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BLOCKCHAIN AND IOT FOR DIGITAL TRACKING OF FOOD EXPORT-IMPORT FLOWS

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Abstract. Global food demand is increasingly outpacing production, leaving an estimated 690–780 million people food-insecure, with the burden concentrated mainly in Asia and Africa. Cross-border food trade, which could help alleviate these deficits, is constrained by fragmented and paper-based data flows that weaken end-to-end traceability, increase transaction costs, and slow regulatory audits.

This study proposes and evaluates a distributed digital-tracking architecture that integrates Internet of Things (IoT) sensing, permissioned blockchain technology, and edge-cloud stream processing. Telemetry data on temperature, humidity, shock, seal integrity, and geolocation are preprocessed and cryptographically signed at the edge. Critical state transitions are then anchored on a consortium ledger, where smart contracts encode shipment conditions, certification checks, and conditional payments.

A privacy-preserving data model separates sensitive attributes off-chain while maintaining a tamper-evident on-chain audit trail. The study also defines a KPI/KRI framework that links telemetry data to operational and compliance outcomes, including service level, delay variance, spoilage, dispute frequency, and auditability. Performance is assessed in pilot corridors using pre–post comparisons against matched control cases.

The results indicate improved transparency, faster exception handling, and reduced reconciliation effort, suggesting lower waste and transaction costs. The findings demonstrate that IoT-anchored and blockchain-secured traceability can enhance efficiency, trust, and regulatory compliance in food export-import networks while contributing to broader food security objectives.

Keywords: Uzbekistan, blockchain, Internet of Things (IoT), digital traceability, edge-cloud, smart contracts, food export-import, supply chain governance, KPI/KRI, compliance, food security.

Аннотация. Глобальный спрос на продовольствие всё в большей степени опережает объёмы производства, в результате чего, по различным оценкам, от 690 до 780 миллионов человек сталкиваются с проблемой продовольственной необеспеченности, при этом основная нагрузка приходится на страны Азии и Африки. Трансграничная торговля продовольствием, способная способствовать сокращению данного дефицита, сталкивается с ограничениями, обусловленными фрагментированными и преимущественно бумажными потоками данных, что снижает уровень сквозной прослеживаемости, увеличивает транзакционные издержки и замедляет проведение регуляторных аудитов.

В исследовании предлагается и оценивается распределённая архитектура цифрового отслеживания, интегрирующая технологии Интернета вещей (IoT), разрешённого блокчейна (permissioned blockchain) и потоковой обработки данных в среде edge-cloud. Телеметрические данные о температуре, влажности, механических воздействиях, целостности пломб и геолокации предварительно обрабатываются и криптографически подписываются на периферийных устройствах. Ключевые изменения состояния фиксируются в консорциумном реестре, где смарт-контракты обеспечивают контроль условий транспортировки, проверку сертификационных требований и выполнение условных платежей.

Для обеспечения конфиденциальности используется модель хранения данных, предусматривающая размещение чувствительной информации вне блокчейна при сохранении неизменяемого аудиторского следа в распределённом реестре. Кроме того, разработана система KPI/KRI-показателей, связывающая телеметрические данные с операционными и комплаенс-результатами, включая уровень сервиса, вариативность сроков доставки, объёмы потерь продукции, частоту возникновения споров и возможности аудита. Эффективность предложенного подхода оценивается на пилотных транспортных коридорах посредством сравнительного анализа показателей до и после внедрения системы с использованием сопоставимых контрольных групп.

Полученные результаты свидетельствуют о повышении прозрачности процессов, ускорении обработки нештатных ситуаций и снижении затрат на сверку данных, что способствует сокращению потерь продукции и транзакционных издержек. Результаты исследования подтверждают, что прослеживаемость, основанная на технологиях IoT и защищённая механизмами блокчейна, способна повысить эффективность, уровень доверия и соответствие нормативным требованиям в экспортно-импортных продовольственных цепочках поставок, одновременно содействуя достижению целей продовольственной безопасности.

Ключевые слова: Узбекистан, блокчейн, Интернет вещей (IoT), цифровая прослеживаемость, edge-cloud, смарт-контракты, экспорт и импорт продовольствия, управление цепочками поставок, KPI/KRI, комплаенс, продовольственная безопасность.

INTRODUCTION

Globalized food supply chains depend on timely and reliable information about the identity, condition, and movement of goods as they pass through farms, processors, logistics providers, ports, customs authorities, and retailers. In export-import corridors, this need becomes even more important due to cross-jurisdictional documentation, sanitary and phytosanitary requirements, cold-chain compliance, and the economic costs associated with delays or product recalls. However, existing data flows often remain fragmented across proprietary systems and paper-based processes, making end-to-end traceability difficult, audits expensive, and dispute resolution slow. Information asymmetry and limited visibility increase transaction costs, weaken quality assurance, and reduce the level of trust among consumers and regulators.

The convergence of Internet of Things (IoT) sensing technologies and blockchain ledgers offers a structured pathway for the digital tracking of food export-import flows. Low-power sensors and edge gateways can continuously capture data on temperature, humidity, shock, seal integrity, and geolocation, while geospatial events can record custody transitions. A permissioned blockchain provides an immutable and time-stamped record of these events. Smart contracts can encode shipment conditions, certification checks, and conditional payments, enabling automated exception handling when parameters deviate from agreed thresholds. By anchoring critical events on a shared ledger and linking them to verifiable telemetry, stakeholders can obtain a tamper-evident audit trail without transferring full control over their databases.

In Uzbekistan, ensuring the population's access to food products remains one of the important national priorities. In 2023, the country's industry produced food products worth 65,174.7 billion soums, agricultural products worth 404,648.6 billion soums, and food-related industrial products worth 17,968.3 billion soums. During the same period, food imports amounted to 1,962.4 billion soums, while food exports reached 4,141.8 billion soums. These figures indicate that further development of the food industry in Uzbekistan can help expand export capacity, strengthen the country's position among major food-exporting economies, and transform the food industry into a more profitable sector capable of attracting additional investment into the national economy [1].

In recent years, Uzbekistan has been implementing accelerated reforms aimed at increasing food production and processing volumes, as well as expanding exports of finished products. In particular, the "Uzbekistan–2030" Strategy was approved by Decree of the President of the Republic of Uzbekistan No. PF-158 dated September 11, 2023 [2]. The strategy defines important tasks, including the development of food processing, increasing the share of technologically advanced products in industry from 25 percent to 32 percent, doubling labor productivity in the processing industry, and ensuring that the processing rate of agricultural products exceeds 25 percent. The implementation of these objectives, together with the organizational and economic development of the food industry, requires in-depth scientific research and determines the relevance of the present study.

The Development Strategy of New Uzbekistan for 2022–2026, approved by Decree of the President of the Republic of Uzbekistan No. PF-60 dated January 28, 2022 [3]; Decree No. PF-36 dated February 16, 2024 "On Additional Measures to Ensure Food Security in the Republic" [4]; Decree No. PF-217 dated December

28, 2023 “On Measures to Ensure Price Stability of Basic Food Products in Consumer Markets” [5]; Decree No. PF-217 dated December 22, 2021 “On Research into Reforms in the Food and Agriculture Sector” [6]; Resolution No. PQ-58 “On Measures to Further Improve the Strategic Planning and Management System” [7]; Resolution dated September 9, 2020 “On Measures to Accelerate the Development of the Food Industry of the Republic and Ensure Continuous Provision of the Population with High-Quality Food Products” [8]; Resolution No. PQ-4643 “On Measures to Further Improve the Management System of the Agrarian and Food Sectors” [9]; and Resolution No. PQ-4406 dated July 29, 2019 “On Additional Measures for Deep Processing of Agricultural Products and Further Development of the Food Industry” [10] create an important regulatory basis for this research. The present study can contribute to the implementation of the tasks defined in these regulatory and legal documents [11].

In this regard, international food industry companies emphasize that the food industry is not a single sector, but rather a set of interrelated industries that produce, process, store, package, distribute, and sell food products. It includes farming, food production, food processing, storage, packaging, distribution, retail trade, and catering services. The food industry consists of the following main components [12]:

1. Agriculture. This refers to the production of food, feed, fiber, and other essential products. It includes crop production, livestock farming, and fish farming. It also covers the production of agricultural machinery, fertilizers, and seeds used to support agricultural production.
2. Food processing. Since most agricultural products are seasonal and perishable, food processing converts raw materials into marketable food products. Packaging and processing protect food from environmental effects, extend shelf life, and improve product quality [13].
3. Food distribution. This includes the transportation, storage, and sale of food products to consumers. Transport networks are used to integrate the various stages of the food industry [14].
4. Regulation and control. Food production and distribution are governed by specific rules and requirements designed to ensure quality and safety. These regulations are established by government authorities, and food industry enterprises must comply with them in order to operate effectively.
5. Financial services. These include insurance and credit mechanisms that support the production and distribution of food products. Insurance policies help cover financial losses that may occur in the industry. Therefore, food accounting and finance specialists must work closely with all stages of the food industry to evaluate opportunities and manage risks.
6. Research and development. Research in any area of the food industry generates relevant information for the sector. Today, the food service sector has significant potential for research and development. Particular attention is given to consumer behavior, factors influencing purchasing decisions, and customer attitudes and opinions [15].
7. Marketing. Marketing is one of the main tools for promoting information about food products. Food marketing includes various forms of advertising aimed at encouraging the purchase and consumption of food and beverages. It can influence eating behavior by shaping the sociocultural elements of the food environment.

The organizational aspects of food industry development include economic reforms, a stable raw material base, market and transport infrastructure, scientific and technological progress, effective management methods, and the presence of a competitive environment. The economic aspects include investment, labor force competence, technologies, tax incentives and preferences, financial flexibility, and an attractive investment climate.

In general, the development of food industry infrastructure is achieved through comprehensive support for local food production enterprises and the creation of favorable operating conditions. Food industry infrastructure development is a complex and multi-stage process. Studies show that the food chain system becomes effective when all its processes are closely interconnected and developed in parallel. If one process in the system is inefficient, it may reduce the effectiveness of the entire food chain. Therefore, when developing programs for food industry infrastructure, it is important to consider the full range of organizational, economic, and legal aspects.

Many countries continue to face persistent food security challenges. International experience shows that resilience depends not only on production capacity but also on transparent and well-governed cross-border supply chains. The United States emphasizes integrated infrastructure and sector-wide digitalization. Canada demonstrates shared, multi-level responsibility for food safety. Italy relies on regional specialization and strong integration between industry and agriculture. Germany reduces waste and closes production loops through efficient processing and energy recovery. The Netherlands supports growth through a knowledge-based science-industry system. China aligns supply with health-oriented demand while incentivizing primary producers. Russia prioritizes technical modernization and investment, while Belarus emphasizes systemic planning of flows across agriculture, transport, and storage. A common feature across these models is the need for reliable and verifiable data on product identity, condition, and custody in order to reduce losses, shorten audits, and strengthen trust.

Building on these lessons, blockchain and IoT technologies for digital tracking of food export-import flows provide both a technological and governance-oriented pathway. IoT sensors and edge gateways capture data on temperature, humidity, shock, seal integrity, and geolocation. A permissioned blockchain records time-stamped custody events and certification checks through smart contracts. Privacy-preserving data partitioning protects commercially sensitive information while maintaining an immutable audit trail. This digital tracking layer supports key policy objectives observed in international practice, including efficiency, safety, traceability, and market access. It can reduce transaction costs, spoilage, and disputes while enabling targeted incentives and compliance oversight. This paper adapts these practices to Uzbekistan's export-import corridors by specifying an appropriate architecture, KPI/KRI indicators, and evaluation methods suitable for large-scale implementation.

LITERATURE REVIEW

In the field of blockchain and IoT-based digital tracking of food export-import flows, a number of scholars have conducted research on the development of the food industry, food supply chains, digitalization, and the organizational and economic factors affecting the efficiency of food production.

According to Y. Gusarova [17], the food industry represents a set of enterprises engaged in processing agricultural raw materials and producing final food products for consumer needs. The role and importance of the food industry are determined primarily by its capacity to produce food products and ensure their availability to the population.

Economist M. Rudnev [18] emphasizes that the effective organization of industrial production of agricultural products depends on the rational balance of land, technical and other production resources, labor, and financial resources. He also notes that the optimal integration of production sectors with supporting sectors is a fundamental condition for ensuring the sustainable development of food production.

M. Akhmatilov [19], in his research, highlights that the strategic goal of food industry development programs should be the mobilization and effective use of internal resources, as well as the creation of favorable conditions for attracting foreign investment.

According to S. Dokholyan and M. Vartanova [20], the relatively low efficiency of food production facilities is influenced by several organizational and economic factors. These include a mismatch between raw material production volumes and processing capacities, the separate location and independent organization of raw material production and processing enterprises, and insufficient coordination between them. As a result, financial resources may become dispersed, which reduces economic efficiency. In addition, although large harvests are produced in areas with high agricultural potential, a significant part of the crop may be lost during the harvesting period, which negatively affects the efficiency of the overall food chain.

V. Gonsharov [21] argues that the growing demand for high-quality food products, together with the need to reduce adverse effects on consumers and optimize the final product cost, makes innovative technologies one of the key factors in the development of food industry enterprises.

T. Shivrina [22] notes that identifying threats and opportunities in the development of food industry enterprises requires an assessment of external environmental factors, since the food market is one of the most competitive markets. Population growth increases the consumption of semi-finished and finished food products, which creates a need to launch new production capacities for food processing and production.

According to Y. Shevchenko [23], enterprises operating in a competitive environment must take into account all of the above-mentioned factors in order to develop the food industry effectively. Therefore, in many cases, food industry development requires modernization, technical re-equipment of production facilities, and increased investment in innovation.

Regarding the establishment of such a system, T. Yespalov [24] emphasizes that the functioning of the food market is largely determined by economic conditions and production factors. According to him, digitalization is one of the most important modern factors, as it reduces risks and costs in food production, promotes more efficient use of resources, and supports technological advancement. The experience of countries with a developed food industry also shows that the introduction of information technologies into production can reduce unplanned costs by up to 20 percent.

Overall, the organizational aspects of food industry development include economic reforms, a stable raw material base, market and transport infrastructure, scientific and technological progress, effective management methods, and a competitive environment. The economic aspects include investment, labor force competence, technologies, tax incentives and preferences, financial flexibility, and an attractive investment climate. In this context, blockchain and IoT technologies can serve as important tools for improving digital traceability, strengthening supply chain transparency, reducing losses, and increasing trust in food export-import flows.

RESEARCH METHODOLOGY

The study employs an explanatory and design-oriented methodology that integrates risk governance with multi-criteria decision analysis and enterprise-level evidence from vertically integrated chemical firms operating under “Uzkimyosanoat”. The unit of analysis is the enterprise-year.

Verified financial, operational, and ESG/HSE data for 2020–2023 are compiled, cleaned, normalized, aligned to a common periodicity, and extended to 2030 through scenario-based projections. Transformation risks, including feedstock volatility, solvency pressures, asset obsolescence, process and energy inefficiency, market-share erosion, innovation gaps, as well as environmental and governance exposures, are formally mapped to corresponding control mechanisms. These mechanisms include pricing and cost policies, liquidity buffers, modernization and maintenance measures, resource-efficiency programs, market development tools, R&D and talent pipelines, compliance procedures, managerial restructuring, and incentive systems.

Decision rights and escalation pathways are defined across upstream, midstream, and downstream units. This enables the development of a risk–control register used for both ex-ante design and ex-post monitoring. Baseline and innovative scenarios are constructed to project control intensities and potential shocks up to 2030. Risk-adjusted performance is then calculated by discounting projected scores using severity parameters inferred from historical deviations.

Reproducibility is ensured through versioned code, archived indicator definitions, weight matrices, scoring rubrics, and clearly documented assumptions.

ANALYSIS AND RESULTS

Food exports and imports play a significant role in ensuring food production, industrial processing, the formation of strategic reserves, the full satisfaction of consumer demand, and the strengthening of national food security.

Food products can generally be classified into three main categories:

1. Food products produced directly through agricultural activities;
2. Industrially processed food products;
3. Various additives and chemical substances used in the production, processing, and preparation of food products.

Naturally, no country can independently produce all products and inputs included in these categories. Differences in geographical location, climatic conditions, natural resources, biological characteristics, and economic potential result in variations in the structure of food production among countries. For example, countries with access to seas and oceans often produce a larger share of seafood products, whereas landlocked countries tend to specialize in agricultural and livestock products.

Accordingly, dietary patterns also vary across countries. Nevertheless, human demand for food products has many common features. Particularly in the modern information age, consumers can easily obtain information about different types of food products available worldwide. In addition, growing awareness of health and environmental sustainability has increased demand for environmentally friendly and high-quality food products. Since such products are not available in every country, international trade in food products continues to expand.

From this perspective, food imports are often an economic necessity, while food exports represent an important source of revenue. Although food products are generally classified as essential goods and may generate lower profit margins than certain industrial or high-value products, the continuous growth in global food demand has significantly increased the economic attractiveness of food exports.

For countries specializing in food production and processing, food exports constitute an important source of foreign exchange earnings. Conversely, for countries that cannot fully satisfy domestic food demand through their own resources, food imports remain essential. As a result, most countries participate in food export-import activities, either to capitalize on their comparative advantages or to ensure the availability of products that cannot be produced domestically in sufficient quantities.

Therefore, while countries seek to increase national income through the export of competitive food products, they also rely on imports to meet excess demand or to obtain products that cannot be efficiently produced domestically. This demonstrates the strategic importance of export-import activities for the organizational and economic development of the food industry.

According to official statistical data, the total export volume of Uzbekistan reached 337,959.3 billion soums in 2023, of which industrial products accounted for 211,753.5 billion soums. During the same year, exports of fruit and vegetable products amounted to 65,122.2 billion soums.

For comparison, the total export volume of the republic amounted to 20,668.1 billion soums in 2010 and increased to 32,225.4 billion soums in 2015. Exports of industrial products reached 16,746.8 billion soums in 2010 and increased to 21,216.0 billion soums in 2015. Service exports amounted to 2,118.3 billion soums in 2010 and rose to 7,910.9 billion soums in 2015.

Similarly, exports of fruit and vegetable products increased from 1,803.1 billion soums in 2010 to 3,098.5 billion soums in 2015 and further expanded to 10,368.5 billion soums in 2020 (Table 1).

Table 1
Structure and dynamics of export products made in Uzbekistan, billion soums[25]

Years	Total exports	*Including*		
		Industrial products	Fruit and vegetable products	Services
2010	20,668.1	16,746.8	1,803.1	2 118.3
2011	25,716.7	19,427.2	3 235.3	3,054.3
2012	25,717.3	19,823.4	1,426.1	4,467.8
2013	30,099.5	21,084.8	2,837.3	6 177.5
2014	31,414.3	20,834.5	3,557.5	7,022.3
2015	32 225.4	21 216.0	3,098.5	7,910.9
2016	36,076.8	25 103.3	1,686.7	9,286.8
2017	65,956.4	49,445.4	3,687.6	12,823.4
2018	114,033.4	82,092.7	7 185.6	24,755.0
2019	154,365.9	113 134.5	10,750.3	30,481.0
2020	152,400.0	121,915.9	10,368.5	20 115.5
2021	177 186.6	139,481.6	10,277.0	27,428.0
2022	219 429.0	156,919.2	12,669.4	49,840.4
2023	337,959.3	211,753.5	65 122.2	61,083.6

According to the analysis, in 2023 (compared to 2010), the total volume of exports carried out in the republic increased by 16.4 times, including exports of industrial products by 12.6 times, exports of services by 28.8 times, and exports of fruit and vegetable products by 36.1 times, occupying the highest rating in this regard (Figure 2).

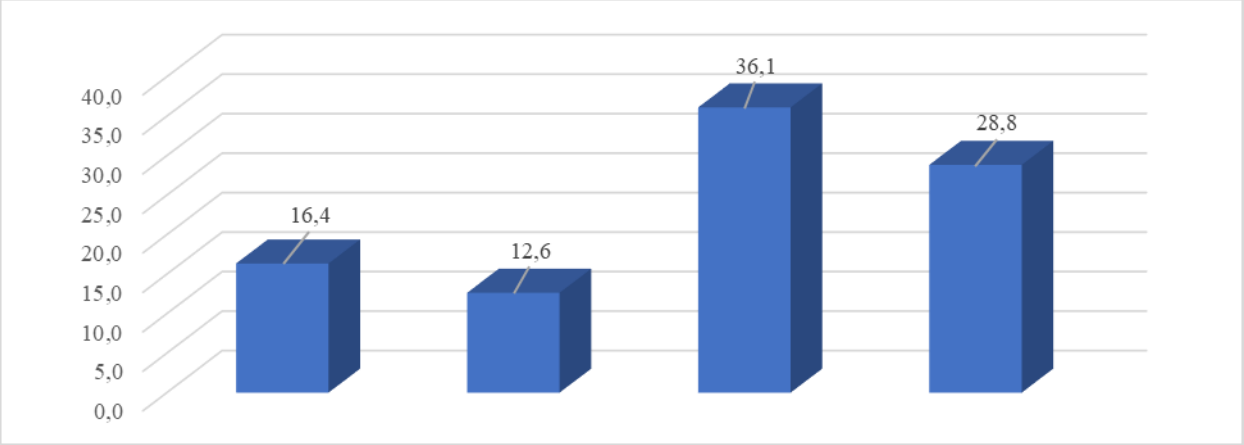

Figure 2. Change in export products in 2023 (compared to 2010), times[26]

According to statistical analysis (based on the baseline method), compared to the baseline period (2010), the growth of fruit and vegetable exports was higher than that of industrial exports in 2011-2015, but this advantage was reversed in the export of industrial products in 2016-2022. However, in 2023, the growth of fruit and vegetable exports again led with a 23.5-fold increase (Figure 3).

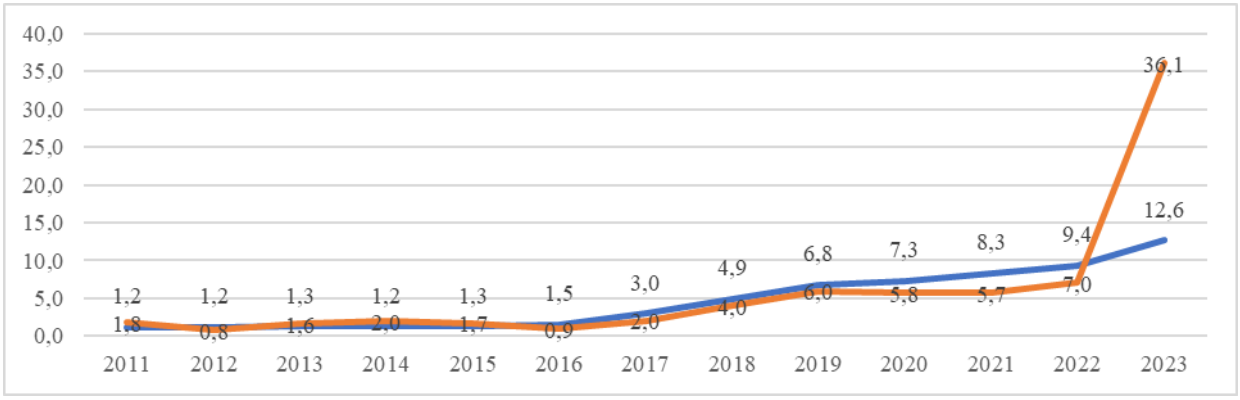

Figure 3. Trends in exports of industrial and horticultural products, times (base period 2010)[27]

Also, according to the chain-wise analysis of these changes, in 2023 (compared to 2022), exports of industrial products increased by 1.3 times and exports of fruit and vegetable products by 5.1 times (Figure 4).

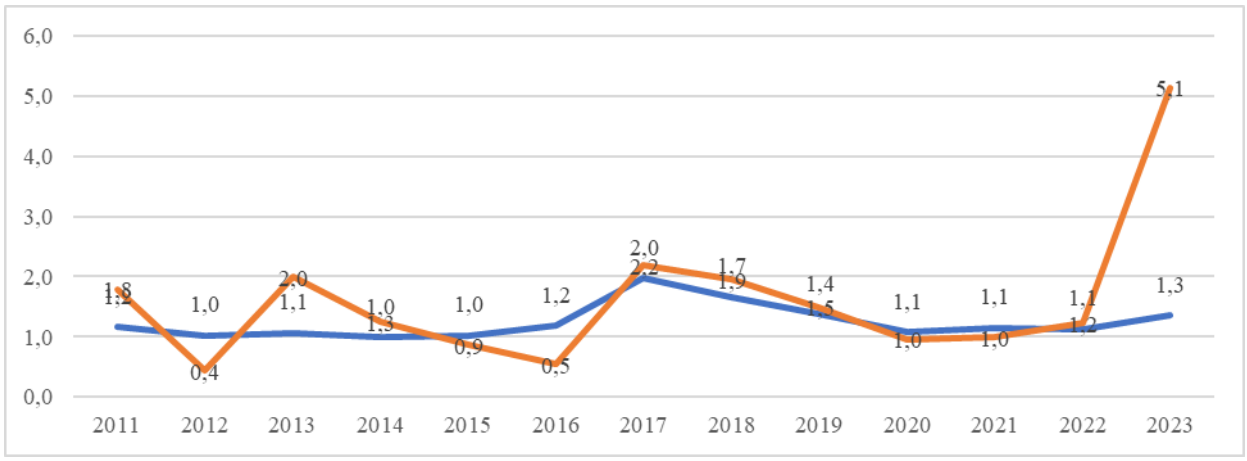

Figure 4. Trends in exports of industrial and horticultural products, times (chain-linked, compared to the previous year)[28]

According to the chain-link method, higher growth rates in industrial exports compared with fruit and vegetable exports were observed in 2012, 2015–2016, and 2020–2021. In contrast, higher growth rates in fruit and vegetable exports compared with industrial exports were recorded in 2011, 2013, 2017–2019, and 2023.

According to statistical data, in 2023, the total import volume of Uzbekistan amounted to 448,691.3 billion soums, of which industrial products accounted for 415,197.8 billion soums. During the same year, imports of fruit and vegetable products reached 3,235.8 billion soums.

For comparison, the total import volume of the republic amounted to 14,618.8 billion soums in 2010 and increased to 31,756.6 billion soums in 2015. In particular, imports of industrial products amounted to 13,807.6 billion soums in 2010 and rose to 29,201.9 billion soums in 2015. Imports of services amounted to 780.0 billion soums in 2010 and reached 99.3 billion soums in 2015.

In addition, imports of fruit and vegetable products amounted to 30.6 billion soums in 2010, 99.3 billion soums in 2015, and 930.2 billion soums in 2020 (Table 2).

Table 2
Composition and dynamics of imported products in Uzbekistan, billion soums[29]

Years	Total imports	*Including*		
		Industrial products	**Fruit and vegetable products**	**Services**
2010	14,618.2	13,807.6	30.6	780.0
2011	19,458.5	18,463.8	27.6	967.0
2012	24 192.9	22,757.1	39.9	1,395.9
2013	29 239.8	27 190.1	54.3	1,995.4
2014	32,271.3	29,594.0	80.5	2,596.9
2015	31,756.6	29 201.9	99.3	2,455.3
2016	36,061.8	33,547.8	103.5	2,410.4
2017	72,239.1	61,233.9	354.7	10,650.5
2018	156,908.3	139 142.9	586.1	17 179.3
2019	214 203.1	191,917.9	767.4	21,517.8
2020	212,968.3	199,828.2	930.2	12,209.9
2021	270 870.9	250 470.0	1,612.0	18,788.8
2022	340,069.7	309 372.5	2,516.3	28 181.0
2023	448,691.3	415 197.8	3 235.8	30,257.8

According to the analysis, in 2023 (compared to 2010), the total volume of imports in the republic increased by 30.7 times, including imports of industrial products by 30.1 times, imports of services by 38.8 times, and imports of fruit and vegetable products by 105.7 times, reaching the highest level (Figure 5).

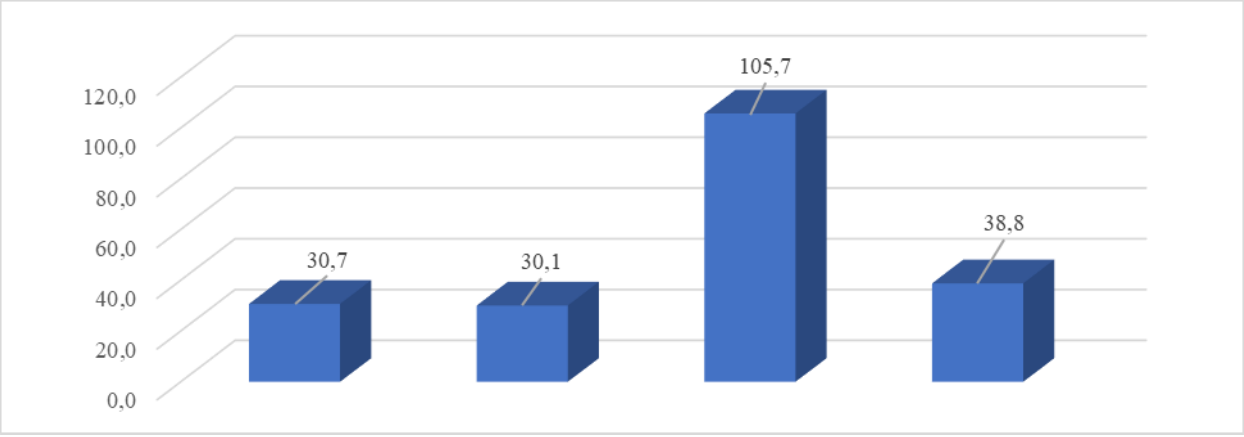

Figure 5. Change in imported products in 2023 (compared to 2010), times[30]

According to the analysis (based on the baseline method), while imports of industrial products had a higher growth rate in 2011-2013 (relative to the growth rate of imports of fruit and vegetable products) compared to the baseline period (2010), this advantage is observed in imports of fruit and vegetable products from 2014 to the present (Figure 6).

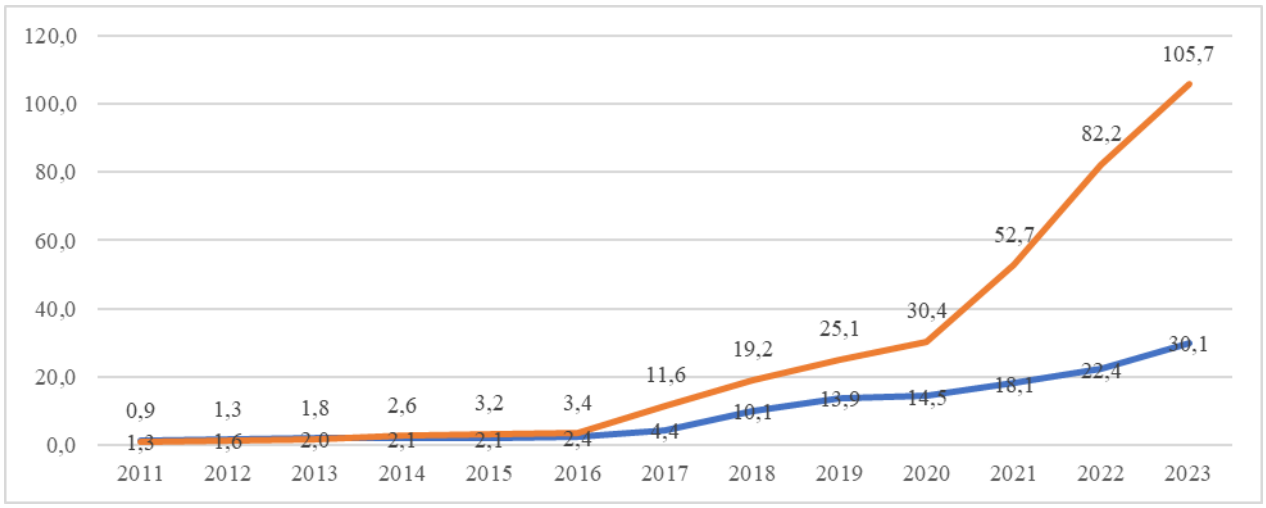

Figure 6. Trends in imports of industrial and horticultural products, times (base period 2010)[31]

Also, according to the results of the chain-wise analysis of these changes, in 2023 (compared to 2022), the volume of imports of industrial products and fruit and vegetable products increased by 1.3 times, while on average between 2011 and 2023, imports of industrial products increased by 1.3 times, and imports of fruit and vegetable products by 1.5 times (Figure 7).

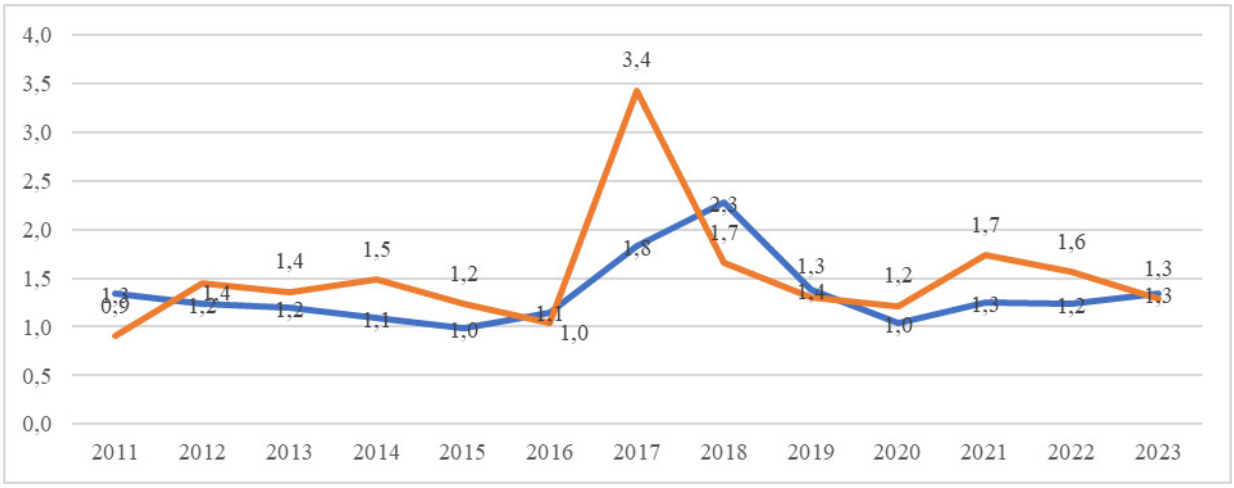

Figure 7. Trends in imports of industrial and horticultural products, times (chain-linked, compared to the previous year)[31]

According to the chain method, high growth rates in imports of industrial products (relative to the growth of imports of horticultural products) were observed in 2011, 2016, and 2018-2019, while high growth rates in imports of horticultural products (relative to the growth of imports of industrial products) were observed in 2012-2015, 2017, and 2020-2022.

In 2023, our country imported more products (services) worth 110,732.1 billion soms compared to its total exports. It is also noted that during this period, imports of industrial products (compared to exports) exceeded exports by 203,444.3 billion soms, while exports of fruit and vegetable products exceeded imports by 61,886.4 billion soms (Table 3).

Table 3
Export-import balance, billion soums

Years	Total	Industrial products	Fruit and vegetable products	Services
2010	6,049.9	2,939.2	1,772.5	1,338.3
2011	6,258.2	963.3	3,207.7	2,087.2
2012	1,524.4	-2,933.6	1,386.2	3,071.9
2013	859.7	-6 105.4	2,783.0	182.1 4
2014	-857.0	-8,759.4	3,477.0	425.4 4
2015	468.8	-7,986.0	2,999.2	5,455.6
2016	15.0	-8 444.5	1,583.1	6,876.4
2017	-6 282.8	-11,788.5	3,332.9	172.9 2
2018	-42,874.9	-57,050.1	6,599.6	7,575.7
2019	-59,837.2	-78 783.3	9,982.9	8,963.2
2020	-60 568.3	-77,912.3	9,438.3	7,905.6
2021	-93,684.2	-110,988.4	8,664.9	8,639.2
2022	-120 640.7	-152,453.3	153.2 10	21,659.4
2023	-110,732.1	-203,444.3	61,886.4	30,825.8

If we look at the above analysis for the period 2010-2023, the total excess of imports over exports occurred in 2014 and 2017-2023, while for industrial products, the highest import volume was observed in 2012-2023. However, for the period 2010-2023, it can be seen that exports of fruit and vegetable products and services (relative to imports) were higher.

Of course, export-import is of great importance in the activities of industries and has a certain quantitative impact. In particular, the export and import of fruit and vegetable products directly affects the development of the food industry.

CONCLUSION AND RECOMMENDATIONS

The results of the article show that the food industry is both structurally important and dynamically connected to the wider economy. On the supply side, Uzbekistan's agricultural base in 2023 remained substantial, including about 8.43 million tons of grains and pulses, 3.57 million tons of potatoes, 11.55 million tons of vegetables, 2.55 million tons of melons, 3.12 million tons of fruits and berries, and 1.74 million tons of grapes. These indicators provide a broad raw material base for downstream processing.

Input-output and econometric evidence indicate that the sector is highly embedded in industrial development. A one-unit increase in food industry output is associated with a 10.5-unit increase in total industrial output and an 8.8-unit increase in manufacturing output, which confirms the sector's multiplier role in industrial growth and structural diversification.

Investment and productivity diagnostics reveal a more nuanced picture. During 2010–2023, the average economic efficiency of fixed-capital investment was about 18.8 billion soums in food processing, compared with 9.8 billion soums in manufacturing overall. At the same time, the average economic efficiency of fixed assets in food processing reached approximately 3.2 billion soums. Cobb-Douglas estimates suggest that the average output response to investment — where one unit of investment generated about 18.4 units of food industry output — weakened by 2023 compared with 2010, declining by approximately 3.1 times. This indicates diminishing returns from capital deepening and highlights the need to shift toward higher-quality and productivity-enhancing projects, including modernization, energy efficiency, process control, and maintenance.

By contrast, the output response to labor strengthened significantly. On average, one unit of labor resources corresponded to about 267.6 units of output, while labor productivity increased by approximately 7.1 times over the analyzed period. This divergence implies that recent gains have been driven more by scale, skills, and workflow improvements than by capital alone. Therefore, future competitiveness depends on combining selective capital investment with organizational and technological modernization.

Trade elasticities further demonstrate how external integration supports domestic processing. Regression results show that a one-unit increase in exports and imports of fruit and vegetable products is associated with 0.9 and 17.9 additional units of food industry output, respectively. The relatively high import coefficient may reflect the role of imported primary or intermediate inputs in reducing seasonality and improving capacity utilization through off-season supply, quality grades, or product varieties suited to specific processing lines. At the same time, the positive export coefficient indicates that access to external markets helps expand production, encourages quality upgrading, and strengthens incentives for investment.

Taken together, these findings justify a dual policy focus: facilitating the efficient import of critical raw and intermediate inputs to stabilize production capacity, while simultaneously expanding export readiness to capture economies of scale and higher value-added opportunities.

Overall, the empirical evidence supports three interrelated priorities. First, it is necessary to maintain the sector's macroeconomic role as a driver of industrial growth by directing capital toward projects with clear productivity effects, such as energy-efficient production line upgrades, cold-chain and quality control systems, and digital process monitoring. This would help reverse the decline in investment efficiency.

Second, labor productivity gains should be consolidated through skills development, process standardization, and incentive-compatible governance at the enterprise level.

Third, trade complementarities should be strengthened by reducing logistics and certification barriers, aligning product portfolios with export demand, and ensuring timely access to imported inputs that ease seasonal and varietal constraints.

If these measures are implemented consistently, they can transform the strong multiplier effects of the food industry into sustained industrial growth, higher value added, and improved food security outcomes.

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