2 = 0.769), purchasing power (PP) (r = 0.73) makes a significant contribution to aggregate efficiency (CPav). An increase in it by 1% leads to an increase in CPav by 0.0528%, and vice versa, a decrease in the level of commodity movement connectivity and the level of inventory by 1% leads to an increase in SCav by 0.0973% and 0.9189 units, respectively.

In Model 3 (R^2 = 0.847), a decrease in the link ratio (SCav) is influenced by the share of retail trade (Srt) (−0.39). An increase of 1% leads to a decrease in SCav by 0.085%; an increase in the average efficiency coefficient (SCav) (r = −0.85) by 1% leads to a decrease in the connectivity ratio (SCav.) by 3.39%; a decrease in the price index (PI) (r = 0.42) by 1% leads to an increase in SCav by 0.022%.

This circumstance is of high importance in the formation of directions for improving the system for promoting food products from the field to the consumer.

5. Discussion

At present, the importance of intermediary structures in the agri-food market and its individual product segments varies significantly but tends to decrease on average (Kotler and Armstrong 2005). However, we observe an upward trend in certain food markets (Harrison and Van Hoek 2008).

Reducing the value of connectivity (SCav.) can significantly affect the increase in the effectiveness of the entire supply chain of the distribution system. Therefore, one of the main directions for increasing its efficiency is to reduce the connectivity in food products promotion from the producer to the final consumer, which is possible by optimizing the structure and quality of intermediary links.

At the same time, we confirmed that, in models 1 and 2, statistically significant factors affecting

(a) the efficiency in aggregate agro-food supply chains (CPav) are trade connectivity ratio (SCft.); agricultural production efficiency (CPag.); FP production efficiency in industry (CPi.p.); FP trade efficiency (CPt.); purchasing power (PP); and stock level (I_l).

Improving the performance of each link in the supply chain could lead to an improvement in the overall performance of the supply chain, as confirmed by Bui and Nguyen (2021). At the same time, in our opinion, the greatest influence is exerted by the efficiency in trade (regression coefficient 0.2831), the efficiency in production and sale of FP in industry (CPi.p.) (0.2604), and the efficiency in agriculture (0.2018). The decrease in connectivity also has a significant effect (−0.0117), i.e., the number of intermediaries in the overall supply chain and increasing the purchasing power of the population (PP).

(b) the connectivity ratio of supply chains (SCav), which is the share of retail trade in the WTO Chamber of Commerce and Industry (Srt) (−0.085); the coefficient of efficiency in supply chains (CPav.) (0.0339); and the price index for FP (PI) (0.0227).

In Model 3, the share of retail trade in Vtt and the efficiency coefficient (CPav.) have an inverse relationship with the connectivity of goods (SCav). This means that increasing efficiency in supply chains leads to a decrease in the number of connectivity and intermediaries in supply chains, which is confirmed by research (Makarevich 2017; Tyapukhin and Ermakova 2022).

The fact that links have an inverse relationship with the efficiency in supply chains indicates the need for qualitative improvement and optimization of the organizational structure of supply chains in the direction of reducing their number. The existence of a link between efficiency and the connectivity in supply chains is shown in work by Makarevich (2017), where it is revealed that an increase in the volume of wholesale trade leads to a decrease in the connectivity in commodity movement.

We found that, with an increase in the share of retail trade, the connectivity in the movement of goods in the supply chains decreases. In part, this can be explained by the fact that in Kazakhstan most of the agro-food products are sold through wholesale and retail markets and retail chains.

According to the data obtained, factors such as the efficiency in supply chains (−3.399) and the share of retail trade in Vtt (−8.598) have a great influence on the supply chain link ratio (SCav). This can be partly explained by the peculiarities of Kazakhstan's reality in trade. In Kazakhstan, there are exceeding numbers of unorganized and organized retail intermediaries (individual entrepreneurs, retail stores, and wholesale and retail markets), and the sales infrastructure (modern warehouse space and retail facilities) significantly lags behind developed countries (Raimbekov et al. 2021).

Special attention should be paid to the level of stocks (I_l)) and purchasing power (PP) of the population. In order to reduce stocks (I_l)) and their turnover, it is necessary to actively develop warehouse facilities and logistics centers, which causes a decrease in the coefficient of connectivity in supply chains and the containment of prices for food products, which will favorably affect the purchasing power of the population.

Furthermore, the obtained regression coefficients have explicable values and understandable directions of influence. As already mentioned, reducing the value of connectivity is an important factor in increasing economic efficiency in the SC FP.

Based on the assessment of the effectiveness of supply chains and the connectivity in the commodity distribution system in Kazakhstan:

- the main trends inherent in the process of trade development in Kazakhstan are identified; the factors that significantly affect the efficiency in supply chains and the links in the commodity distribution system are identified;
- it is established that, for the formation and development of an effective supply chain and civilized trade, further integration of supply chains into the commodity distribu-

tion system is necessary, which helps to optimally load the distribution channels of goods, reduce costs, reduce the number of intermediaries, and improve the quality of service and product safety;

- based on the results of the analysis of the efficiency in supply chains, it was determined that increasing the sustainability of commodity-carrying food supply chains at all stages—from production to consumption—requires an integrated and coordinated approach (infrastructure, warehouses, financial resources, etc.) in their management;
- formation of more stable and diverse distribution systems, including shorter distribution chains (by reducing the length of supply chains);
- the uniform degree of concentration of commodity flows (production and consumption) in the regions of the country requires a differentiated approach to the creation of regional and interregional commodity distribution networks.

Prospects for improving the efficiency in supply chains and reducing the connectivity in the distribution of agricultural products should be based on:

(1) the close interaction of all market participants and more efficient use of existing wholesale, retail, and catering enterprises, which should help to reduce costs in the commodity distribution system when selling products by minimizing the number of intermediaries in the supply chain between the producer and consumer;
(2) modernization of existing wholesale and retail trade enterprises as the infrastructure of the food market, which involves the maximum use of the capabilities of modern innovative technologies and logistics in order to speed up the process of delivering goods to the consumer with minimal costs and maximum preservation of product quality to meet the demand and needs of the population in goods and services;
(3) the smooth functioning of food distribution chains on a well-established supply of basic food products. One of such measures is the close placement of production and consumers, an increase in the volume of production for delivery to local markets to the main sources of consumption, which is a condition for creating short commodity distribution chains with or without minimal intermediaries.
(4) reduction in stocks and creation of wholesale and retail distribution centers at the locations of manufacturing enterprises (manufacturers), which makes it possible to respond more effectively to changing consumer demands;
(5) improving the efficiency in each channel in the supply chains should move towards reducing costs, consolidating purchases and sales of agri-food products to ensure the volume of work performed, improving the quality of customer service.

6. Conclusions

The conducted research confirms that, in order to increase the efficiency in supply chains, it is necessary to include all links of the logistics supply chains from the manufacturer to the end consumer and improve the factors affecting them.

For this purpose, a methodology is proposed for assessing the impact of agri-food supply channels on the efficiency and link in supply chains. This technique will reduce the number of intermediaries and speed up the turnover process.

The key factors influencing the efficiency and chain links in supply chains have been identified, based on which regression models have been established.

The efficiency in each link in the supply chains and the availability of their inventories are the key factors in improving the performance of the entire supply chain of agricultural products, whereas the link ratio that characterizes the number of resales negatively affects the efficiency in supply chains. It is revealed that the efficiency in the supply chains of each link increases with the transition to each subsequent level of supply channels: from the primary source of production to the consumer. The findings of this empirical study are supported by literature analyzing the impact of supply chain efficiency and supply chain link ratio, with a particular focus on the key factors that contribute to creating efficient and sustainable links between links in agri-food supply chains.

The following recommendations are offered to reduce the link ratio and improve the efficiency in supply chains:

(1) stimulating activities to improve the efficiency in processing and food processing enterprises through the use of innovative and digital technologies, which will lead to an increase in the overall efficiency in the supply chain;
(2) stimulation to increase the income of the population by increasing the number of self-employed and individual entrepreneurs in the field of agricultural production and trade, increasing their purchasing power;
(3) increase in turnover and decrease in stock level due to optimization, monitoring, and implementation of automated logistics technologies, construction of warehouses, storage facilities, and distribution centers;
(4) introduction of digital technologies for measuring, tracking, and controlling material flows in the supply chains of agri-food products;
(5) an increase in the share of retail trade in the total volume of turnover using non-standard methods of sales in retail (online trade, mobile retail, etc.), which will lead to a decrease in the level of connectivity in commodity movement.

The results of the analysis will allow to further carry out an integrated policy to improve the efficiency and sustainability of sales channels in the supply chains of agri-food products, as well as to adopt a coordinated policy on measures to support and stimulate the sphere of production, sales, and trade based on their priority and degree of influence on the level of their overall efficiency and connectivity in the supply chains. The practical implementation of the recommendations will optimize costs, reduce the connectivity in supply chains, and increase the efficiency and stability in supply chains.

7. Limitation And Future Research

Due to lack of information on other supply channels, such as the volume of transportation of food products and their costs, storage volumes and their costs, etc., studies were conducted only on three supply channels: production, sales, and trade. The authors suggest that the following areas of research may be related to the inclusion of other supply channels, as well as the study of more specific types of products as information accumulates. In addition, future research could be improved by further exploring the multilateral links between exports, imports, GDP, real incomes of the population, wholesale and retail turnover, and the level of connectivity in commodity movement.

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

Notes

[1] On the approval of the national project on entrepreneurship development for 2021–2025 https://adilet.zan.kz/rus/docs/P2100000728 (in Russian) (accessed on 28 March 2023).

[2] Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan http://stat.gov.kz (in Russian) (accessed on 10 March 2023).

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