

Article

Towards Better Understanding of Socioeconomic Resilience Challenges in Food Systems of the Baltic States: Focus on Agriculture

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Abstract

Global food systems have faced multiple shocks that threaten the implementation of their main functions. This article analyzes the most recent studies and aims to develop a socioeconomic resilience assessment dashboard for agriculture as a component of the food system and estimate the resilience of the Baltic states in 2013 and 2023. The selected years allow us to compare resilience before and after the most recent agricultural market crisis. The resilience assessment dashboard includes leading and lagging indicators and uses the distance to a reference measure normalization method to compare resilience indicators in individual countries with the EU average. Leading indicators, focusing on the ability of the system to implement changes, distinguish the Estonian case and suggest that structural patterns of this country could empower different actions to increase resilience compared to other Baltic states. Lagging indicators, focusing on the key functions of the system, suggest that the Baltic states have improved their nutritional security; however, this research identifies a high concentration of ex-EU imports for the fats and oils group, the animal products group, except for the CN03 category, and the vegetable products group, with the exception of the CN08 and CN09 categories, as an important resilience challenge of national food security. The results imply the importance of policy actions aiming at the further development of national trade networks and the diversification of import markets. Farm economic viability indicators, except for debt ratio, evidence annual instability and unfavorable resilience compared to the EU average, while, in Latvia and Lithuania, agriculture remains an important employer and contributes to the resilience of national economies. The analyzed leading indicators suggest that the Baltic states could prioritize different agricultural policy actions and budget allocation addressing national farm viability and agricultural employment challenges.



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1. Introduction

Agriculture is an economic activity in which uncertainty is recognized as a rule [1]. However, the number and the range of the most recent crises in agri-food systems are above the initial expectations, and the situation of food security around the world has worsened. Therefore, academic studies have introduced the notion of ‘polycrisis’ in order to highlight the severe impact of multiple interconnected shocks on global food security. Climate change effects, the COVID-19 pandemic, and the most recent geopolitical conflicts are recognized as key sources of ‘polycrisis’ [2]. However, each country has different

exposure to specific manifestations of ‘polycrisis’, and it forms important differences in agriculture and unique national food systems. For example, research for China shows that global warming had a different impact on the decline in grain production between regions [3]. These concerns are addressed in the 2030 Agenda for Sustainable Development, which includes multiple food-related resilience aspects in the Sustainable Development Goals [4]. The second goal calls for the transformation of food systems into a zero hunger paradigm, ensuring sustainability, resilience, and equity.

Although ‘resilience’ became a buzzword, the future of resilient food systems in the European Union (EU) depends on our understanding of this phenomenon, which in turn determines strategic development goals and success measures. Over recent decades, the resilience concept has attracted considerable attention from policymakers and academic societies around the world and has spread across different areas [5], including academic research on food systems. Some useful contributions that build extensive knowledge about this phenomenon and resilience assessment frameworks in different components or food systems were made by [6–12]. The most recent studies provide contributions to food systems’ resilience research at different levels, namely, household or farm, community, sector, country, etc. Examples of such studies are provided by [1,5,13–15]. It is important to note that resilience research differs in terms of coverage of sustainability dimensions. For example, resilience studies could have a clear focus on economic or socioeconomic indicators [2,15], delve into the environmental dimension of resilience [16], deepen knowledge about the nexus between the selected economic and environmental indicators that influence resilience [17], or examine resilience by applying a sustainability prism [18,19].

The resilience assessment challenge is addressed by applying different methodological approaches. Researchers investigate individual resilience measures [16,20], create dashboard frameworks and analyze indicators that cover important aspects of resilience [2,5], construct composite resilience indices as well as conduct detailed analysis of sub-indicators [13,15,21–24], etc. Although the dominant share of this research relies on comparable secondary data, some studies with a narrower geographical coverage create additional value employing surveys [25] and expert valuations [5,26] to shed light on different aspects of food systems’ resilience. In many reviewed resilience assessment studies, the identification of the research method is a challenge because researchers rely on combinations of complementary methods that allow sound methodological frameworks to be established.

Although there are many academic contributions in this area, most of the proposed resilience assessment frameworks take an outcome-based perspective and target specific risks, while it is widely recognized that the improvement of resilience to one specific risk could sabotage the resilience to other types of risks. The study by [7] argues that resilience assessment measures change due to an evolving environment as time passes, and researchers propose combining resilience capability and outcome perspectives to develop resilience assessment methodologies. This article addresses the above issues and develops an original function-based resilience assessment framework that covers leading and lagging indicators.

This article aims to develop a socioeconomic resilience assessment framework for agriculture as a component of the food system and estimate the resilience of the Baltic states in 2013 and 2023. Building on the most recent resilience research, this article reviews resilience measures that could be employed as leading and lagging indicators, develops the resilience assessment dashboard, and analyzes the resilience situation of Estonia, Latvia, and Lithuania within the EU context.

It should be noted that the available research mainly focuses on the resilience situation in Lithuania [15,26] or specific EU niches (for example, direct payments’ impact

on resilience [27]) and does not cover the most recent shocks in the global food system, while the situations in Latvia and Estonia remain a neglected research area. In light of the geopolitical situation, this article provides original materials that identify resilience challenges at the upstream level of food systems of the Baltic states, and these results could be a useful contribution to academic discussion and political discourse. The Baltic states have borders with Russia and used to have trade relations, contributing to the functioning of national food systems. Thus, this article selects the year 2013 as the starting point for the analysis, before the beginning of the geopolitical conflict, and the year 2023, which shows the adaptation of the Baltic states to introduced sanctions, the change in trade behavior, and the resilience of food systems. The focus of this contribution is not covered by previous academic studies, while the article provides the most recent statistics and covers the time gap of the current research; the original material could be a starting point for further in-depth research and could be interesting for policymakers.

The results suggest that the Baltic states have important differences in leading resilience indicators that could imply favoring specific development priorities and actions to increase the resilience of national food systems. The analysis of lagging indicators suggests that the Baltic states could improve the resilience of the food security function by expanding the network of import partners, while farm economic viability indices, except for the debt ratio, show that the situation in the Baltic states is worse than the EU average.

2. Resilience Assessment Dashboard Development

This section defines resilience within the framework of this research, discusses the main socioeconomic functions of agriculture that have paramount importance for the development of sustainable and resilient food systems, reviews function-related measures of resilience, and introduces resilience leading indicators.

2.1. Definition of Resilience

The complexity of food systems is unveiled by heterogeneous components of these systems identified by [28,29], namely, the production of agricultural products that could include important byproducts for other areas of bioeconomy, processing, distribution, retail, or preparation, food consumption, and waste management that covers the aforementioned components. Production of agricultural products is widely recognized as one of the most vulnerable components of food systems, and one that requires improved resilience.

The multidimensional and context-specific construct of resilience [7,27], as well as complexity of food systems [8,30], inspired the emergence of many resilience definitions that covered different components of the food system and had specific research focuses, for example, farm [18,24], farming system [5,19], agriculture [15,27], regional resilience within the global supply chain [31], food system [2,8], etc.

This article defines resilience of agriculture within the context of this study as the ability of this sub-system to preserve, maintain, and ensure recovery of the key functions for the functioning of food systems despite different shocks and stressors. This article focuses on key socioeconomic functions (see Section 2.2 for more details) that allow us to develop the resilience assessment dashboard; however, the list of key functions could change over time and depend on the research area (for example, the environmental aspect of agriculture will introduce new key functions). Indeed, the definition is adopted for this research, and it is important to bear in mind that in a broader context, agriculture plays an important role in bioeconomy. Although a quick recovery of functions is often mentioned as an important characteristic of resilience, this aspect is critical for the performance of the food and nutrition security function. However, some shocks and stressors require fundamental lasting changes to maintain functions in the future. Thus, the engineering conception of

resilience that understands the phenomenon as bouncing back to the equilibrium or the pre-shock state [32,33] and describes persistence capacity [18], appears to be an improper way to understand resilient food systems in the long-term context of ongoing ‘polycrisis’.

The complex system approach implies that returning to the pre-shock state is not necessarily a possible or desired condition, while resilience is understood as a capacity to absorb shocks, adapt, and transform in order to maintain key functions of the system [15]. The study by [18] underlines the importance of adaptive and transformative capacities to ensure stability of the system. Thus, the understanding of resilience as a process or a development capacity of the system to adapt and thrive [32] better reflects the reality and corresponds to the research direction of this study.

Moreover, resilience is introduced as a complementary key category of sustainability [18] that empowers the capacity to preserve the food system in the long run and enables sustainability [8]. The study by [18] employs the underlying perspective approach to understand the difference between resilience and sustainability. Researchers link sustainability with the well-being of future generations, while resilience is described as the capacity to adapt and accommodate shocks and stresses [18].

Academic research distinguishes specific and general resilience [1,27,34]. According to [1], specific resilience targets specific (often well-known) sources of risks, and this focus could have a negative impact on the ability of the system to deal with unforeseen shocks or other risks. There is no ‘one-size-fits-all’ resilience model because involved actors and risks differ [7]. Nevertheless, the general resilience concept offers a more holistic approach and encourages us to think about different risk sources and uncertainties, allowing us to set priorities and plan relevant allocations. General resilience could be linked with characteristics and capacities of the system that empower better reaction to multiple shocks [34]. In fact, general resilience allows us to introduce a long-term horizon and think about strengthening the weak places that are critical for the implementation of the key functions of food systems. In this context, the key functions become a starting point for the development of the relevant resilience assessment framework.

2.2. The Role of Agriculture in Food Systems: Key Socioeconomic Functions

The EU Common Agricultural Policy (CAP) allowed food systems to be established that empowered access to safe food. However, a high level of food security and a wide range of consumer options are not sustainable and negatively affect the needs of future generations. In this context, agriculture plays a tremendously important role, and the smooth switch to resilient and sustainable food systems is possible only if the evolving agricultural sub-system ensures the performance of key functions.

Article 33 of the Treaty of Rome sets the availability of supplies and reasonable prices for consumers as important objectives of the CAP. The studies by [15,19,27] also identify the production of food and other agricultural goods at affordable prices as the main function of resilient farming or agricultural systems. Nowadays, a trade-off between local and imported agricultural commodities and food products has become an important dilemma of sustainable food systems. On the one hand, the COVID-19 pandemic and the most recent geopolitical conflicts showed the vulnerability of food systems that rely on imported products. On the other hand, some countries have more favorable conditions to produce certain products at affordable prices and increase the sustainability of the global food system. Imported products also allow us to manage food supplies and ensure the availability of nutritious food at reasonable prices in case of unfavorable developments in national agriculture.

The sustainability concept transforms the mindset and launches discussions about changes in production and consumption patterns as well as other sub-systems of food

supply chains in order to implement food and nutrition security functions at lower environmental, economic, and social costs. The Farm to Fork Strategy introduces the change in paradigm and describes the goal related to food and nutrition security, highlighting the access to sufficient, nutritious, and sustainable food, while the growing role of affordable sustainable food is linked with fair remuneration in the supply chain and competitiveness of the EU supply sector [35].

After the establishment of the EU, the Treaty of Rome described agriculture as an integral part of broader socioeconomic functions. Article 33 highlights the importance of a fair standard of living for the community involved in agricultural activity, supports productivity growth, and market stabilization. Agricultural production is recognized as one of the most vulnerable components of the EU food system. Thus, at the level of agriculture, the resilience and sustainability of food systems are associated with functions that deal with farm viability and issues of farmer income [15,19,27] as well as employment on farms [15,19,27].

To conclude, the maintenance of resilient and sustainable food systems relies on the following key socioeconomic functions of agriculture: food and nutrition security, economic viability of farming activity, and provision of employment.

2.3. Resilience Measures for Key Socioeconomic Functions of Agriculture: Lagging Indicators

2.3.1. Resilience Measures of Food and Nutrition Security Function

The report of the World Food Summit in 1996 identifies food availability and stability as critical dimensions of food security. In individual countries, food availability and affordability could be ensured by combining the output of domestic agricultural production with imported products. However, the most recent geopolitical conflicts and the COVID-19 outbreak forced reconsideration of the nexus between global trade, national food security, and strategic autonomy.

Nevertheless, an OECD report [36] argues that the reliance on local raw products does not necessarily increase resilience, and, from an economic perspective, such a strategy is a less favorable alternative compared to the diversification of suppliers. Isolated national food systems eliminate a wide range of safe and nutritious products that can not be produced under certain climatic conditions. Some agricultural products could be produced at higher economic or environmental costs and reduced quality compared to imported products, which implies that the switch to self-sufficiency compromises price affordability and influences the wellbeing of society. Thus, global trade is recognized as essential for the maintenance of supply, diversification of food alternatives, and price stabilization [4].

The aforementioned arguments suggest that sustainable national food systems must be integral components of the global food system, and this aspect introduces a dualistic nature of resilience assessment measures for food availability and stability dimensions. On the one hand, national food and nutrition security is linked to domestic agricultural production and related resilience. Thus, this function could be measured by estimating the quantity of produced agricultural product [15,27] or agricultural production related indices [2], value-related indicators of agriculture (such as gross value added or value of gross production) [15,27], agricultural output and intermediate consumption ratio [23], agricultural output volatility [22], crop production diversification [16], etc.

On the other hand, the globalization feature introduces such resilience measures as foreign trade balance [15,27], import and export indicators [2,15] that could be estimated in terms of amounts or values, indicators that deal with market diversification or risk level [22,23], etc. Although the OECD report [36] provides strategies that increase national autonomy and favor foreign trade, the same report raises the issue of friendly countries and growing uncertainties. It implies that resilience estimation should rely on a deeper

knowledge of foreign trade and the observation of changes in the structure of dominant partners and trade concentration in order to sound the alarm about changes that reduce the resilience of the national food system. Measures of market concentration and competitiveness (for example, see [37]) could be employed to understand changes in resilience of food systems, while the Herfindahl-Hirschman Index (HHI) is recognized as the most widespread measure to investigate trade concentration.

According to [2,25], food (and nutrition) security function covers three dimensions, namely availability, access, and utilization. The aforementioned measures allow us to analyze the availability of food supplies in the country; however, the availability of supplies does not necessarily mean that households have access to food and can afford a nutritious diet. Research on food insecurity [2,7] or food security stability estimation deals with food access and utilization issues. This aspect of food and nutrition security function relies on indicators that investigate dietary diversity [21] or food consumption [2] scores, share of population experiencing food insecurity [2], share of population that cannot afford healthy diets [2], etc.

The food and nutrition security aspect of price affordability could rely on such measures as food expenditure-related indicators per capita [21], retail agrifood prices [15], ratio (retail prices levels) of agrifood products to all consumption goods [15,27], etc. Food price stability could be estimated applying indicators of price volatility [2], namely food price inflation and commodity-related indicators of food price anomalies. The study by [19] proposes focusing on the analysis of changes in output and input prices.

To conclude, the resilience indicators of food and nutrition security function cover lagging indicators that empower the analysis of food availability, access, and utilization. The analysis of the availability of national food supplies employs the share of gross value added (GVA) in total structure and the HHI for the import market as resilience indicators. As Article 33 of the Treaty of Rome links the availability of supplies at reasonable prices to the consumer level, this paper relies on indicators of nutritious food affordability and the share of food in expenditure to explore changes in food access and utilization. This approach shows how the trade-off between domestic and foreign agricultural commodities and food products allows the objectives of the CAP to be reached.

2.3.2. Resilience Measures of Economic Farm Viability and Employment Functions

Farmers have been recognized as a foundation of the well-functioning national food system since the establishment of the EU, as the primary function of the agricultural sub-system is food and nutrition security. However, economic farm viability and fair remuneration for agricultural production remain central challenges of the CAP. In the academic literature, the economic aspect of resilience is widely addressed, investigating such indicators as the number of farm exits [15] or various financial indicators such as profit or profitability [15,23,24,27], profit distribution [15], ratios of return on invested capital or assets [27], value added [15], gross margin per hectare or livestock unit [19], productivity measures [24], expense-to-income ratio [27], etc.

Resilient agricultural systems have access to external resources, and farm viability is often linked with lower debt levels. This aspect of economic viability could be covered by indicators of debt level [22], access to credit [15], debt-to-asset ratio [15,27], solvency [15,27], liquidity [24], etc. Changes in economic farm viability indicators can be employed in a broader context, explaining the development of structural patterns in national agriculture and the attractiveness of self-employment on farms.

In the EU, agriculture historically played an important role in the national employment structure; however, this situation is changing. The study by [38] suggests that a 'prosperity paradox' led to the replacement of local workers by a migrant labor force and the exit of

uncompetitive small farms due to the growing concentration of agricultural production. The COVID-19 pandemic revealed the dependence of food systems on a cheap migrant labor force, and farmers became more motivated to invest in technology that reduced this type of vulnerability.

On the one hand, this transformation of the employment structure changes the economic resilience of countries. According to [39], regions where the contribution of agriculture to the structure of gross domestic product and employment is relatively important demonstrate better stability in employment during economic slowdowns. Employment stability during a crisis could be linked to a relatively more favorable food and nutrition security situation in a country. This aspect of agricultural resilience could be explored employing such indicators as changes in employment levels [15,39] and employment variation coefficients [39], unemployment rates [27], share of agricultural employment in total structure [15], labor productivity [27], etc.

On the other hand, the shrinking of the agricultural labor force is programmed by globalization processes that force farms to compete by reducing inputs, and the labor force plays an important role. Low wages and the seasonal nature of jobs encourage local workers to change occupation in order to ensure stable income and resilience of their households, and give way to a cheap migrant force, while this behavior influences the food and nutrition security of agricultural workers. This resilience aspect introduces such measures as changes or deviations of income level of agricultural workers [15,23,27], changes in the ratio of agricultural income to average salary in the country [15], etc.

To conclude, this article selects three indicators of resilience that cover the economic farm viability function, namely, farm net income, output–input ratio, and debt ratio. The choice of resilience indicator for the employment function is strongly influenced by the availability of comparable data for all EU countries. Changes in employment function are investigated by applying the share of agriculture in the total employment structure.

2.4. Resilience Measures of Agriculture: Leading Indicators

The ‘polycrisis’ implies that the EU agriculture must evolve in order to ensure the maintenance of the main functions critical for the performance of food systems. The capacity of the agricultural system to absorb shocks and stresses, bounce back, or evolve depends on the structural patterns that are closely related to the ability to implement innovations.

Agricultural innovations play a paramount role in the establishment of resilient food systems because they cover a wide range of problems threatening the implementation of key functions of agriculture. For example, innovations could improve the availability of food supplies and solve nutritional value challenges, reacting to the needs of a growing population and limitations introduced by climate change, solve problems of economic viability on vulnerable farms that create a more diverse and resilient agricultural production basis for the food system, foster life quality in livelihoods, etc. According to [40], innovation and technology are among the major drivers leading to the transformation of food systems, while the institutional environment is critical to direct those innovations and technologies in order to achieve the desired impact on food systems. Researchers in their study [40] argue that such institutional environments could support specific technological advancement and innovation transfer that influences knowledge dissemination and access, innovation arrangements, and property rights.

It should be noted that the profitability of the farm and the financial viability of new sustainable farm technologies determine the decisions of farmers to implement innovation [41]. Thus, short-term economic goals of farmers often become an obstacle on the way to more sustainable practices. In this context, the role of institutional environments in unlocking the potential of innovations and technologies is critical because well-considered

regulation and support frameworks can reduce inequalities and increase the resilience of food systems. Meanwhile, agriculture remains one of the most vulnerable components of food systems, which requires special attention to combat inequality. The study by [42] argues that improved support distribution, aiming to reduce inequality, could increase adaptive capacity on farms and support the resilience of agriculture. Indeed, some structural patterns of national agricultural systems could be classified as resilience leading indicators because they influence the implementation of innovations and the spread of technologies.

The most recent research suggests that gender [40,43–46], age [40,45,46], education (skills and knowledge) [40,45,46], and on-farm resource levels or business scale [40,42,45,46] are important characteristics that are related to inequality and power imbalance issues in agriculture. On the one hand, the most recent research provides evidence that the aforementioned characteristics of social capital and farm size influence the use of technology, access to information and services, and the ability to implement innovations, and could influence the resilience of agriculture.

On the other hand, this research links those characteristics with features of national agriculture that could determine the unique paths towards the establishment of resilient and sustainable food systems. For example, research suggests that female farm managers often own small farms, seek family and work balance, and demonstrate higher concern about environmentally friendly farming practices [47], while male farm managers often seek to maximize profit. The study by [43] reports that small female farms show similar economic results; however, they offer better environmental results. Less mechanized farming activity, diversified farming income, and higher value-added production are recognized as important characteristics of female farms [47]. The study by [48] links green transformations with new possibilities to increase female participation in agriculture and provides evidence that the EU countries without specific green transformation patterns have lower shares of female agricultural entrepreneurs. Thus, the role of female farm managers is important for the establishment of sustainable food systems, while the change in the gender structure of farm managers influences the resilience of national agriculture.

The ageing of farmers leads to gradually declining activity and physical capacity to operate farms, while the future of the farm is strongly influenced by farm succession prospects [18] that determine farm management and investment strategies. The generational renewal indicator and the share of farm managers with full agricultural education could be identified as resilience leading indicators. Studies by [45,46] suggest that the aforementioned characteristics are associated with the ability to adopt new technologies and improve the digitalization of agriculture.

Over recent decades, the number of small farms has decreased dramatically. Many smallholders face economic viability challenges [49]. Small farms often cannot afford investments [18] and face disregard in terms of public support and investments [42,49]. However, small farms make a multifaceted contribution to the resilience of food systems. Smallholders contribute to household livelihood portfolios, improving food and nutrition security [49,50], improving the environmental dimension by maintaining genetic diversity on farms and providing ecosystem services [50], and coping with rural poverty alleviation [49], contributing to employment function implementation. The study by [45] identifies digitalization of agriculture as a threat that could accelerate the growth of digitally equipped large-scale farms and increase their role in agricultural output at the expense of smallholders. Thus, academic studies argue that institutional environments must address inequality challenges in agriculture and develop innovative support mechanisms that allow vulnerable farms to improve competitiveness and remain an important part of the food system.

To conclude, the potential of national food systems to absorb shocks and stressors or transform the system depends on structural patterns of agriculture. This article includes resilience leading indicators that identify vulnerable groups of farmers with different potential to develop innovations and technologies on farms, namely generational renewal ratio, gender equity ratio, the share of farms with full agricultural training, and the share of small farms. Government support for agricultural research and development (R&D) sheds some light on the national attempts to increase the resilience of food systems and could facilitate the transition towards more resilient food systems, unlocking innovation and technology for target groups of farmers.

3. Materials and Methods

This article investigates the change in the resilience indicators of Estonia, Latvia, and Lithuania compared to the EU average and reports on the resilience situation in 2013 and 2023. The first year shows the resilience situation before the occupation of Crimea, when the Baltic states were able to organize trade with all neighboring countries. In 2022, the intervention of the Russian military introduced turmoil in the global market. According to [42], the conflict threatened the availability of food supplies and resulted in the rise of food prices, introduced the re-evaluation of agricultural policy measures, and changed international trade flows. This study selects 2023 as the year that shows the adaptation of the Baltic states to changes in global trade after the COVID-19 pandemic and the introduction of sanctions.

Based on the analysis of the most recent studies on the resilience of food systems, this article develops a function-based resilience assessment dashboard (FBRAD) for agriculture, hereinafter referred to as a component of the food system, that combines resilience leading and lagging indicators (Table 1). FBRAD indicators are calculated by employing secondary data from the Eurostat and FADN databases. For the year 2023, data on structural patterns of agriculture (GRR, GER, FAT, SF) are not available, and indicators are calculated by employing the most recent agricultural census data for 2020.

Table 1. FBRAD: leading and lagging indicators.

	Code	Indicator	Measurement	Details	Source
Leading indicators	GRR	generational renewal ratio of farm managers	-	65 years and over farm managers/less than 35 years farm managers	Eurostat
	GER	gender equity ratio of farm managers	-	female farm managers/male farm managers	Eurostat
	FAT	the share of farm managers with full agricultural training	%	(farm managers with full agricultural training/total number of farm managers) $\times$ 100	Eurostat
	SF	the share of small farms	%	(holdings less than 5 ha/total number of holdings) $\times$ 100	Eurostat
	GSARD	government support for agricultural R&D	EUR per capita	government support for agricultural R&D per capita	Eurostat

Table 1. Cont.

	Code	Indicator	Measurement	Details	Source
Lagging indicators	AGVA	the share of agriculture in total gross value added	%	(GVA of agriculture, forestry and fishing at current prices/total GVA at current prices) $\times$ 100	Eurostat
	HHI	Herfindahl-Hirschman index	-	the HHI for the individual CN group is calculated as a sum of the squares of the import market shares for individual country (the aggregated HHI applies weights of individual CN groups in import structure)	Eurostat
	ANF	affordability of nutritious food	%	the share of population that is not able to afford a meal with meat, chicken, fish (or vegetarian equivalent) every 2nd day in the income group classified as 60.0% below the median equivalized income	Eurostat
	FE	the share of food expenditure	%	(nominal food expenditure per capita/nominal actual individual consumption per capita) $\times$ 100	Eurostat
	FNI	farm net income	EUR	gross farm income – depreciation – total external factors + balance subsidies and taxes on investment	FADN
	OIR	farm output–input ratio	-	total output/total input	FADN
	DR	farm debt ratio	-	total liabilities/total assets	FADN
	AE	the share of agriculture in total employment	%	(employment in agriculture, forestry and fishing (thou persons)/total employment (thou persons)) $\times$ 100	Eurostat

The FBRAD combines leading and lagging resilience indicators. Conceptually, leading indicators are understood as proactive measures that could give advance warning [51], because these indicators are oriented to the future performance. Leading indicators could help us to understand how change can be realized through appropriate policy making and implementation. Lagging indicators are reactive as they communicate results employing current or past performance outcomes [51]. Changes in leading indicators influence the outcomes of lagging indicators and allow us to develop the overall resilience of food systems. The developed framework covers leading indicators that focus on agricultural production and influence changes in the food system through the improvement of farm viability and agricultural employment resilience. These leading indicators have paramount importance for the establishment of a sound background for the implementation of other functions of food systems.

Leading indicators include resilience measures that influence the potential of the agricultural system to implement change and the ability to cope with shocks and stressors. These indicators allow us to compare national structural patterns that could facilitate or impede transition towards a more resilient and sustainable food system. In fact, those indi-

cators report on changes in adaptive and transformative capacities of the system. Leading indicators cover key measures that describe innovation and technology implementation potential that is closely related with resilience of agricultural systems, namely, generational renewal ratio of farm managers (GRR), gender equity ratio of farm managers (GER), the share of farm managers with full agricultural training (FAT), the share of small farms (SF), and government support for agricultural R&D per capita (GSARD).

Lagging indicators combine outcome-based indicators that allow us to investigate changes in the performance of key socioeconomic functions of the investigated agricultural system. Food and nutrition security function is covered by the following resilience indicators: the share of agriculture in total gross value added (AGVA), the Herfindahl-Hirschman index (HHI), the affordability of nutritious food (ANF), and the share of food expenditure (FE). Farm economic viability and employment functions are analyzed applying the following resilience indicators: farm net income (FNI), farm output–input ratio (OIR), farm debt ratio (DR), and the share of agriculture in total employment (AE).

The formulas applied for the calculation of leading and lagging resilience indicators are provided in Table 1 (see Details). For the analysis of the dependence of food supplies on foreign markets, this article additionally employs the decomposition of the HHI into the intra-EU and extra-EU area (hereinafter in-EU and ex-EU) imports and introduces additional resilience indicators, namely, trade balance and the share of ex-EU imports, in order to understand the risks associated with the availability of current food supplies and identify the resilience challenges.

To calculate the HHI value for the individual product group, this article adopts the formula provided in [37,52]. The aggregated HHI includes three groups of two-digit combined nomenclature (CN): animal products (CN01–CN05), fats and oils (CN15), and vegetable products (CN06–CN13). The aggregated HHI uses an aggregation that allows for reward-based indicators in accordance with the weights [53] of the CN groups in their total import structure. The aggregated HHI value for the country *i* (or the EU) is calculated by applying the following formula:

$$HHI = \sum_{j=1}^m w_j HHI_j \quad (1)$$

HHI_j —the HHI value for the *j*th CN group; w_j —weight of the *j*th CN product group in the import structure.

The sum of weights of all investigated CN product groups for the import in country *i* (or the EU) is equal to 1.

$$\sum_{j=1}^m w_j = \sum_{j=1}^m \frac{S_j}{S} = 1, \quad (2)$$

S_j refers to the import value for the *j*th CN group; S is the total import value for all investigated CN groups.

It should be noted that the selection of weights for the composite indicator is widely recognized as a serious methodological challenge that has an impact on the results [53,54]. Aggregated HHI values were additionally calculated employing the non-weighted arithmetic average method [54], and the results suggest that the weighting procedure did not disturb import market concentration classification results.

The interpretation of HHI values of individual CN groups allows us to classify major categories of market concentration; however, the introduction of reliable thresholds remains a challenge. Examples of such thresholds are provided in [52,55]. This research employs an indicative assessment provided by [52], where values below 0.10 characterize a non-concentrated import market, $0.10 \leq HHI \leq 0.18$ refer to a moderately concentrated import market, and values above 0.18 describe a highly concentrated import market. The concentration group affiliation is recommended only for individual CN product groups,

while the aggregated HHI values are included in FBRADs, as the resilience indicator should be employed to monitor changes in development direction rather than to classify import market concentration level.

This article also provides a more detailed analysis of farm economic viability indicators during the period 2013–2023 because annual economic results are strongly dependent on weather conditions and other shocks (for example, crop or animal diseases, trade bans or introduced limitations, etc.). This research limitation is overcome by investigating the development and trendline trajectories of annual resilience indicators.

The FBRAD provides normalized resilience indices that compare the development of the individual resilience indicator in the investigated country with the EU average. For the individual indicators in Table 1, the distance to a reference measure [56] logic is applied:

$$R_{k,i}^{t*} = \frac{r_{k,i}^t}{r_{k,EU}^t}, \quad (3)$$

$R_{k,i}^{t*}$ —the value of the normalized index for the k th resilience indicator in the i th Member State at the time t ; $r_{k,i}^t$ —the value of the k th resilience indicator in the i th Member State at the time t ; $r_{k,EU}^t$ —the average value of the k th resilience indicator for the EU at the time t . The EU average data include 27 Member States that have constituted the EU since 2020.

It should be noted that the normalized values allow us to compare the national value with the EU average, referred to as 1, and estimate the distance between values. However, this method of normalization does not introduce the same index range for the investigated indicators and depends on the patterns of the individual resilience indicators.

It should be noted that research limitations are introduced by data availability and frequency. The developed FBRAD employs normalized indicators and requires statistics from all Member States to estimate the gap between the investigated country and the EU average. This approach narrows the choice of informative resilience indicators eligible at the national level. The aforementioned challenge is especially relevant for the estimation of the employment function because detailed national statistics differ, and some indicators are not supported in all Member States.

4. Results and Discussion

This section provides resilience leading and lagging indices for Estonia, Latvia, and Lithuania. FBRADs allow us to compare the resilience situation in individual Member States and explore the change in the gap between individual countries and the EU average in 2013 and in 2023. Research results are enriched by a broader academic discussion referring to the previous research.

First, Section 4.1 examines the related values of the leading indicators in Table 1 and provides a radar chart that shows deviations of national indicators from the EU average in each of the two years, 2013 and 2023. This section also provides the discussion linking the results with the most recent research. Second, Section 4.2 examines the related values of the lagging indicators in Table 1 and provides a radar chart that shows deviations of national lagging indicators from the EU average in each of the two years, 2013 and 2023. Section 4.2.1 investigates lagging indicators of food and nutrition security function in the Baltic states and supplements analysis with more detailed results for imports introducing clustered boxplots of HHI values showing import concentration differences for ex- and in-EU trade, while the provided table clusters product groups applying trade balance, import market concentration, and the share of ex-EU imports in total import structure criteria in order to identify the dependence of product groups on ex-EU imports and discuss the related resilience challenges. Section 4.2.2 delves into the in-depth analysis of

lagging indicators that describe economic farm viability and employment functions. This section is supplemented by charts that show changes in the normalized indices of economic indicators during 2013–2023 and includes meaningful trend models, discussing the results in light of previous studies.

4.1. FBRAD Results: Resilience Leading Indicators

The FBRADs with the resilience leading indices for the Baltic states are provided in Figure 1. Normalized resilience indices allow us to compare the situation in the investigated country with the EU average and observe the change in gaps of the leading indicators over the analyzed years. To be specific, 1 refers to 100.0% equivalent and shows the situation when the country has the same leading indicator value as the EU average. The index value above 1 could be linked with the change in percentage points away from the EU average and shows that the leading indicator of the country is higher than the EU average, and vice versa.

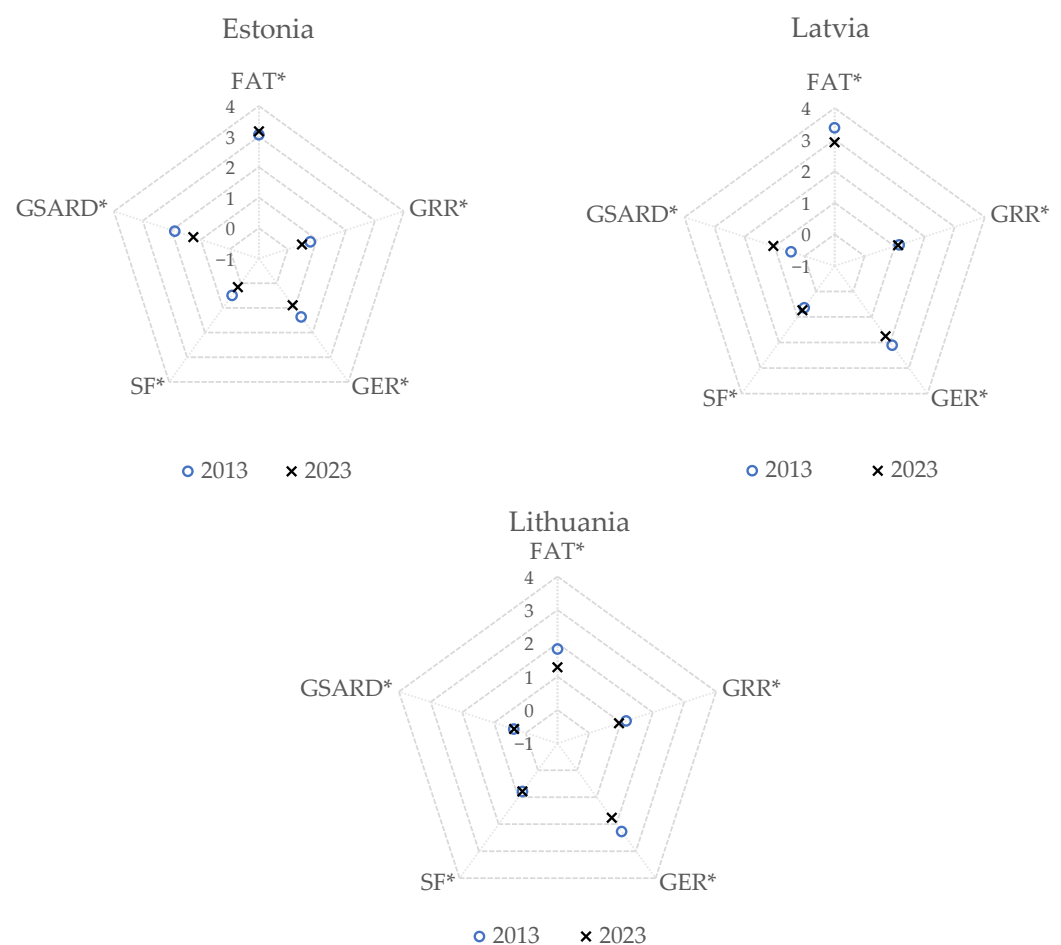


Figure 1. FBRADs for the Baltic states: leading indicators, where score 1.0 is the EU average. Note: GRR*—the normalized index of generational renewal ratio of farm managers, GER*—the normalized index of gender equity ratio of farm managers, FAT*—the normalized index of the share of farm managers with full agricultural training, SF*—the normalized index of the share of small farms, GSARD*—the normalized index of government support for agricultural R&D per capita.

During the past decades, the ageing of farm managers has been widely recognized as a paramount challenge for EU agriculture. Generational renewal problems and the absence of heirs on farms are of the utmost importance when it comes to determining whether the senior manager invests in innovations and technologies, changing the resilience of the farming system, or runs business as usual. In the EU, the ratio between senior and young

farm managers remains almost at the same level, and the GRR_{EU} indicator falls from 5.2 to 5.1 over the period considered. In fact, Eurostat data suggest that, in the EU, five senior farm managers are replaced by one young farm manager. Thus, the desired direction of national development is GRR values below 1, referred to as the EU average (Figure 1). The best generational renewal situation is in Estonia, where the most recent GRR_{EE}^* value accounts for 48.7% of the EU average, and the improvement in the ratio between senior and young farm managers is remarkable (from 4.0 to 2.5). In Latvia, the generational renewal situation is the worst (from 6.0 to 5.7) compared to the other Baltic states, and GRR_{LV}^* indices report on values higher than the EU average. In Lithuania, GRR_{LT} shows a switch from a value above the EU average to a more favorable situation over the period considered (from 6.0 to 4.8).

The ageing of farm managers and the unwillingness of young people to continue the farming business are associated with the declining role of small farms in national agricultural systems. In the EU, the role of small farms remains almost at the same level over the period considered, as the SF_{EU} value, reporting on the share of small farms, drops from 67.3% to 63.8%. In the Baltic states, SF^* values below 1 suggest that the share of small farms in national agricultural structures is lower than the EU average (Figure 1). Although small farms are an important element of the resilient food system, the dominance of small farms is often related to the economic viability challenges on farms. Thus, the desired development direction is a value below the EU average, referred to as 1. However, countries must find the desired balance between large-scale farms and smallholders in order to ensure the resilience of national food systems. Lithuania, where small farms represent half of agricultural holdings, maintains the position of the Baltic state with the highest share of small farms, while, in Estonia, the decline in the numbers of small farms is the fastest (from 33.0% to 10.4%), and the share of small farms accounts for one-tenth of holdings at the end of the period considered. Latvia is the only Baltic state where the SF_{LV}^* value increases as the share of small farms is growing, and small farms increase the share from 42.6% to 47.0%. Ageing of farm managers and the rapid decline of small farms in the Baltic states could be explained by the common history. After the collapse of the Soviet Union, the Baltic states restored property rights and denationalized land. As a result, the enrollment of a large number of farmers who owned small holdings took place at the same time. In 2004, the Baltic states joined the EU, and the size of holdings began to grow, reacting to the change in the competitive environment. However, differences in national agricultural policies and support schemes determined the unique structures of national agricultural systems in the Baltic states.

Education of farmers is the paramount layer of social capital that empowers accumulation, development, and employment of skills that allow the most recent challenges to be addressed and to increase the resilience of food systems. Higher level of education is often linked with improved ability of farm managers to implement innovations and deeper knowledge about food systems. Figure 1 suggests that the Baltic states have a more favorable potential to accelerate their transition towards higher resilience on local farms because FAT^* values are higher than 1, referred to as the EU average. In the EU, the share of farm managers with full agricultural training, FAT_{EU} , increases from 8.4% to 10.2% over the period considered. The opposite trend is only in Lithuania, where the FAT_{LT} value falls from 15.4% to 13.0%; however, the share of farm managers with full agricultural training remains higher than the EU average. Estonia and Latvia have the most favorable situation as FAT^* values are almost three times higher than the EU average, and the corresponding value for Latvia increases from 28.4% to 29.6%, while, in Estonia, the growth is from 25.7% to 32.3%. Eurostat suggests that the Baltic states have a larger share of people with a high educational attainment level compared to the EU average, and this pattern remains valid

for agricultural training. However, in Lithuania, the FAT_{LT} value is lower as agricultural activity struggles with a negative image and the unwillingness of young people to take over their family farms. Thus, the educational system faces difficulties attracting students to agricultural studies.

Gender equity of farm managers also plays an important role, as research provides evidence that the structure of national agriculture influences resilience. Research suggests that male managers often seek profit maximization. Thus, economies of scale result in the growth of the average farm size, and the Estonian case confirms this statement as the value of GER_{EE} falls from 0.5 to 0.4. Female managers often run small businesses due to multiple roles in society; they look for innovative niches that allow them to diversify family income and to reduce poverty. Such small farms have a strong potential to increase the resilience of local food systems. Although the results suggest the improvement of female participation as GER_{EU} value, describing the EU average, increases from 0.4 to 0.5, the number of female managers is almost twice as low as that of male managers, while the desired condition is gender balance. Thus, values above the EU average, referred to as 1, are the desired direction of agricultural development (in 2023, the value of 2 shows a balanced gender structure). In all Baltic states, GER^* values follow the opposite direction and demonstrate the shrinking share of female farm managers in national agriculture; however, Latvia and Lithuania have a remarkably high number of female managers compared to the EU average. In Latvia, the GER_{LV} value remains almost stable (0.8), while, in Lithuania, the GER_{LT} value falls from 0.9 to 0.8. The high participation of women in agriculture could be explained by gender equity and the historical dominance of small farms that allow women to participate in agriculture. Unfortunately, the Baltic states are moving towards large-scale farming in order to stay competitive on the EU market, and this trend reduces the number of holdings owned by women managers.

The aforementioned leading indicators demonstrate important structural patterns that influence resilience potential on farms and in national agriculture. However, the development and dissemination of innovations, as well as the spread of technologies on farms, could be accelerated by investing in agricultural R&D. In the EU, government support for agricultural R&D per inhabitant ($GSARD_{EU}$) increases from EUR 5.8 to 8.1 over the investigated period. Figure 1 shows that the situation in Lithuania is the most disadvantageous. $GSARD_{LT}$ value increased from EUR 2.2 to 3.0 and was remarkably lower than the EU average. In 2023, the $GSARD_{LT}^*$ index is the lowest compared to the other Baltic states. Latvia manages to triple the $GSARD_{LV}$ indicator from EUR 2.6 to 8.4 over the period considered and reaches the position of slightly above the EU average in 2023. In Estonia, the $GSARD_{EE}^*$ indicator declines, but the value remains above the EU average, and the corresponding change is from EUR 11.0 to 10.1.

To sum up, the resilience leading indicators of the Baltic states identify remarkable differences in structural patterns of agricultural systems that could result in different visions of resilient food systems and the introduction of specific resilience improvement actions based on the unique strengths of national agricultural systems. In the context of the Baltic states, Estonia has an exceptional position with the minor role of small farms in the structure, the best generational renewal situation, the highest share of farm managers with full agricultural training, the dominance of male farm managers, and the highest per capita support for agricultural R&D combined with the availability of external resources (see Section 4.2.2). These structural patterns could be associated with better potential to invest in innovations, especially in digital technologies, compared to the other Baltic states. The minor role of small farms could also determine differences in the allocation of a budget for R&D directions, compared to the other Baltic states.

The Estonian situation describes the agricultural system that gravitates towards the productivist strategy as a response to the food security challenge. According to [45], the digitalization of agriculture often supports a productivist strategy that serves to maximize export-oriented agricultural output and increase the share of large, capital-intensive conventional farms at the expense of other farms. The digitalization of large-scale farms in such a context could lead to the higher contribution of the small share of digitally equipped farms to agricultural output [45], while food security dependence on several actors increases the vulnerability of the food system in case of crisis. Meanwhile, neglected small farms play an important role in the resilience of local food systems as they often represent agroecological or organic farming practices. Thus, researchers [45,46] highlight the importance of equity and inclusion in developing, distributing, and adopting innovations and technologies among farmers.

Although small farms are recognized as a key element of resilient and inclusive transformation of rural areas [49], the provided research results suggest that structural changes in the agricultural systems of Latvia and Lithuania are not finished. The analysis of resilience leading indicators in these countries shows an unfavorable generational renewal situation that could result in a further decline in the number of small farms and female managers on farms. On the one hand, the ongoing transformation influences sustainability, because the most recent research links the dominance of male farm managers and large-scale farms with differences in environmental management behavior [47,48]. On the other hand, the similarities of structural patterns encourage the introduction of specific support actions to improve the resilience of vulnerable groups of farmers. Cross-border cooperation and knowledge exchange could be useful instruments for the establishment of efficient support frameworks, while actions could include specific measures targeting support for innovations on vulnerable farms, improved access to credit for small farms, and development of innovation-relevant skills and knowledge.

In Lithuania, the lowest support for agricultural R&D in tandem with structural patterns that introduce the largest group of ageing farm managers on small farms, combined with the shrinking share of female managers and the lowest share of managers with full agricultural training compared to the other Baltic states imply that a stronger focus on equity and inclusion should be a compulsory feature of the support framework. The low GSARD_{LT}* index, combined with the aforementioned structural patterns, demonstrates the unfavorable situation of Lithuania compared to the other Baltic states. The reduction in the support gap, directing higher allocations to develop and implement inclusive innovative solutions and improve the viability of vulnerable farms, could have a positive effect on the resilience of the Lithuanian food system.

4.2. FBRAD Results: Lagging Indicators

The FBRADs with lagging indices for the Baltic states are provided in Figure 2. Normalized resilience indices allow us to compare the situation in the investigated country with the EU average during the analyzed years. In Figure 2, 1 refers to the situation when the country has the same value of the lagging indicator as the EU average; the index value above 1 shows that the lagging indicator of the country is higher than the EU average, and vice versa.

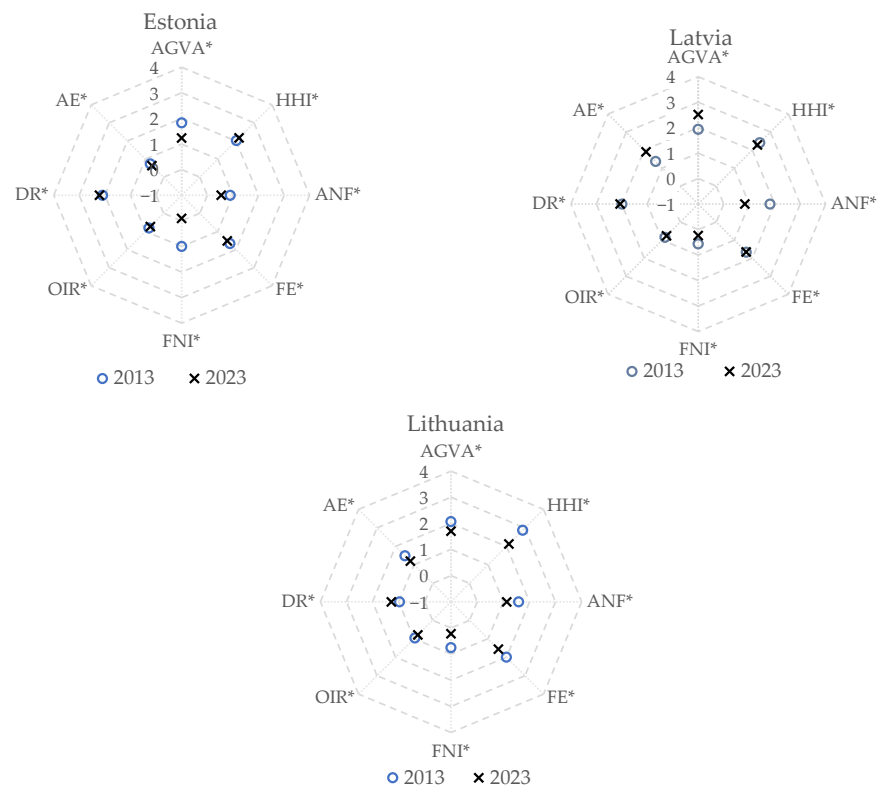


Figure 2. FBRADs for the Baltic states: lagging indicators, where score 1.0 is the EU average. Note: AGVA*—the normalized index of the share of agriculture in total GVA, HHI*—the normalized aggregated Herfindahl-Hirschman Index, ANF*—the normalized index of affordability of nutritious food, FE*—the normalized index of the share of food expenditure, FNI*—the normalized index of farm net income, OIR*—the normalized index of farm output-input ratio, DR*—the normalized index of farm debt ratio, AE*—the normalized index of the share of agriculture in total employment.

4.2.1. Resilience Indices of Food and Nutrition Security Function

The ability of national food systems to secure the availability of nutritious food at affordable prices is investigated employing ANF* and FE* indices (Figure 2). The desired development direction of indicators, which is associated with improved resilience, is a decline in value. Eurostat statistics report on the improving situation in the EU as the affordability of a nutritious meal every second day (ANF_{EU}) for the investigated group of income falls from 26.0% to 22.3% over the period 2013–2023. In Estonia, ANF_{EE}^* values lower than 1 suggest better nutritional food availability than the EU average, and the share of the population facing nutritional challenges reduces almost twice from 23.3% to 12.2% over the investigated period. In Lithuania and Latvia, the share of population that could not afford nutritious food every second day is remarkably higher than the EU average in 2013, and Latvia manages to improve the situation up to the ANF_{LV}^* value below the EU average over the analyzed period (from 47.3% to 18.4%), while, in Lithuania, the ANF_{LT} value drops from 41.2% to the values slightly above the ANF_{EU} (25.2%). The improved availability of nutritious food in the Baltic states is determined by growing incomes and improved physical access to diverse food.

All Baltic states have a higher share of nominal expenditure for food per capita compared to the EU average, which remains almost stable and demonstrates the change in FE_{EU} value from 9.6% to 9.4% over the period considered. It should be noted that the desired index development direction is a decline in value and a move towards the EU average, referred to as 1. In 2013, the highest FE* value, suggesting the largest share of food expenses in individual consumption, was in Lithuania (changing from 19.1% to 14.6%), and, in 2023, the Baltic states have almost similar FE* values. Latvia demonstrates a slight

drop in value, from 15.9% to 15.6%, while Estonia manages to reduce expenditure for food from 15.9% to 14.3%. In the case of the Baltic states, the difference between the EU average and national FE values could be explained by differences in annual earnings in Member States. After the accession to the EU, annual earnings in new Member States increased remarkably, resulting in higher consumption per capita and the decreasing share of food expenses in total expenditure during the period 2013–2023.

The food supplies availability dimension is covered by the AGVA* and HHI* indices (Figure 2). The share of agriculture in the total GVA of the EU (AGVA_{EU}) drops from 1.9% to 1.8%. In the Baltic states, AGVA* values above 1 suggest that this economic activity plays a more important role in the structure of national GVA than in the EU. Over the period 2013–2023, Estonia and Lithuania follow the change pattern of the EU average, and the national AGVA indicator in Estonia declines from 3.5% to 2.2%, while AGVA_{LT} drops from 3.9% to 3.0%; however, the pace of change is higher than in the EU. In Latvia, the share of agriculture in total GVA increases and in 2023 accounts for 4.5%, compared to 3.7% in 2013. The study by [39] shows that the importance of agriculture in the structure of the national economy influences the resilience patterns of the country and the reaction to economic shocks.

Another important aspect of agricultural commodities and food products' availability is foreign trade. The aggregated HHI* values suggest that the Baltic states have higher levels of import market concentration and less diversified networks of import partners compared to the trade relations developed by all EU Member States. In the EU, both aggregated HHI_{EU} values are 0.09, suggesting that the situation remains stable and the failure of imports from several countries does not influence the resilience of the EU food system, and allows for maneuvering between many trade partners to ensure the functioning of supply chains. In the Baltic states, HHI* values above 2 show that national import markets gravitate towards a high level of concentration. However, Figure 2 suggests that in Lithuania and Latvia, extreme events on global markets have encouraged reconsideration of the dependence on trade partners, and HHI* values slightly decreased. The situation in Estonia remains almost stable.

The aggregated HHI* values allow us to investigate the main directions of import concentration development; however, the resilience of national food systems depends on the origin of imports, the self-sufficiency situation, and the importance of the investigated product groups. Figure 3 shows clustered boxplots for the decomposed HHI values that estimate the concentration of ex-EU imports for individual CN product groups. The boxplot charts could be interpreted as follows. The 'box' (blue, yellow, green, or red) shows the interquartile range that covers 50.0% of the middle HHI values for the analyzed country (or EU) and contains the line which refers to the median for the HHI values. The lower whisker (below the 'box') shows the distribution of the HHI values for the first quartile group, while the upper whisker covers the HHI values within the fourth quartile.

For the ex-EU imports, HHI values, whiskers, and interquartile boxplots vary in length in the year 2023 as compared to the year 2013. On the one hand, whiskers report on the decline of maximum HHI values and evidence of import market diversification that increases the resilience of food systems. On the other hand, all Baltic states demonstrate the growth of HHI medians for ex-EU imports and an important switch in the distribution of HHI values above and below the medians. Lithuania and Estonia improve the lower and the upper ends of interquartile boxplots, increasing the resilience of food systems. Latvia demonstrates a decline in the length of the interquartile boxplot in 2023, suggesting the gravitation of HHI values within a narrower range and with a higher median. In Latvia, the outlier refers to the group of animal products (LV04) and evidences the increase in imports from Ukraine in 2023. Imports from this country increased seven times compared to the

year 2021, and Ukraine dominates in ex-EU imports of the LV04 product group in 2023. The LV04 product group represents only 5.2% in total ex-EU import value, while in-EU imports exceeded nine-tenths of imports for this group. Nevertheless, Table 2 allows us to state that this group of products does not threaten the resilience of the national food system, because the trade balance is positive and the share of ex-EU imports in the import structure of this product group is low.

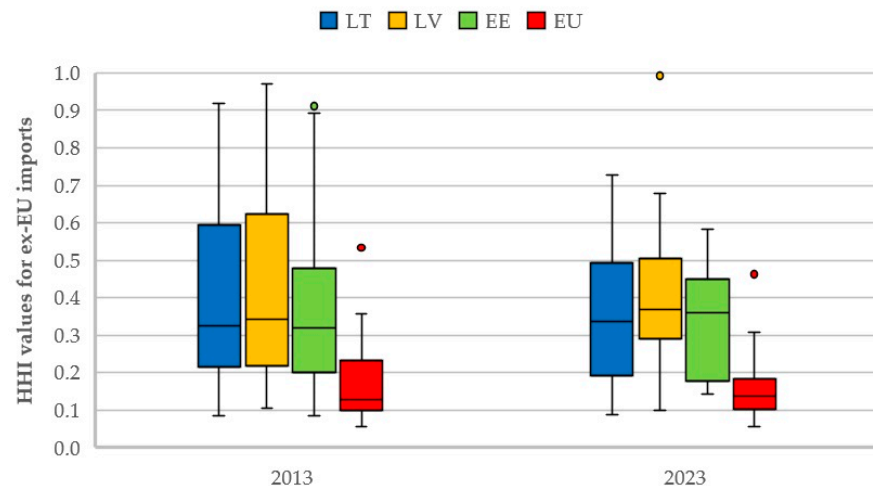


Figure 3. Clustered boxplots of HHI values for ex-EU imports. Note: capital letters refer to the assigned codes: the European Union—EU, Estonia—EE, Latvia—LV, Lithuania—LT.

In the EU, the interquartile range of boxplots and the distribution of HHI values within the box decrease in length, while the median increases. The whiskers do not cover one group of animal products (EU01), but Table 2 suggests that the high HHI value for ex-EU trade does not threaten the resilience of the EU food system.

For in-EU imports, the change in situations of the Baltic states differs (Figure 4); however, the high level of import concentration remains a feature of many individual product groups. Estonia demonstrates the most impressive progress in reducing the interquartile range of the boxplot and the maximum value in 2023; however, the median and the lower end of the interquartile boxplot increase. In the case of Lithuania and Latvia, the medians of the HHI values improve, but the overall assessment of the boxplot change patterns does not provide evidence of a remarkable resilience improvement related to in-EU imports.

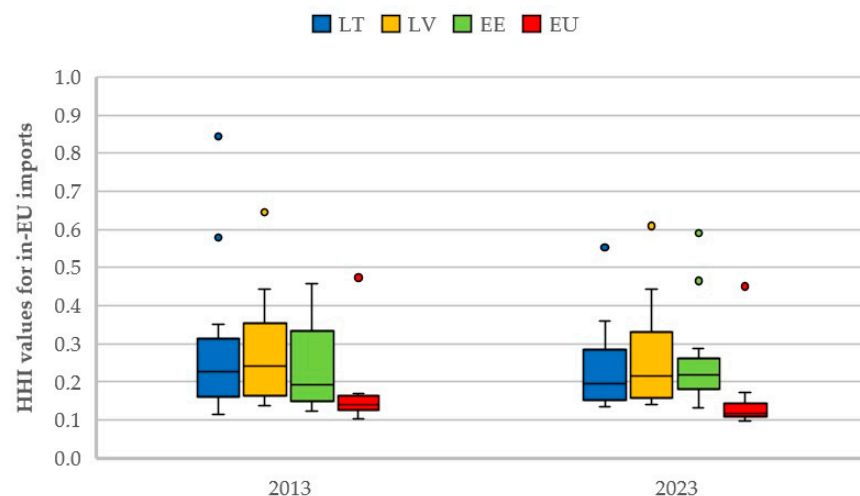


Figure 4. Clustered boxplots of HHI values for in-EU imports. Note: capital letters refer to the assigned codes: the European Union—EU, Estonia—EE, Latvia—LV, Lithuania—LT.

In Lithuania, Estonia, and the EU, extreme outliers show the highly concentrated import market for one group of vegetable products (LT06, EE06, EU06). This group has a negative trade balance in all Baltic states; however, Table 2 suggests that trade mainly relies on more resilient in-EU imports. In Estonia, one group of animal products with a positive trade balance (EE01) remains highly concentrated in 2023 (Table 2).

Table 2. Ex-EU imports of the Baltic states and the EU by product category in 2013 and 2023.

Ex-EU Share in Total Imports (%)	Positive Trade Balance			Negative Trade Balance		
	Ex-EU HHI <0.10	Ex-EU HHI (0.10; 0.18)	Ex-EU HHI ≥0.18	Ex-EU HHI <0.10	Ex-EU HHI (0.10; 0.18)	Ex-EU HHI ≥0.18
2013						
<10.0			LT01, LT02, LT04, LV01, LV04, LV10, LV11, EE04, EU01, EU04, EU11	EE08	LV07	LT06, LT07, LT09, LV02, LV05, LV06, EE02, EE05, EE06, EE07, EE11, EE13
10–19.9	EU06, EU07	EE03	LT11, LV12, EE01, EE10, EU02	LT08	LV08, LV09	LT05, LV03, EE09
20.0–29.9		EU10	LT12, EE12			EE15
30.0–39.9					LT03	LT13, LV15
40.0–49.9	EU13		LT10	EU08		LT15, EU05
≥50.0					EU09, EU03, EU12	LV13
2023						
<10.0		EU11	LT01, LT04, LT11, LV01, LV04, LV11, EE01, EE04, EU01, EU04		LT09, EE08, EE09,	LT02, LT06, LV02, LV06, EE02, EE06, EE07, EE11
10–19.9		EU02, EU06		LV09	LV03, LV08, EU07	LT05, LT13, LV05, LV13, EE05, EE12
20.0–29.9		EE03	LT07, LT10	LT08		LV07, EE13
30.0–39.9			LT12, LV10, EE10, EU10		LT03, EU05	LT15
40.0–49.9	EU13		LV12	EU08		
≥50.0					EU03, EU09, EU12	LV15

Note: capital letters refer to the assigned codes: the European Union—EU, Estonia—EE, Latvia—LV, Lithuania—LT. Number codes refer to the combined nomenclature codes used by Eurostat (01—live animals; 02—meat and edible meat offal; 03—fish and crustaceans, molluscs and other aquatic invertebrates; 04—dairy produce; birds' eggs; natural honey; edible products of animal origin, not elsewhere specified or included; 05—products of animal origin, not elsewhere specified or included; 06—live trees and other plants; bulbs, roots and the like; cut flowers and ornamental foliage; 07—edible vegetables and certain roots and tubers; 08—edible fruit and nuts; peel of citrus fruit or melons; 09—coffee, tea, mate and spices; 10—cereals; 11—products of the milling industry; malt; starches; inulin; wheat gluten; 12—oil seeds and oleaginous fruits; miscellaneous grains, seeds and fruit; industrial or medicinal plants; straw and fodder; 13—lac; gums, resins and other vegetable saps and extracts; 15—animal or vegetable fats and oils and their cleavage products; prepared edible fats; animal or vegetable waxes).

The dynamic geopolitical situation and the most recent global trade challenges suggest that EU Member States must pay attention to ex-EU imports because dependence on a highly concentrated import structure could lead to failures of supply chains within the EU. Table 2 clusters the HHI values of ex-EU imports for individual product groups, applying the foreign trade balance and the share of ex-EU imports to the total imports criteria. For example, LV01 refers to live animal imports in Latvia, and Table 2 shows a similar situation in 2013 and in 2023. This product group has a positive trade balance, while the ex-EU imports are highly concentrated and represent less than 10.0% in the LV01 import structure for Latvia. The identified clusters allow us to explore the changes in import structure and link them with the resilience of food systems. The negative trade balance, combined with a strong reliance on ex-EU imports and the high level of ex-EU market concentration, identifies potential resilience threats.

In the EU, resilience concerns could be linked with the high share of ex-EU imports and negative trade balances of two animal product groups (EU03, EU05), fats and oils (EU15), and three vegetable product groups (EU08, EU09, EU12). The aforementioned product groups have unconcentrated or moderately concentrated import markets and could improve the resilience of the EU food system by diversifying a network of trade partners or maintaining developed unconcentrated import markets. The gravitation of individual product groups towards the dominance of in-EU imports could be an important step in increasing the resilience of the EU food system. The ex-EU animal product import markets are more concentrated compared to the vegetable product markets; however, the EU Member States often rely on the in-EU market, which could satisfy their needs.

Research results suggest that the Baltic states project their trade relations relying on in-EU imports, while the share of ex-EU imports is low in the dominant share of product groups. This approach allows the resilience of national food systems to increase. However, for product groups with a negative trade balance, high import concentration, and a notable share of ex-EU imports in the total structure, the current situation could be improved by reducing the share of ex-EU imports and diversifying the partners network, as both in- and ex-EU imports remain highly concentrated.

4.2.2. Resilience Indices of Economic Farm Viability and Employment Functions

The resilience of the economic farm viability function is estimated by applying the FNI*, OIR*, and DR* indices (Figure 2). The comparison of these indices allows us to assess the attractiveness of farming activity in the Baltic states compared to the EU average.

FNI allows us to analyze the annual dynamics of agricultural activity profit or loss and evidence the remuneration for production factors in the investigated agricultural systems. According to FADN, the average EU farm net income (FNI_{EU}) demonstrates a remarkable value growth from 17,152 EUR in 2013 to 31,013 EUR in 2023. In Lithuania, the FNI_{LT} value falls from 12,903 EUR to 6845 EUR. The FNI_{LV} value goes down from 9650 EUR to 7380 EUR. In Estonia, the FNI_{EE} value is negative because profit is replaced by loss (from 17,086 EUR to −2999 EUR). Figure 2 allows us to assume that the situation of economic farm viability in the Baltic states deteriorates, and farming becomes a less attractive economic activity. However, in the case of agriculture, the comparison of two financial years can be misleading, because farm economic performance could be influenced by shocks that disturb results for the particular year.

To eliminate this research limitation, Figure 5 allows us to analyze changes in FNI* values during the period 2013–2023. The results suggest that the FNI* values in the Baltic states, with random annual exceptions in Estonia, do not generate the average EU level. During the analyzed period, Estonia, maintaining the structure with the minor role of small farms, demonstrates the most dramatic surges and declines in FNI_{EE}^* values from the EU

average. Although the development of FNI_{EU} values suggests gradual improvement of economic viability in the EU and allows a linear trendline with a reliable coefficient of determination to be drawn, steep fluctuations of FNI^* values in the Baltic states demonstrate remarkable national deviations from the EU development trendline. Thus, national linear trendlines with positive slopes have coefficients of determination explaining less than 20.0% of data variance in variables for the individual country.

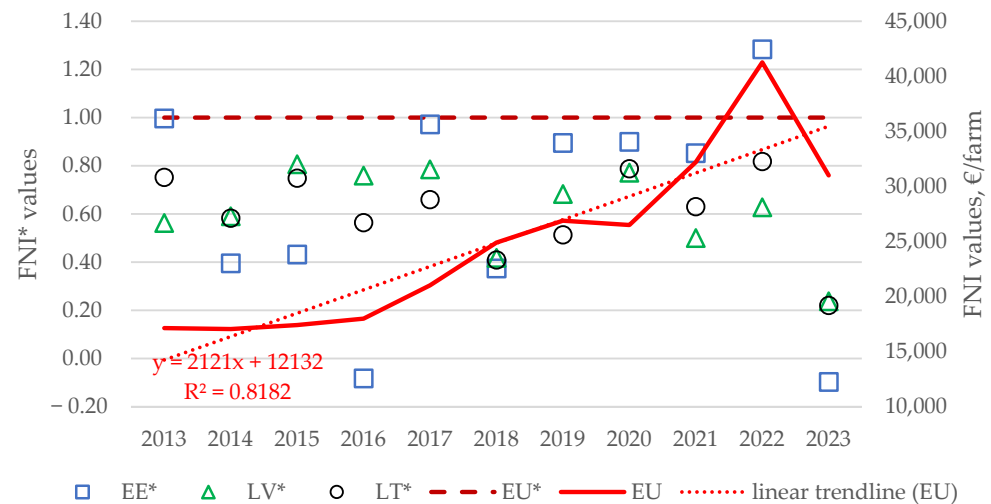


Figure 5. Development of FNI^* values in the EU and the Baltic states, where * refers to the normalized index for the identified country or the EU.

The results are in line with the study by [15] that investigates the average profitability of Lithuanian farms and highlights the instability of the indicator during the period 2010–2019. Research [15,27] also highlights the importance of support for the farm profitability and economic resilience of agriculture. Although this study allows us to identify the positive slopes in FNI development trends of the Baltic states over the period considered, the instability of the FNI indicator, combined with values below the EU average, remains an important challenge to farm viability. It is important to note that the average farm size in the Baltic countries is larger than the EU average, but countries still do not reach the FNI_{EU} level and have huge potential to improve business performance and efficiency in order to increase the resilience of national food systems. FNI development patterns influence the readiness to stay in business and intertwine with declining self-employment on farms.

The economic attractiveness of farming activity depends on the dynamics of OIR values. Growing values of the OIR indicator could be linked with the improving efficiency of the national agricultural system, better economic viability, and increased resilience of farms. The comparison of OIR* values for 2013 and 2023 reports on the worsening economic viability of farm situations in all Baltic countries as the normalized index declines and the gap between the national indicator and the EU average value increases (Figure 2).

In the EU, annual OIR_{EU} values increase from 1.12 in 2013 to 1.14 in 2023 and demonstrate improving business performance efficiency that could be linked to the growing resilience of the EU food system (Figure 6). Although annual changes in prices and production volumes influence OIR_{EU} values, FADN data suggest that annual OIR_{EU} fluctuations are sharp, but farm output always compensates for farm input.

Indeed, this situation is not typical for the Baltic states as Estonia and Latvia always struggle to reach at least a balance between output and input, and only in 2022 is output higher than input; however, the values of the normalized index remain below the EU average. The OIR_{EE} value goes down from 0.90 in 2013 to 0.83 in 2023, and the OIR_{LV} value falls from 0.95 in 2013 to 0.87 in 2023. The situation in Lithuania differs, as annual OIR_{LT}

values show that only four years out of eleven had higher input than output, and, in 2022, the OIR_{LT}^* value is higher than the EU average. In Lithuania, the OIR_{LT} value falls from 1.07 in 2013 to 0.90 in 2023.

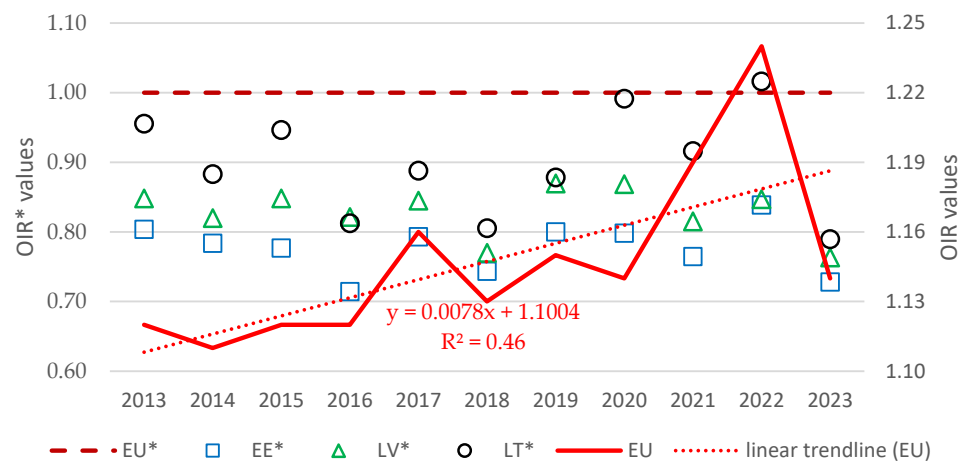


Figure 6. Development of OIR^* values in the EU and the Baltic states, where * refers to the normalized index for the identified country or the EU.

Steep variations of OIR_{EU} values result in a linear regression model with a coefficient of determination that manages to explain only 46.0% of variations in the variable; however, the positive slope suggests growth of the OIR_{EU} value over the period considered. Meanwhile, the fluctuation patterns of national OIR values allow us to develop models that explain less than 10.0% of the variance in the dependent variable. It should be noted that these models also have positive slopes and imply a minor improvement in resilience. However, the development of OIR indicators does not evidence a remarkable improvement in economic viability in the Baltic states over the period considered. To increase resilience, the Baltic states must improve the ratio between output and input on farms and seek national values above the EU average.

The study by [42] argues that credit availability could be linked to farm performance, while the ability to overcome economic difficulties and investment prospects on farms could be influenced by optimal credit management. In this context, DR becomes an important indicator of resilient agricultural systems. In 2013 and 2023, the average EU debt ratio DR_{EU} remains unchanged and accounts for 0.16 (Figure 7).

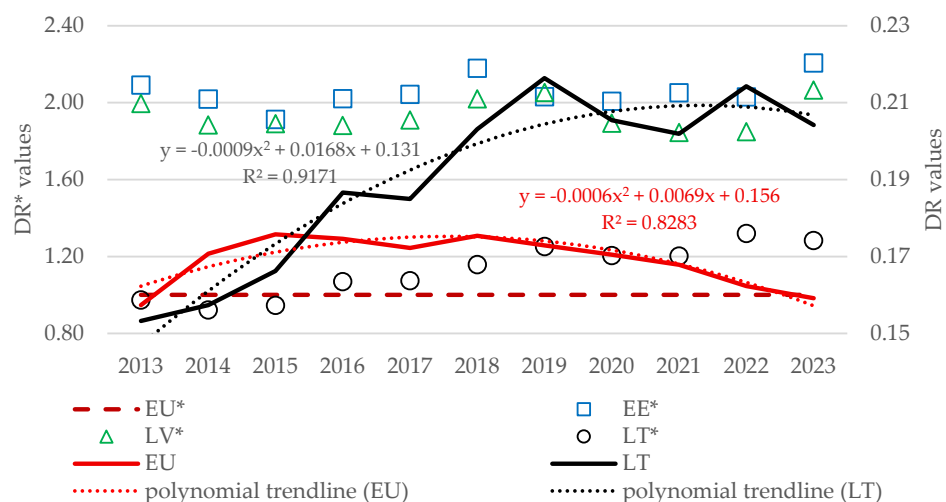


Figure 7. Development of DR^* values in the EU and the Baltic states, where * refers to the normalized index for the identified country or the EU.

In the Baltic states, total liabilities represent a higher share of total assets compared to the EU average, and, in 2023, DR^* values are above 1 (Figure 2). Compared to the EU average, Estonian and Latvian farms have DR^* values almost twice as high and attract a higher level of external resources. On Latvian and Estonian farms, total liabilities account for about one-third of the total asset value. The DR_{LV} value increases from 0.31 in 2013 to 0.33 in 2023; the same growth trend is valid for Estonia (from 0.33 to 0.35). The Baltic states manage to attract more short-term loans than the average EU farm, while DR values remain low and total assets cover total liabilities. Access to credit supports the resilience of national food systems. In both countries, the development of DR values follows the polynomial trendline; however, the model explains only about one-third of the variance in the dependent variable.

In this context, the situation of Lithuania differs because the country manages to improve access to external resources over the period considered (the DR_{LT} value increases from 0.15 to 0.20). In 2013, the DR_{LT}^* value was below the EU average, and, since 2016, the index has exceeded DR_{EU}^* values. The development of DR_{LT} values allows a polynomial trendline to be drawn that explains 91.7% of the variance in the variable. Although the availability of borrowed money on Lithuanian farms improves and exceeds the DR_{EU} values, the access to external finances in the other Baltic states is more favorable. The most recent research for Lithuania [15] argues that access to credit mainly improves for large-scale farms, while other farmers experience difficulties in attracting external resources. The analysis of DR values by economic farm size in the FADN database supports the previous findings and suggests that access of small farms to external finance sources is limited. This implies that the institutional environment must deal with inequity in external finance access in order to improve agricultural resilience.

Employment is often considered as the main function of the economy, while changes in this area influence the resilience of the economy. In the EU, the share of employment in agriculture AE_{EU} decreases from 5.6% to 4.1% over the period 2013–2023. The long-term process of replacing the agricultural labor force with capital that employs innovative technologies instead of people is not finished and has become a relevant topic during the COVID-19 crisis, which demonstrated risks related to migrant workers.

In Lithuania and Latvia, agricultural employment remains an important element in the total employment structure that exceeds the EU average, while structural changes in Estonian agriculture determine the rapidly declining role of this economic activity in total employment and demonstrate a position below the EU average (Figure 2). Estonia and Lithuania demonstrate the sharper employment contraction. In Estonia, the share of agricultural employment fell from 4.1% in 2013 to 2.6% in 2023, while the AE_{LT} value shrank from 8.4% to 5.0%. The share of agricultural employment in Latvia increased from 7.6% in 2013 to 7.9% in 2023. The study by [39] implies that the declining shares of agriculture in gross domestic product and employment structure lead to a more vulnerable employment situation during economic slowdowns and influence resilience. Thus, the role of agriculture in the economic resilience of Estonia and Latvia differs.

5. Conclusions

This article develops a function-based resilience assessment dashboard including leading and lagging indices. The developed dashboard could be employed by policymakers to monitor key indicators of socioeconomic performance and alert about undesired changes in the resilience of food systems. Resilience leading indicators deal with patterns that could facilitate or impede the implementation of innovations and influence changes in food systems. The leading indices allow us to cluster countries with similar structural patterns and develop common solutions addressing specific resilience challenges.

The leading indices suggest that Estonia has distinct differences in structural patterns compared to the other Baltic states, namely, a low share of small farms, relatively high presence of young farmers, high share of farm managers with full agricultural education, and dominance of male farms combined with the highest per capita governmental support for agricultural R&D. The aforementioned patterns are associated with better potential of farms to invest in innovations and develop an agricultural system that links food security with a productivist strategy.

In Latvia and Lithuania, agriculture remains an important component of economic resilience; however, leading indicators imply that structural transformations of agricultural systems are not completed. In these countries, the ageing of farm managers and the importance of vulnerable groups of farms in the agricultural structures require similar inclusive policy responses focusing on specific innovations and the development of a relevant institutional environment architecture. Structural patterns imply that resilience could be enhanced by focusing on access to credit and facilitation of different forms of cooperation of small farms, supporting R&D activities that develop innovations for vulnerable farms, and investing in education and training initiatives. In Lithuania, the increase in governmental support for agricultural R&D could be recommended as an important action that could have a positive impact on the resilience of the national food system.

Lagging indicators report on the implementation of key functions of agriculture. Analysis of indices for food and nutrition security function allows us to highlight several important aspects. First, all Baltic countries made progress in improving nutritional security over the period 2013–2023; however, the share of food expenditure in actual individual consumption remains above the EU average. Second, research suggests that the most recent geopolitical conflicts and the COVID-19 pandemic did not introduce fundamental changes, and import markets of the Baltic countries gravitate towards a high level of concentration. Nevertheless, the results evidence the change in behavior and attempts to diversify import markets, especially in Latvia and Lithuania. Although ex-EU imports are more concentrated compared to in-EU imports, the dominance of in-EU imports in the import structure of different product categories is an indisputable advantage that increases the resilience of national food systems in the Baltic states. Nevertheless, the policy implication could be a recommendation to develop a more diversified network of trade partners for both in- and ex-EU import markets to increase the resilience of national food systems in case of crisis (for example, disease outbreak, natural disasters, etc.) in other countries. Indeed, the highly concentrated agricultural production patterns in the EU challenge this strategy, and national import concentration issues require attention from both national and EU policymakers.

In the Baltic states, economic farm viability remains a paramount resilience challenge of food systems, introducing further structural changes in agriculture. Despite the larger average farm size compared to the EU average, the Baltic states face high instability of profits and output–input balance challenge, while these indices often evidence performance below the EU average. The distinctive feature of the Baltic states is access to external finances above the EU average. Latvia and Estonia have indices almost twice as high, while the situation in Lithuania gradually changes from values below the EU average to values above the EU average over the period considered. Nevertheless, small farms often face unequal treatment and struggle to attract external resources. The aforementioned economic viability situation influences the self-employment on farms; however, in Latvia and Lithuania, agriculture remains an important element of the national employment structure.

It is important to admit that the agriculture of the Baltic states has transformed after the EU enlargement in 2004, and changes in performance of individual farming types are diverse. This research provides the overall picture of the agricultural resilience situation in Baltic states, and the research focus on the resilience in individual farming types, including structural differences and the impact of different business scales and models on resilience and related food chains is a promising research niche.

Although this article has a clear socioeconomic resilience focus, it is important to recognize that resilient food systems must ensure the implementation of key environmental functions that are closely intertwined with the implementation of socioeconomic functions. In fact, the disregard for nature-based resilience could lead to the failure of key socioeconomic functions in the long run. Nature-based indicators of resilience (for example, dealing with soil health and conductive ecosystems, climate and natural disasters, pollution) often challenge the engineering conception of resilience, implying that return to the pre-shock state is an undesired alternative, and support the development of a complex system approach recognizing the importance of transformation. Thus, future research could deal with the aforementioned limitations and supplement the resilience framework with key environmental indicators. The academic discourse could be enriched by an in-depth analysis of environmental indicators of resilient food systems, including the accumulation of deeper knowledge about regenerative agriculture, and the contributions that allow us to improve the understanding of the interaction between socioeconomic and environmental indicators, providing useful insights for policy actions.

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