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ECONOMIC RESILIENCE AND COMPETITIVENESS OF AGRI-FOOD CHAINS IN WARTIME: THE CASE OF UKRAINIAN ANIMAL HUSBANDRY

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Abstract. The economic resilience and global competitiveness of agri-food chains are critical components of national economic security, particularly in times of geopolitical instability. The full-scale Russian invasion of Ukraine had a highly disruptive effect on the macroeconomy as a whole, including livestock agri-food chains driven by agricultural enterprises and households. This study evaluates how these chains can preserve their viability under extreme risk conditions through structural adaptations and market reorientations. The study *hypothesis* was that Ukrainian livestock agri-food chains had developed distinct institutional and structural patterns of economic resilience, enabling them to maintain international competitiveness despite wartime pressures. The purpose of the research was to evaluate the structural changes, market adaptability and trade competitiveness of Ukrainian animal husbandry between 2021 and 2024, as the sector establishes stronger links with the EU. The research *methodology* used available official statistics and encompassed quantitative econometric tests (Student's T-test), regional cluster optimisation modelling and trade balance analysis. The *findings* revealed a significant structural divergence. Agri-food chains anchored by agricultural enterprises demonstrated high economic stability in capital-intensive sectors such as egg production, pork production and poultry production. The agri-food chains led by smallholder households only retained dominant market shares in the highly fragmented milk and honey niches. Optimisation modelling identified three distinctive economic clusters in regional agribusiness, mirroring pre-war configurations but with an increased focus on exports. Despite massive asset destruction, the paper proves that strategic resource reallocation and a pivot to exporting to the EU market allowed Ukrainian agri-food chains to remain competitive in international trade. This lays the groundwork for their integration into the EU's Common Agricultural Policy (CAP).

Keywords: economic resilience, agri-food chains, cluster optimisation, international trade, EU agricultural integration.

JEL Classification: C12, C38, Q13, Q17

1. Introduction

Animal husbandry is an essential part of agriculture and contributes to global food security. This is because livestock production supports rural livelihoods, provides essential nutrients, and ensures the resilience of the food system thanks to more predictable output compared to the volatile cycles of crop cultivation. Broadly defined, agri-food chains comprise the activities that provide food to consumers throughout the production, processing and distribution cycle. The initial foundations and driving forces of agri-food chains are agricultural enterprises and households, making their structural and spatial features the core focus of this study.

Both natural and human-made global and local disasters have a significant disruptive effect on animal farming. The consequences can include losses of livestock, broken supply chains and surges in the price of basic inputs such as feed and fuel. This can result in economic pressure forcing some producers to prioritise cost-efficiency over sustainable practices, which could affect the environment by exacerbating air and water pollution and jeopardising animal welfare. Overall, food availability and affordability may be threatened,

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particularly in countries where the population relies heavily on animal products.

The full-scale Russian invasion of Ukraine, which began on 24 February 2022, brought additional, unprecedented challenges to the entire country and its economy. The livestock sector has suffered severe repercussions. Kotykova et al. (2024) estimated the economic implications of military combat, which led to the destruction of farms and transport infrastructure, power outages and the loss of biological assets, such as cattle, pigs and poultry. Hostilities have hindered the delivery of feed, veterinary services and finished product shipments, particularly in Ukraine's frontline regions. Producers are also facing a shortage of skilled labour due to military mobilisation and forced civilian migration.

From a macroeconomic perspective, the transformation of Ukraine's livestock sector during the military conflict is not just an agricultural issue; it is also a complex process of developing the economic resilience of supply chains. The survival of agri-food chains, which are centred around agricultural enterprises and households, has a direct impact on national trade balances, fiscal stability and import substitution dynamics. Furthermore, as Ukraine progresses towards EU candidate status, evaluating the competitiveness of its agricultural production and its ability to comply with EU Common Agricultural Policy (CAP) instruments is a key economic priority (CAP, 2026). It should be noted that a full assessment of deep integration into the CAP requires regulatory and institutional analysis, which is beyond the scope of this paper. Instead, this study lays the empirical groundwork by analysing whether Ukrainian agribusiness possesses the basic economic stability required to withstand open market competition.

2. Literature Review

On a global scale, the demand for livestock production is expected to almost double by 2050 due to population growth, increasing disposable incomes and growing consumer awareness of the nutritional benefits of animal proteins (Akash et al., 2022). However, intensive livestock production practices can lead to negative ecological impacts, such as air, water and soil pollution, and the overuse of scarce natural resources, such as land and water. To a certain extent, the impact of greenhouse gases generated by livestock can be reduced by breeding more productive species, feeding them properly, and managing manure effectively. Conversely, Cheng et al. (2022) substantiated the direct and indirect impacts of climate change on livestock farming. In other words, animal production faces numerous environmental and economic challenges that hinder its sustainable development and impact animal performance and welfare. In particular, when exposed to high temperatures, animals become susceptible to disease and produce lower quality, smaller quantities of products. In addition, losses are incurred in livestock feed based on grains and oilseeds due to global warming and more frequent natural disasters. Therefore, new technologies and practical insights are needed to address these issues, given that livestock products are the fastest-growing area of agricultural output worldwide.

The European Common Agricultural Policy (CAP) provides a clear macroeconomic framework for developing the livestock sector, promoting sustainable practices, animal welfare, biodiversity and food security derived from animal products across the EU. However, several of its core principles are still the subject of ongoing debate. Key challenges include the absence of standardised regulations on greenhouse gas emissions, the implementation of temporary dairy quotas conflicting with the liberalisation of the common agricultural market, and the unequal distribution of funds and subsidies between large-scale enterprises and smallholder farms. This funding asymmetry often favours intensive agriculture over traditional farming activities, resulting in rural degradation (Adams et al., 2023; Giuliani & Baron, 2025). Thus, these structural tensions highlight the complex integration challenges that neighbouring agricultural sectors, including Ukrainian farming, face and must overcome through their own internal adaptability and resilience.

Many scholars have examined specific features of key livestock sectors. Kumar et al. (2022) concluded that the digitalisation of precision farming systems, remote monitoring and AI-driven management could facilitate the adoption of effective biosecurity, agroecology and recycling principles in animal husbandry. Meanwhile, Yu and Jensen (2022) focused on the multifaceted issue of pork production, which is in high demand in Asia, particularly in China and the EU. Although pig-related greenhouse gas emissions account for less than 10% of those from beef production, they are twice as high as those from poultry. This is why leading pork producers in the USA, Canada, Denmark, Spain and Brazil must balance economic growth opportunities with environmental sustainability. Bist et al. (2024) emphasised that, as of 2020, poultry meat represented almost 40% of global meat production and had become pivotal in meeting global protein demands. The proposed farming concept incorporated circular economy principles, utilised alternative feed sources, and emphasised the importance of implementing climate-smart technologies to enhance resilience and market competitiveness while minimising the poultry sector's ecological footprint. Similarly, applying contemporary green technologies to the dairy sector is essential for reducing environmental impact while maintaining high commercial viability

(Bhat et al., 2022). In the egg sector, while international trade expansion yields substantial revenue, it also exposes producers to market shocks driven by shifting animal welfare housing mandates and transboundary poultry disease outbreaks (Szollosi, 2021). Kuts and Makarchuk (2023) examined the risks associated with beekeeping, which are an integral part of honey production, particularly in Ukraine. Ukrainian farmers, who operate on the principle of providing good value for money, are among the top five exporters in the global honey market, competing with producers from China, India, Argentina and Vietnam.

Unlike climate change, which has numerous natural factors behind its development, human-made disasters such as industrial accidents and military conflicts have a detrimental impact on food systems in countries that are directly affected by their consequences, causing inevitable international ripple effects. The war between Russia and Ukraine has profoundly disrupted global food security and commodity trading networks, affecting areas far beyond the immediate combat zones (Abay et al., 2023). Galanakis (2023) concluded that the world is experiencing a concentrated period of crises and challenges related to climate change, the ongoing war triggered by geopolitical conflicts, and the ongoing effects of the pandemic. Together, they call into question food safety, security and sustainability. While food security was not directly threatened in the EU, the Russian invasion of Ukraine caused tangible indirect agricultural shocks in the form of increased prices for food commodities, fertilisers, fuel, and energy (Chepeliev et al., 2023). In contrast, the war had an immediate impact on Ukraine, with one in three Ukrainians suffering from food insecurity. Therefore, Ukrainian livestock farmers have tried their best to contribute to crisis relief efforts (Rudolfsen et al., 2024). According to calculations by Rossokha et al. (2023), Ukrainian animal husbandry requires investments of over 900 million EUR to restore production levels to those of 2021. Furthermore, losses of assets in cattle breeding and beef production raise doubts about their ability to remain viable contributors to national food security. Glushkov (2025) set out potential avenues for future growth in Ukrainian animal husbandry, including the implementation of innovative, energy-efficient, eco-friendly technologies; the automation of all production processes; the digitalisation of farm management; and comprehensive veterinary support in breeding, feeding and environmental safety.

Recent economic literature emphasises that the integration of transition economies into advanced trade zones such as the EU requires high structural competitiveness of domestic value chains. Authors analysing the alignment of Ukrainian agribusiness with the EU's Common Agricultural Policy (CAP) emphasise that post-war recovery must navigate stringent European environmental, quality and biosecurity standards. However, there is a lack of quantitative research in the empirical literature on how wartime macroeconomic shocks affect the dual structure of agribusiness and its subsequent export potential. The **purpose** of this scientific study is therefore to analyse the economic sustainability of these agri-food components as a prerequisite for European integration, and to bridge this gap.

3. Methodology

The **object** of this study is livestock farming in Ukraine. The **subject** of the study is the structural, spatial and economic changes in the indicators of primary livestock production during the war period of 2022–2024. The underlying **hypothesis** is that Ukrainian livestock producers have developed distinct patterns of adaptation in terms of structural efficiency, spatial stability and trade competitiveness in the process of integrating with the EU during wartime.

To address this hypothesis, the article was established around the following **tasks**:

1) To examine the structural efficiency and economic stability of agricultural enterprises versus households in livestock production.

2) To employ regional cluster optimisation to assess spatial economic specialisation and market adaptability in 2022-2024.

3) To evaluate Ukrainian international trade competitiveness and trade balance shifts compared to the benchmarks as of 2021.

Statistical **data** analysed for the period 2021–2024 was retrieved from official websites and other reliable online sources (UkrSTAT, 2025). The **methodological framework** of the research was based on statistical tests, optimisation modelling, comparative analyses and illustrative charts, all of which were designed to confirm the conclusions drawn.

The first research task involved using a Student's T-test to calculate the mean percentage share of animal products from enterprises and households for the period 2022–2024, relative to the corresponding pre-war indicators (100% in 2021). The analysed Tcalc was calculated by the formula:

$$\mathrm{Tcalc} = (\mathrm{AV} - 100)\sqrt{\mathrm{N}} / \mathrm{SD},$$

where AV denoted the sample average, SD was the sample standard deviation, N=3 was the sample size. Tcrit designated the critical value for the Student T-test with the significance level α and degrees of freedom N–1. If the inequality $|\mathrm{Tcalc}| > \mathrm{Tcrit}$ is true, then the examined average share of animal production is remarkably different from the supposed benchmark level of 100% with probability $(1-\alpha)$. And vice versa, if the inequality $|\mathrm{Tcalc}| \leq \mathrm{Tcrit}$ holds, then the tested average share of animal production is acceptably close to the benchmark level of 100%. The total output from animal

husbandry enterprises and households was visualised using 100% stacked bar charts.

The second research task employed cluster optimisation applied to shares Rmj of J products from M=24 regions in Ukraine. Each of I clusters was represented by its center Cij, i=1,…,I, j=1,…,J. These values were the sought variables of the offered cluster optimisation model. Its restrictions were as follows:

$$\min_{m=1,\ldots,M} Rmj \le Cij \le \max_{m=1,\ldots,M} Rmj,\ j=1,\ldots,J.$$

The model objective function looked like:

$$\sum_{m=1,\ldots,M} \min_{i=1,\ldots,I} \sum_{j=1,\ldots,J} \left(Rmj - Cij\right)^2 \to \min .$$

Arguments of the calculated minima allocated regions to the closest optimal centers of clusters, that is:

$$i(m) = \arg(\min_{i=1,\ldots,I} \sum_{j=1,\ldots,J} \left(Rmj - Cij\right)^2), m=1,\ldots,M.$$

This approach enabled conclusions to be drawn about the observed hardships by comparing regional contributions to national animal husbandry before and during the war.

The third research task used tables and bar charts to visualise changes in the trade balance of the key animal products examined, revealing the adaptability of Ukrainian livestock production in challenging conditions.

4. Results

The main animal products in Ukraine are meat, cow's milk, eggs and honey. Within the meat sector, poultry and pork account for over 85% of the total volume, outperforming beef thanks to shorter production cycles and greater economic sustainability. Consequently, this research focused on the five main outputs of Ukrainian animal husbandry: pork, poultry meat, milk, eggs and honey.

Firstly, Ukrainian livestock farming, like the entire national agricultural sector, has a dual production structure, combining large-scale agricultural enterprises with small rural households, which form the basis of agri-food chains. Despite having varying access to innovative technologies and production scale, these producers are distinguished by their resilience and ability to adapt to crises. According to the research methodology, this ability was explored using a Student's T-test to analyse population means. The results relative to the 2021 baseline are displayed in Table 1.

Figure 1 illustrates the shifts in sector dominance by visualising the structural distribution of total output between agricultural enterprises and households immediately before and during the war.

Secondly, in line with the research methodology, cluster optimisation was used to assess the spatial economic architecture of Ukrainian agribusiness across 24 regions. The model identified regional groups that made similar contributions to national livestock production during the pre-war and wartime periods (see Table 2).

Thirdly, in line with the research methodology, Figures 2 and 3 present data on the enhancement of competitiveness identified and the shifts in the trade balance of the explored livestock products affected by the war.

5. Discussion

The empirical findings provide valuable insights into the macroeconomic adaptation strategies employed by agri-food chains, comprising both agricultural enterprises and households, in response to unprecedented pressure and shocks.

Firstly, the true inequalities $|Tcalc| \le Tcrit$ for pork, poultry, and milk (Table 1) confirm statistically significant resilience of agricultural enterprises through the economic efficiency of vertical integration. In the face of surging energy costs, labour shortages and limited capital, agricultural enterprises have leveraged economies of scale. They invested in capital-intensive, energy-saving technologies and automated asset management to preserve their market position. In

Table 1
Student T-test for producers in animal husbandry

Product	Type of producers	AV, %	SD, %	|Tcalc|	Tcrit
Pork	Enterprises	96.85	4.84	1.13	4.30
	Households	81.49	3.98	8.06	4.30
Poultry Meat	Enterprises	98.92	6.74	0.28	4.30
	Households	79.88	1.30	26.90	4.30
Milk	Enterprises	101.80	6.41	0.49	4.30
	Households	78.44	7.39	5.05	4.30
Eggs	Enterprises	83.22	3.00	9.70	4.30
	Households	82.13	4.37	7.08	4.30
Honey	Enterprises	72.26	11.11	4.32	4.30
	Households	84.96	6.96	3.74	4.30

Source: author's own calculation

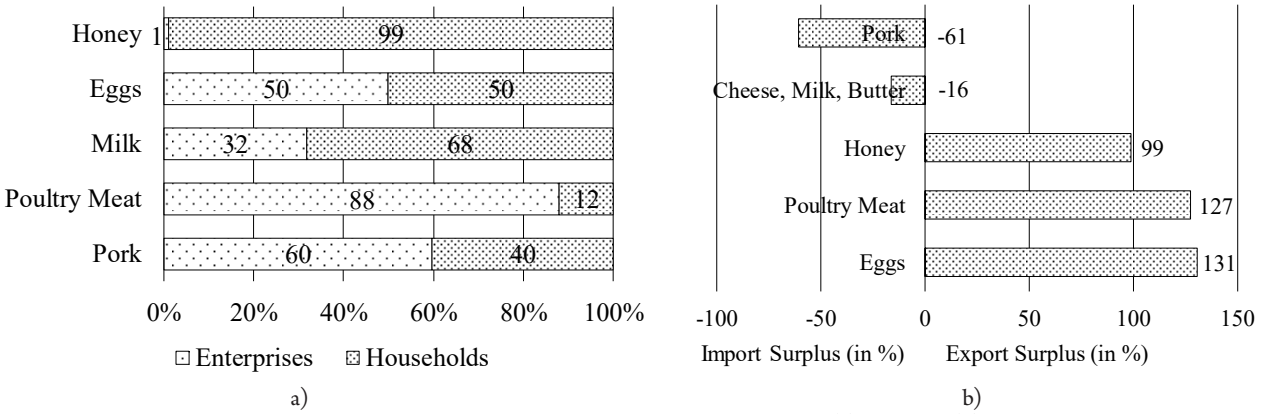

Figure 1. Production shares of enterprises and households in livestock farming in 2021 (a) and 2024 (b)

Source: author's own calculation

Table 2

Regional clusters with similar scales of animal production

Cluster	Regions	Year	Center, %				
			Pork	Poultry Meat	Milk	Eggs	Honey
1	Chernihiv, Chernivtsi, Donetsk, Ivano-Frankivsk, Kharkiv, Kherson, Khmelnytskyi, Kirovohrad, Luhansk, Lviv, Mykolaiv, Odesa, Poltava, Rivne, Sumy, Ternopil, Volyn, Zakarpattya, Zaporizhzhia, Zhytomyr	2024	3.6	1.4	3.9	3.0	4.1
		2021	3.7	1.3	4.0	3.0	4.1
2	Cherkasy, Dnipropetrovsk, Vinnytsia	2024	4.8	23.7	5.7	6.2	5.6
		2021	4.6	23.5	5.2	5.2	5.1
3	Kyiv	2024	14.7	2.2	4.6	21.6	1.8
		2021	11.5	3.1	4.2	23.6	2.2

Source: author's own calculation

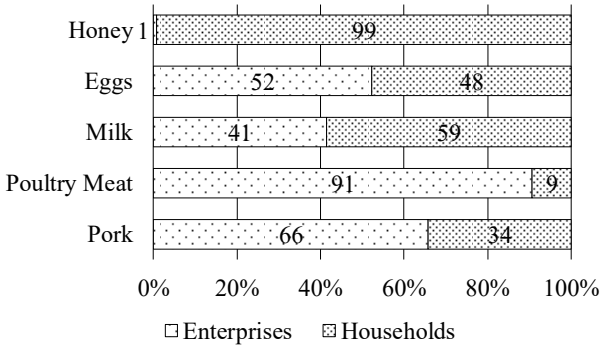

Figure 2. Changes in the average trade balance of livestock products in 2022-2024 compared to 2021

Source: author's own compilation

contrast, the true inequalities |Tcalc| > Tcrit in the case of pork, poultry meat and milk production in households meant that they suffered from low financial flexibility and high transaction costs, resulting in a scale shrink and food insecurity (Kvasha et al., 2024). The decrease in egg production, down to 82–83% of the 2021 benchmark level, was fairly consistent across enterprises and households. Conversely, the true inequality |Tcalc| ≤ Tcrit suggested that households remained relatively stable in honey production that was partly relocated from the areas of military hostilities to safer regions. Figure 1 shows that enterprises did not initially participate in honey production. However, by 2024, they had increased their contribution to total pork, poultry meat, milk and egg production by 2–9%. Nevertheless, households continued to produce most of the milk and honey. Therefore, structural divergence shows that agri-food chains led by agricultural

Table 3
Top exporters and importers of the major products of Ukrainian animal husbandry for 2021-2024

Product	2021	2022	2023	2024
	Top Importers			
Eggs	UAE, Latvia, Israel	Latvia, Singapore, Italy	Italy, Latvia, Singapore	Italy, Israel, Poland
Poultry Meat	Saudi Arabia, Netherlands, Slovakia	Netherlands, Saudi Arabia, Slovakia	Netherlands, Saudi Arabia, Slovakia	Netherlands, Saudi Arabia, Slovakia
Honey	Poland, Germany, Belgium	Germany, Poland, France	Germany, Poland, France	Germany, USA, Poland
Milk and Butter	Moldova, Azerbaijan, Israel	Poland, Moldova, Israel	Moldova, Poland, Israel	Moldova, Bulgaria, Poland
	Top Exporters			
Cheese	Poland, Germany, Netherlands	Poland, Germany, Netherlands	Poland, Germany, Netherlands	Poland, Germany, Netherlands
Pork	Denmark, Poland, Netherlands	Denmark, Netherlands, Poland	Denmark, Netherlands, Canada	Canada, Denmark, Netherlands

Source: author's own compilation

enterprises are the main stabilisers of the national market and ensure food is affordable, preventing inflationary food price shocks. At the same time, however, agri-food chains in milk and honey production still rely heavily on output from households.

Secondly, the cluster optimisation model indicates a high degree of spatial economic stability. The retention of the three-cluster structure from 2021 to 2024 shows that regional agricultural specialisations are highly robust. Cluster 1 (comprising 20 regions) forms the basis for domestic market saturation and localised short supply chains, thereby mitigating logistics risks (Vasylieva, 2017). Cluster 2 comprises three regions that are major livestock production hubs using cutting-edge technologies (Karamushka et al., 2018). Cluster 3 comprises the capital, Kyiv, a leader in animal husbandry with access to the best resources. The main focus of Cluster 1 was milk and honey production. Cluster 2 focused on producing poultry meat and eggs. Cluster 3 had the strongest positions in pork and egg production. The economic synergy between these clusters ensured dual benefits: safeguarding domestic food security and sustaining export revenues, which were crucial for macroeconomic stability during the war.

Thirdly, the international trade analysis (Table 3) reveals that Ukrainian agribusiness remains highly competitive on the global stage. Despite severe infrastructure damage, trade flows to the EU remained highly resilient, saturating respective global market segments with quality products, as in 2021. The main exports were milk and butter, which were sent to Bulgaria and Poland. Germany and Poland were the main importers of honey. The 31% and 27% expansion in egg and poultry exports respectively reflects a successful market pivot, particularly to Italy, Poland, the Netherlands and Slovakia. This was capitalised on by the temporary liberalisation of EU trade regimes. The high level of cheese imports from Poland, Germany and the Netherlands highlights the interconnection between the Ukrainian and EU food markets, as well as the untapped potential of Ukrainian agri-food chains. Conversely, the significant decrease in pork (-39%) and dairy imports (-84%) suggests that domestic producers are effectively replacing imports. While comprehensive integration into the EU CAP involves long-term alignment with complex regulatory pillars, these immediate wartime trade shifts act as an empirical stress test. The shorter logistics routes discovered only partially mitigate the military risks that continue to burden Ukrainian farmers. On the other hand, Ukrainian producers have to comply with EU high-quality standards, such as strict controls on veterinary drug use, microbiological criteria, and ensuring stress-free animal welfare during breeding, transit, and slaughter. There must also be complete traceability of products within the 'farm to fork' chain, which is meant to guarantee food safety (Regulation (EC) No 178/2002, 2002). The ability to adapt to EU market standards in times of crisis sets a positive baseline for Ukraine's structural readiness for the EU's Common Agricultural Policy frameworks during post-war reconstruction.

6. Conclusions

This study confirms the hypothesis that Ukrainian livestock and food production chains are highly resilient and flexible in the face of severe geopolitical shocks.

In terms of structural efficiency, agri-food chains coordinated by agricultural enterprises proved their ability to stabilise the market, maintaining output volumes close to pre-war levels through advanced capital management. In contrast, agri-food chains anchored by households were more vulnerable economically, dominating highly fragmented niches such as beekeeping and local dairy supply.

In terms of spatial stability, the regional agribusiness architecture has shown remarkable stability by

preserving its three-cluster optimisation structure. This spatial configuration strikes an effective balance between localised domestic supply chains and highly concentrated, technologically advanced export hubs.

A significant increase in poultry and egg exports to EU nations within the trade development and EU integration focus confirms the high international competitiveness of Ukrainian agricultural products. The sector has successfully executed a strategic trade pivot while implementing deep import substitution in the pork and dairy sectors.

Overall, the structural adaptability demonstrated by Ukrainian agri-food chains provides an essential empirical baseline for their future integration into the EU market. Although full integration into the CAP remains an institutional process involving several stages, the optimisation models prove that Ukrainian agribusiness has the core resilience needed to transition into European value chains. Future research should monitor how these regional clusters adapt as temporary trade preferences evolve into permanent bilateral frameworks under the EU's Common Agricultural Policy.

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