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ECONOMIC RESILIENCE IN EUROPEAN DAIRY FARMS: TRENDS, DETERMINANTS AND CHALLENGES

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Abstract
In the face of increasing economic challenges and changing market conditions, farm resilience is becoming a key issue to ensure its development. The aim of this paper is to analyse the level of economic resilience of farms specialising in dairy farming in the ten largest dairy-producing countries of the European Union between 2004 and 2021. The research applies a self-modified multidimensional index of economic resilience, which includes elements such as vulnerability, intensification, biodiversity, diversification, and performance. The results show a decrease in economic resilience in the analysed farm groups, regardless of their economic size. It was also found that farms with a larger economic size did not demonstrate higher economic resilience compared to farms with a smaller size. The research results indicate a downward trend in the economic resilience index from 2004 to 2021. The key dimensions that affected this indicator were intensification and diversification. This suggests that, to increase their resilience, the dairy farms studied must address challenges such as reducing input use intensity, minimising dependence on hired labour, and diversifying income sources.

Keywords: measuring resilience, multidimensional index, comparative analysis, European dairy farms, farm groups

JEL Classification: Q12, Q13

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Introduction

Agriculture, a primary economic sector, relies on natural resources and supplies raw materials for other industries. However, it faces a contradiction: while necessary to meet growing food demand, it also contributes to climate change. This drives a constant search for solutions that balance productivity with environmental protection and sustainable resource use. (Klein et al., 2014; Scuderi et al., 2021; Dhanaraju et al., 2022).

In addition to environmental conditions, agricultural activity is determined by several other factors. Risk factors are of particular importance, comprising frequently recurring situations that may expose the farm to harm or loss. In the case of dairy farms, these include weather conditions, common plant and animal diseases, restricted access to markets, consumer preferences, changes in agricultural policy, and changes in the labour market (Wolf and Karszes, 2023). Moreover, farms are also exposed to the occurrence of shocks. These are sudden and unpredictable situations that determine the economic performance of farms. There are two types of shocks: external and internal. External shocks include sudden natural hazards (e.g., droughts, floods, frosts, fires, infectious animal diseases), demand and supply shocks affecting price fluctuations, and unexpected changes in the political environment. On the other hand, internal shocks consist of the health problems of farm owner and workers (Berchoux et al., 2019). Specific shocks for dairy farms include infectious animal diseases, volatility of milk and input prices, lack of payment for sold products, unexpected decline in milk quality, and sudden political decisions (e.g., embargo on exports of milk products).

Emerging shocks lead to long-term stress, impacting animal welfare, low milk prices, rising production costs, labour shortages, fake news (e.g., regarding the quality of milk products, the environmental impact of milk production), milk substitutes, deteriorating consumer relations, and legal changes in the dairy sector. (Popp and Nowack, 2020).

Due to the increasing incidence of shocks and stresses, the concept of farm resilience (agricultural system resilience) has emerged. Meuwissen et al. (2019) define farm resilience as "its ability to ensure the provision of the system functions in the face of increasingly complex and accumulating economic, social, environmental, and institutional shocks and stresses, through capacities of robustness, adaptability, and transformability". Our article focuses on one type of resilience, namely, the economic resilience. It is defined multidimensionally as resistance (the ability to cope with economic shocks), absorption (the ability to absorb an economic shock), recovery (the ability to return to a previous state of economic equilibrium), and reorientation (if present, the ability to make structural changes and return to economic equilibrium at a higher level than the initial state) (Martin, 2011).

The aim of the research was to determine the level of economic resilience of farms specialising in dairy farming (dairy farms) located in ten largest milk-producing countries in the European Union (EU). The choice of dairy farms as the subject of the study was motivated by the fact that they are particularly exposed to shocks and stresses in managing crop and livestock production. Economic resilience was the subject of the study and was measured using a multidimensional index. The time horizon of the study was 18 years (2004-2021).

The study is divided into five parts. The first part provides an analysis of the literature on farm resilience, focusing on its definition and measurement. The second part outlines the research methodology, with particular emphasis on the calculation of the economic resilience index. The third part describes the farm groups based on production and economic indicators. The next section presents the results, analysing trends in economic resilience over the examined period and the structure of the economic resilience index, which helps identify the challenges faced by farms. The final part discusses the findings in the context of previous research and provides a summary of the conclusions.

1. Review of the scientific literature

1.1. The concept of economic resilience

The term resilience originates from the Latin resiliō, meaning to rebound or resist. It was first used in the 1940s in psychology, where it was studied how people cope with misfortune and hardship (Hanisch, 2016). Over time, the study of resilience has become interdisciplinary (Alexander, 2013) and has emerged in the context of different fields (Brown, 2014; Quinlan et al., 2016).

Resilience can be defined as the ability of a system to absorb disturbances and adapt, maintaining its core functions, structure, identity, and regulatory mechanisms (Walker et al., 2004). In economic sciences, resilience has gained prominence in analyses of economic crises and is understood as the ability to recover quickly from a shock (Rose, 2004; Martin and Sunley, 2015; Sánchez et al., 2016).

Resilience can be either static, related to maintaining key functions and stability, or dynamic, involving the effective use of resources for recovery, leading to a new state of equilibrium (Fuchs and Thaler, 2018; Xie et al., 2018). It is important to emphasise that both the speed and effectiveness of actions taken after a shock are crucial for the system's return to stable growth (Fingleton et al., 2015; Morkūnas et al., 2018). The key capabilities determining resilience – robustness, adaptability, and transformability – have been extensively discussed in the works of Meuwissen et al. (2019) and form the foundation for the operationalisation of dairy farm resilience adopted in this study.

In the context of agriculture and farms, economic resilience takes on more specific characteristics. Darnhofer et al. (2010) described it as the ability of a farm to adapt its practices in response to various economic shocks and pressures to ensure long-term viability. Béné et al. (2012), in their definition of economic resilience, combined short-term responses with long-term planning and structural adaptation, enabling farms not only to survive, but also to thrive. More recent studies describe economic resilience as the ability of farms to maintain current profitability in the face of perturbations, such as market and production risks and policy changes, and ultimately to move to a new equilibrium (Tendall et al., 2015; Vigani and Berry, 2018).

1.2. Measuring the economic resilience of dairy farms

The development of methods to measure economic resilience in farms has progressed in parallel with the evolution of the resilience concept itself. Initially, the research focused on qualitative methods, such as case studies and ethnographic research, which allowed an in-depth understanding of adaptive strategies and decision-making processes in farms. Although these approaches provided valuable insights into the mechanisms through which farms respond to crises, their limitation was the difficulty in generalising findings to a larger population (Quinlan et al., 2016).

As the need for comparative analysis increased, researchers began to develop quantitative approaches based on economic indicators, econometric models, and multi-criteria assessment methods. Financial indicators, such as liquidity, profitability, technical efficiency, and debt levels, enable an assessment of farm resilience based on accounting data and production outcomes (Shadbolt et al., 2017). Econometric models, in turn, allow for the analysis of external factors affecting farm stability (Cradock-Henry, 2021).

The specific nature of dairy farms means that their resilience cannot be assessed solely on the basis of conventional financial indicators. Milk production is characterised by a high intensity of resource use and sensitivity to market fluctuations and regulatory changes. Therefore, increasing attention has been given to additional factors, such as income diversification, feed autonomy, and the ability to cooperate within agricultural knowledge and innovation systems (AKIS) (Vigani and Berry, 2018; Thorsøe et al., 2020; Kuipers et al., 2024).

The literature increasingly focuses on different dimensions of resilience: robustness (resistance to shocks), adaptability (adjustment capabilities), and transformability (potential for structural change) (Meuwissen et al., 2019). Slijper et al. (2022) proposed a model for quantifying dairy farm resilience, incorporating return on assets (ROA), shock magnitude and depth, and recovery time to assess financial stability. Their approach complements earlier models that focused on liquidity, efficiency, and solvency metrics in the context of farms' ability to respond to shocks (Shadbolt et al., 2017).

This study adopts a multi-dimensional Economic Resilience Index (ERI), developed by Vigani and Berry (2018) but adapted to the specific characteristics of dairy farms. It consists of five main dimensions: vulnerability, intensification, biodiversity, diversification, and performance. A key adaptation in this study was the modification of the biodiversity dimension — rather than using the traditional Simpson's Diversity Index (SID) based on cultivated land area, we applied a SID based on the value of plant production. This adaptation reflects the critical role of on-farm feed production in dairy farms, offering a more precise measurement of the impact of crop structure on farm income stability and economic resilience (Sen et al., 2017; Singh et al., 2023).

Despite advancements in resilience measurement, there is still a lack of comprehensive comparative studies covering dairy farms in different European Union countries, operating under varied institutional and economic systems (Meuwissen et al., 2019; Thorsøe et al., 2020). Contemporary studies primarily focus on economic performance, competitiveness, and sustainability of production (Poczta et al., 2020; Parzonko et al., 2024; Savickienė and Galnaitytė, 2024). These findings indicate that larger-scale dairy farms, with higher technical efficiency and more diversified income sources, tend to exhibit greater economic resilience and greater capacity to adapt to external shocks.

However, the influence of agricultural policy on dairy farm resilience cannot be overlooked. The Common Agricultural Policy (CAP), through direct payment schemes and risk management instruments, enhances farm robustness, but does not always support long-term adaptation and transformation (Buitenhuis et al., 2020). Therefore, it is crucial to consider the role of state policies in developing effective resilience monitoring tools and advisory support systems, as emphasised by Morkūnas et al. (2018).

Based on the identified research gaps and previous studies on economic resilience, the following hypotheses have been formulated:

H1: The economic resilience of the analysed groups of dairy farms increases in the following years of the conducted analysis.

H2: Dairy farms with the largest economic size are characterised by higher economic resilience compared to farms with lower economic size.

H3: There is a high variability in the structure of the economic resilience index of the studied groups of dairy farms, based on the economic size criteria.

These hypotheses are derived from prior research on economic resilience in agriculture and analyses of farm size effects on financial stability. Their verification will provide information on how the components of the Economic Resilience Index and farm size influence adaptability and transformation capacity in response to market and policy changes.

2. Research methodology

The research covered farms with the publicly available European Farm Accountancy Data Network (FADN) code 45 (Specialist milk). The FADN is a survey that collects accountancy data each year from around 80,000 farms located in the EU, representing approx. 5 million farms. Microeconomic data is collected based on a standardised methodology, and the data are representative (European Commission, 2022). The study area covered dairy farms from Germany, France, the Netherlands, Poland, Italy, Ireland, Spain, Denmark, Belgium, and Austria. These are the largest milk-producing countries in the EU, collectively accounting for about 84% of the milk production in the EU. Groups of farms were classified into economic size classes (ES6 typology). This classification is based on the value of the Standard Output (SO) calculated by Member States per hectare or per head of livestock, using basic data for a reference period of five successive years (European Commission, 2015). The study's time horizon covered the years 2004-2021, and the condition for including a country in the analysis was the access to national data for the entire 18-year period. The year 2021 is the most recent for which data has been collected in the FADN database for all EU countries. The study utilised the publicly available FADN database.

Table no. 1 shows the study area by farm groups based on economic size. Only large dairy farms included all ten countries in the study. In the medium-large group, seven countries had full 18-year data, while in the very large group, only four did. Germany and Italy were present in all three groups.

Table no. 1. The way of comparing results

Medium-large dairy farms **50k EUR ≤ SO < 100k EUR**	**Large dairy farms** **100k EUR ≤ SO < 500k EUR**	**Very large dairy farms** **SO ≥ 500k EUR**
Germany, France, Poland, Italy, Ireland, Spain, Austria	Germany, France, Netherlands, Poland, Italy, Ireland, Spain, Denmark, Belgium, Austria	Germany, Netherlands, Italy, Denmark

The measurement of economic resilience (ER) was based on a multidimensional index developed and validated by Vigani and Berry (2018). The index is constructed from five dimensions: Vulnerability (V), Intensification (I), Biodiversity (B), Diversification (D), and Performance (P). Vigani and Berry (2018) used Simpson's Diversity Index (SID), based on a matrix of crop types and crop areas for each farm, to measure the Biodiversity dimension.

In our study, we utilised the same index (SID), but based on the output value of each crop produced. This approach has been used by Sen et al. (2017), Debasis et al. (2018), Singh et al. (2023). Table no. 2 provides details on calculating the economic resilience index (ERI).

Table no. 2. Calculation method for the Economic Resilience Index (ERI) dimensions

Name of the ERI index dimension	Description of the ERI index dimension
Vulnerability (V)	$V = \frac{\textit{Total liabilities}}{\textit{Total assets}} \times 100$ A farm that is 'overloaded' with liabilities should be expected to have less financial capacity to absorb unexpected shocks. The desirable level of the indicator is to minimise it (smaller is better).
Intensification (I)	$I = \frac{\textit{Seeds+Fertilisers+Crop protection+Feed+Energy+Contract work}}{\textit{Total Utilised Agricultural Area}} \times 100$ An input- and labour-intensive farm has a reduced ability to adapt to changing financial and production conditions. The desirable level of the indicator is to minimise it (smaller is better).
Biodiversity (B)	Simpson's Diversity Index (*SID*) $SID = (1 - \sum_{i=1}^{n} P_i^2) \times 100$ $P_i = \frac{\textit{value of output for } i^{th} \textit{ crop}}{\textit{Total output}}$ The SID indicator takes values between 0 and 100. A higher value of the indicator signifies a higher biodiversity. Greater crop biodiversity is expected to lead to increased farm resilience. It helps protect the farm against biotic or abiotic stresses, thereby reducing the risk of high variability in production values. The desired level of the indicator is to maximise it (bigger is better).
Diversification (D)	$D = \frac{\textit{Other output}}{\textit{Total output}} \times 100$ A farm that diversifies its sources of income compensates for low income from selected agricultural activities with higher income from other activities, thus stabilising its income. This has a positive impact on the economic resilience of the farm. The desired level of the indicator is to maximise it (bigger is better).
Performance (P)	$P = \frac{\textit{Total output}}{\textit{Total Inputs}} \times 100$ Farms with better economic results can benefit from higher profits and greater liquidity, allowing them to manage periods when unfavourable business conditions (e.g., shocks) arise. The goal is to maximise the indicator (bigger is better).

The calculation of the individual dimensions of economic resilience (Table no. 2) allows the synthetic index (ERI_i) to be calculated. This is carried out in two steps according to the formulas below (Vigani and Berry, 2018):

$$ER_i = (-)\ V_i + (-)\ I_i + B_i + D_i + P_i \qquad (1)$$

$$ERI_i = (ER_i - ER_{min}) / (ER_{max} - ER_{min}) \qquad (2)$$

where:

- ER_i – Economic Resilience;
- ERI_i – Economic Resilience Index;
- ER_{min} – Minimum value of the ER in each economic size group of farms;
- ER_{max} – Minimum value of the ER in each economic size group of farms;
- i=1…..n – Means the farms of the country in the following year of analysis.

The first step of the index calculation was to calculate the ER index according to formula (1). Due to the high variability of the values in their individual dimensions, following the approach of Vigani and Berry (2018), they were scaled using the natural logarithm. The next step was to convert the results of the Vulnerability (V) and Intensification (I) dimensions into negative values. This treatment is necessary because positive values of these dimensions have a negative impact on economic resilience. Finally, the ER index was standardised using the min-max method, resulting in an ERI index ranging from 0 to 1.

3. Research material

Table no. 3 presents the basic parameters characterising the dairy farm groups of different economic sizes. The data indicates that as economic size increases, the average number of dairy cows also grows. For instance, German and Italian medium-large farms had average herd sizes of 24.3 and 28.2 cows, while in the very large group, the number was about ten times higher. There is also considerable variation in milk yield, with medium-large farms having yields about 15% lower compared to the large group. The stocking rate, representing the number of animals per hectare, showed notable differences; for example, Italian farms in the very large group exceeded 5 heads per hectare, indicating a higher level of intensification.

Table no. 3. Selected indicators of dairy farms in the countries analysed (mean 2004 - 2021)

Country	Dairy cows (heads)	Milk yield (tons)	Share of unpaid labour input in total labour input (%)	Total output per AWU (1000 EUR/AWU)	Stocking density (LU/ha)	Output/ input ratio (%)
Medium-large dairy farms 50k EUR ≤ SO < 100k EUR						
Germany	24.3	6.2	97.5	58.3	1.63	114.1
Ireland	39.0	5.2	96.5	63.3	1.72	125.5
Spain	28.3	6.7	96.8	52.4	2.04	135.8
France	31.6	5.8	96.4	65.3	1.09	97.9
Italy	28.2	5.0	89.4	57.7	1.89	142.2
Austria	21.7	6.7	97.7	46.7	1.18	116.2
Poland	31.7	5.9	93.7	33.5	1.89	141.9
Large dairy farms 100k EUR ≤ SO < 500k EUR						
Belgium	66.1	7.0	97.6	110.9	2.28	125.5
Denmark	79.2	8.5	70.0	211.8	2.12	98.4
Germany	65.0	7.4	85.4	123.6	1.96	109.9
Ireland	90.3	5.7	79.7	119.0	2.14	127.6
Spain	71.1	7.2	83.5	97.1	2.92	130.5
France	65.4	6.9	87.7	104.0	1.50	103.0

Country	Dairy cows (heads)	Milk yield (tons)	Share of unpaid labour input in total labour input (%)	Total output per AWU (1000 EUR/AWU)	Stocking density (LU/ha)	Output/ input ratio (%)
Italy	77.8	6.0	79.7	114.9	3.09	153.6
Netherlands	75.4	8.0	90.5	158.9	2.34	113.1
Austria	44.6	7.5	95.2	76.9	1.58	118.6
Poland	69.0	7.0	68.4	58.7	1.85	137.5
Very large dairy farms SO ≥ 500k EUR						
Denmark	233.8	9.0	33.2	278.2	2.28	95.3
Germany	270.9	8.5	17.1	125.5	1.80	94.7
Italy	264.4	7.3	47.2	212.7	5.03	147.4
Netherlands	201.0	8.3	75.9	269.8	2.67	115.3

Employment characteristics reveal that very large German and Danish farms had the lowest share of family labour, at 17.1% and 33.2%, respectively, emphasising the role of hired labour. Labour productivity per AWU (Annual Work Unit) increased with economic size. For example, medium-large Polish farms had a labour productivity of €33.5k per AWU, while very large farms in Germany and Italy reached €123.6k and €114.9k per AWU, respectively. The highest productivity levels, exceeding €200k per AWU, were observed in very large farms in the Netherlands and Denmark (€269.8k and €278.2k, respectively).

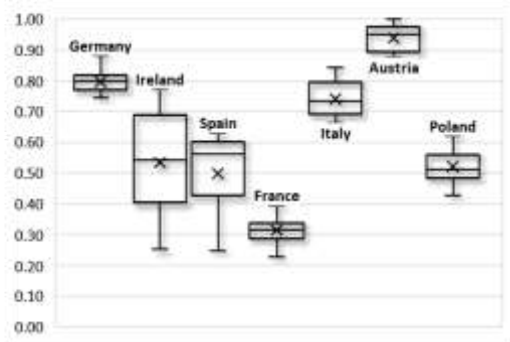
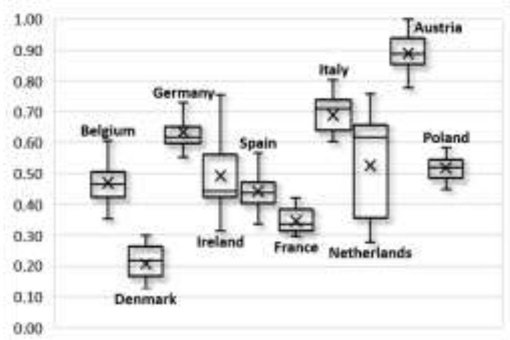
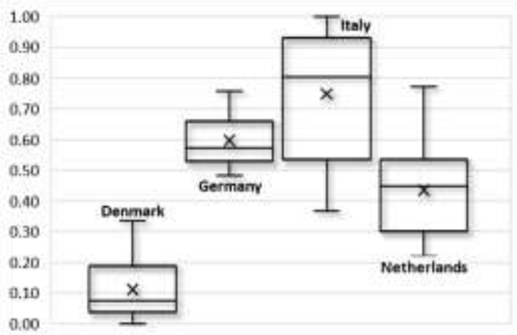
The ratio of production to inputs varies according to the scale and location of the farm. In Italy, for example, farms show very high efficiency, with ratio values ranging from 142.2% on farms in the medium-large group to 153.6% in the large group, suggesting an extremely favourable relationship between income generated and costs incurred. In contrast, Danish farms have an output/input ratio of less than 100%, indicating unprofitable production.

4. Results

The research showed that in the medium-large and large farm groups, the highest average economic resilience index (ERI) calculated for the years 2004-2021 was achieved by Austrian dairy farms (Table no. 4). It exceeded the average levels of the ERI index in other farm groups by more than 0.3 points, with the average ERI index in the medium-large farms group of 0.62 and in the large farms group of 0.52. In both groups, the average economic resilience indices of Irish, Spanish, French, and Polish farms were below the average values. The dispersion of the ERI index over 18 years is the key to assessing economic resilience. In the medium-large group, Irish and Spanish farms had the highest dispersion, while in the large group, it was Dutch and Irish farms. This indicates a high variability in their ability to handle economic shocks, significantly affecting their economic results.

Table no. 4. Values and descriptive statistics of the economic resilience index (ERI)

Medium-large dairy farms 50k EUR ≤ SO < 100k EUR		
	Parameter name	Parameter value (2004-2021)
	Mean ERI index	0.62
	Minimum ERI index	0.32
	Maximum ERI index	0.94

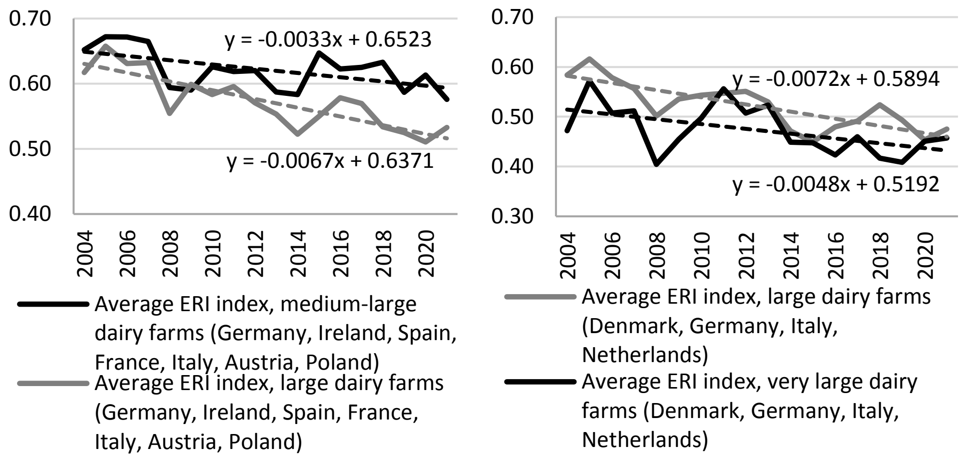
<table>
<tr><th colspan="3">Medium-large dairy farms 50k EUR ≤ SO < 100k EUR</th></tr>
<tr><td>
</td><td>Geometric mean of the chain indices of the ERI index</td><td>-0.73%</td></tr>
<tr><th colspan="3">Large dairy farms 100k EUR ≤ SO < 500k EUR</th></tr>
<tr><td rowspan="5">
</td><td>Parameter name</td><td>Parameter value (2004-2021)</td></tr>
<tr><td>Mean ERI index</td><td>0.52</td></tr>
<tr><td>Minimum ERI index</td><td>0.21</td></tr>
<tr><td>Maximum ERI index</td><td>0.89</td></tr>
<tr><td>Geometric mean of the chain indices of the ERI index</td><td>-1.23%</td></tr>
<tr><th colspan="3">Very large dairy farms SO ≥ 500k EUR</th></tr>
<tr><td rowspan="5">
</td><td>Parameter name</td><td>Parameter value (2004-2021)</td></tr>
<tr><td>Mean ERI index</td><td>0.47</td></tr>
<tr><td>Minimum ERI index</td><td>0.11</td></tr>
<tr><td>Maximum ERI index</td><td>0.75</td></tr>
<tr><td>Geometric mean of the chain indices of the ERI index</td><td>-0.19%</td></tr>
</table>

Note: The X marks the mean ERI index (2004-2021), the horizontal line shows the median, the box represents the interquartile range (Q3-Q1), and the whiskers indicate the minimum and maximum values.

The results of the study indicated that the average index of economic resilience for the very large group was 0.47. Its value was the lowest of all analysed groups. The graph depicting the results of the very large group illustrates that Italian and German farms had the highest economic resilience in this group (Table no. 4). The farms of these countries also achieved some of the highest average ERI index values in the medium-large and large farm groups. In contrast, dairy farms in France, Spain, and Denmark were at the other extreme (lowest average economic resilience index).

Table no. 4 presents the level of the geometric mean of the chain indices of the economic resilience index between 2004 and 2021. Chain indices were used to calculate it. The negative values of this parameter show that, across all farm groups, the economic resilience index decreases each year by an average of between 0.19% and 1.23%. To confirm this, the average values of the ERI index for the period 2004-2021 were collated, and linear trends were determined for identical sets of countries (Figure no.1).

This approach enables accurate comparison between farm groups, revealing a linear decreasing trend in the economic resilience index across all three. Figure 1 shows an increasing gap between the average ERI indices for medium-large and large dairy farms. The trend lines diverge in the following years. In contrast, the average ERI index determined for the large and very large groups was often at a similar level (2011-2015 and 2020), and the trend lines converge. The analysis of the results leads to the rejection of the first hypothesis, which assumed that economic resilience increased across all farm groups during the period under review. The negative geometric mean of the chain indices of the ERI index in the indicates a decline in economic resilience (see Table no. 4). This is also confirmed by the downward linear trends in the average ERI index values for the years 2004-2021 (Figure no. 1).



Notes: The dashed lines show the linear trend of the farm group's economic resilience index

Figure no. 1. Average values of the economic resilience index (ERI) with a linear trend in the analysed groups of dairy farms from 2004 to 2021

Table no. 5 compares economic resilience across countries, showing that most ERI index values declined from 2004 to 2021. Only Polish and Irish farms in the medium-large group and Italian farms in the large and very large groups had a positive geometric mean of the ERI chain indices for 2015-2021, after the EU abolished the milk quota system. Farms were considered to have increased economic resilience if their 2015-2021 average ERI was higher than the overall study period, and their growth rate during this time was positive. Only two farm groups met these conditions:

- In the medium-large group were dairy farms from Ireland, France, and Poland;
- In the large group there were farms from Belgium, Denmark, and Italy.

Table no. 5. Average economic resilience index (ERI) and geometric mean of the chain indices (GM) of the ERI index in the analysed groups of dairy farms by country

Country	Mean of ERI index (2004-2021)	Mean of ERI index (2015-2021)	GM* of ERI index (2004-2021)	GM*of ERI index (2015-2021)
Medium-large dairy farms 50,000 EUR ≤ SO < 100,000 EUR				
Germany	0.80	0.80	-0.20%	-0.97%
Ireland	0.54	0.58	0.70%	4.83%
Spain	0.50	0.36	-2.95%	-7.61%
France	0.32	0.33	-0.70%	1.56%
Italy	0.74	0.77	-0.32%	-3.47%
Austria	0.94	0.89	-0.60%	-0.86%
Poland	0.52	0.57	1.55%	1.63%
Large dairy farms 100,000 EUR ≤ SO < 500,000 EUR				
Belgium	0.47	0.48	-1.60%	1.11%
Denmark	0.21	0.24	-1.29%	7.53%
Germany	0.64	0.61	-1.29%	-0.75%
Ireland	0.49	0.39	-2.59%	0.37%
Spain	0.44	0.39	-3.22%	-4.57%
France	0.35	0.32	-1.39%	0.67%
Italy	0.69	0.72	1.04%	1.82%
Netherlands	0.53	0.36	-4.10%	-0.63%
Austria	0.89	0.84	-0.03%	-1.29%
Poland	0.52	0.53	-0.39%	-2.37%
Very large dairy farms SO ≥ 500,000 EUR				
Denmark	0.11	0.05	-11.50%	31.06%
Germany	0.60	0.53	-2.57%	-2.72%
Italy	0.75	0.89	5.84%	-0.15%
Netherlands	0.44	0.29	-3.92%	2.15%

Note: Geometric mean of the chain indices.

The results in table no. 5 allow us to reject the second hypothesis, which states that dairy farms with the largest economic size have higher economic resilience compared to the other farm groups. This is confirmed, for example, by the fact that the economic resilience index in Danish, German, and Dutch farms classified as very large was lower than the index calculated for the large farm group, which is smaller in economic size.

The highest discrepancies in the structure of the ERI index (4 percentage points) are observed in the dimensions of Vulnerability, Performance, and Biodiversity, occurring between the medium-large and very large farm groups. Conversely, in the Diversification dimension, a difference of 4 percentage points was found between dairy farms in the large and very large groups.

The next step of the study was to calculate the structure of the average economic resilience index from 2004 to 2021. The use of an average was justified because the structure of the ERI index remained almost identical from year to year. Figure no. 2 shows that Intensification (irrespective of the farm group analysed) accounted for the largest share of this ERI index, around 40%, while Diversification represented the lowest share (4%-7% depending on the farm group analysed). The highest discrepancies in the structure of the ERI index (4 percentage points) are observed in the dimensions of Vulnerability, Performance, and Biodiversity, occurring between the medium-large and very large farm groups.

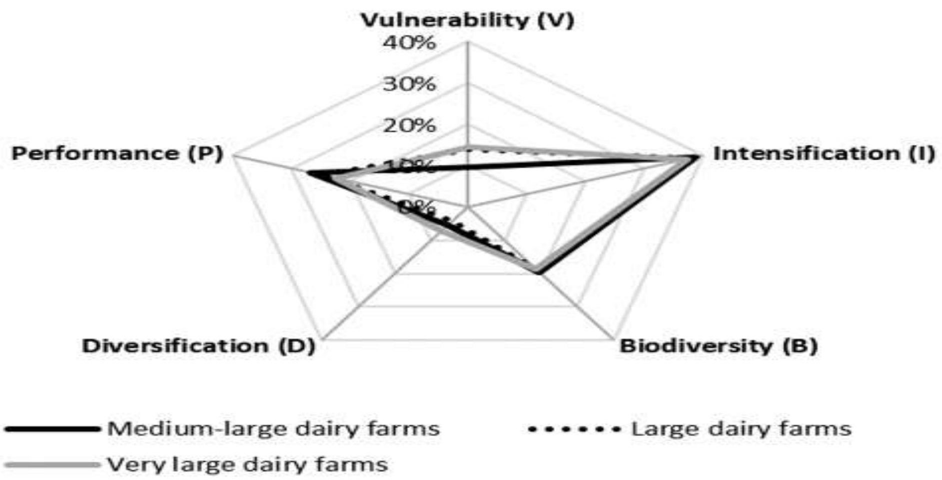


Figure no. 2. Structure of the average economic resilience index in the analysed dairy farm groups

Based on this information, we can reject the third hypothesis, which posits a significant variation in the structure of the economic resilience index among the studied farm groups.

5. Discussion

The results of the study reveal a clear downward trend in the economic resilience of dairy farms in the ten largest milk-producing countries of the European Union between 2004 and 2021. This finding challenges the initial hypothesis that economic resilience would gradually increase over time as a result of technological progress, learning effects, and policy support. Instead, the observed decline reflects increasing pressures from market liberalisation, price volatility, environmental regulations, and a changing policy framework. This aligns with the findings of (Thorsøe et al., 2020), who demonstrated that the liberalisation of the milk market following the abolition of quotas exposed farmers to greater price volatility, thereby weakening their economic stability. Similar conclusions were drawn by Dardonville et al. (2022), who confirmed that intensive systems, despite achieving high productivity, exhibit lower long-term stability than systems based on biodiversity, which rely on ecosystem services to cushion external shocks.

The assumption that larger farms are more economically resilient due to economies of scale is also not substantiated. The results indicate that larger farms, despite their productivity advantages, are more vulnerable to systemic risks arising from their dependence on external inputs and global commodity markets. This observation is supported by the findings of Poczta et al. (2020), who demonstrated that the economic resilience of large farms fluctuates sharply in response to external market shocks and rising production costs. Similar conclusions were drawn by Čechura et al. (2021), who observed that the abolition of milk quotas had increased productivity, but simultaneously led to greater indebtedness and environmental pressure.

The identification of key determinants of resilience confirmed that diversification – both in terms of production structure and income sources – plays a crucial role in enhancing resilience. However, the level of diversification among the farms studied remains relatively low, limiting their ability to absorb economic shocks. This is consistent with the findings of Grilli et al. (2024), who demonstrated that farms integrating both agricultural and non-agricultural activities exhibit greater resilience to price volatility and climate risks. Spiegel et al. (2020), meanwhile, emphasised that farms with broad risk management portfolios – including financial instruments, production flexibility, and market diversification – display higher perceived resilience.

The role of policy as a determinant of resilience requires particular attention. While CAP direct payments and rural development programmes provide short-term income stabilisation, their contribution to building long-term resilience remains ambiguous. As demonstrated by Žičkienė et al. (2022), direct payments enhance short-term financial stability but simultaneously reduce incentives for restructuring, innovation, and diversification – all of which are crucial for long-term resilience. This ambivalence underscores the need to redesign CAP instruments to actively support resilience-enhancing practices rather than merely stabilising income.

Another important factor influencing resilience is the diversification of agricultural production and the use of natural processes. The results confirm that farms actively managing biodiversity and implementing agroecological practices are more resilient and flexible. This is consistent with the findings of Erisman et al. (2016) and Dardonville et al. (2022), who demonstrated that biodiversity-based systems not only offer environmental benefits but also enhance farms' ability to absorb economic and climate-related shocks.

The scope of this study, which extends only until 2021, limits the discussion of the results. Consequently, events such as the war in Ukraine, the energy price crisis, and the disruption of supply chains caused by the COVID-19 pandemic have not been accounted for. As noted by Rikkonen et al. (2024), these recent crises have fundamentally altered production costs, input availability, and market stability, necessitating future studies to update resilience assessments to incorporate these emerging factors.

The study also revealed an imbalance between short-term adaptive strategies and transformational change. Most farms respond to shocks by reducing costs, substituting inputs, and making incremental adjustments. However, more profound transformations – such as transitioning to low-input systems, adopting regenerative agricultural practices, or integrating into local value chains – remain rare. This aligns with the conclusions of Darnhofer (2021) and Reidsma et al. (2023), who argue that true resilience requires not only adaptation but also transformation – a fundamental shift in production models, market relationships, and management structures. Spiegel et al. (2020) stress that effective risk management strategies must be multidimensional, simultaneously addressing economic, environmental, and social risks.

Conclusions

The study sets out three research hypotheses, the verification of which allowed the determination of the level of economic resilience of dairy farms in the years 2004-2021 of the largest milk-producing countries in the EU. All research hypotheses were rejected. The analysis revealed that economic resilience in medium-large, large, and very large dairy farms declined during the studied period. Furthermore, farms with a smaller economic size exhibited a higher average economic resilience index compared to those with a larger economic size – a finding that was unexpected. Furthermore, farms generating a higher average monetary value of agricultural output have a lower capacity to withstand economic shocks, as well as environmental and social changes.

The results also showed that dairy farms located in countries such as Ireland, Spain, and the Netherlands are particularly vulnerable to shocks. This is reflected in the high dispersion of the economic resilience index values of these farms. In the case of Austrian, Polish, and German farms located in the medium-large and large groups, they can be assessed as having high economic resilience. This assessment is based on the ERI index values themselves, as on well as their low disparity during the period 2004-2021.

The research conducted expands the knowledge of which farm groups are particularly vulnerable to sudden shocks and unpredictable situations that impact economic results. Farms with large dairy herds should reassess their business strategies and adopt measures to enhance economic resilience. The structure of the ERI index suggests that European dairy farms can increase their economic resilience, for example, diversifying their sources of income. It was through diversification that Austrian farms exhibited the highest economic resilience compared to farms in other countries. Furthermore, the adoption of technological innovations should be prioritised to reduce production costs and increase automation, which is related to the decreasing availability of labour. Our research also offers valuable insights for future farm support programs and policies. These findings can serve as a basis for discussions on developing targeted solutions and recommendations tailored to different groups of dairy farms. The results indicate that a one-size-fits-all approach may not be effective; instead, support programs should be customised according to each group's resilience to economic shocks.

The study has limitations, including the varying number of countries in each farm group based on economic size due to the FADN database. While this is the best source for data from many farms and EU countries, averaged results may not reflect individual farm situations. Despite these limitations, we are motivated to continue researching the economic resilience of European dairy farms.

Future research on the economic resilience of dairy farms should focus on identifying solutions and best practices to improve their financial stability. The conducted analyses suggest that key areas for improvement include reducing input use intensity and decreasing dependence on hired labour. It is also important to conduct simulations to assess the impact of income diversification on the economic resilience of dairy farms. This can be approached in two ways: first, through milk-based diversification, such as encouraging farms to invest in milk processing; and second, by integrating new income sources while simultaneously reducing production costs, for example, through investments in Biogas plants based on slurry fermentation or environmental protection measures.

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