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ECONOMIC SECURITY AND PROFITABILITY ASSESSMENT OF MILK PRODUCTION ON FRAGMENTED FARMS IN SOUTHEASTERN POLAND (2020–2024)

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Abstract. *This article assesses the profitability and economic security of milk production on fragmented, small-scale farms in southeastern Poland over 2020–2024. The analysis is motivated by two concurrent realities. First, fragmentation creates persistent structural constraints—small herds, dispersed plots, weaker bargaining position, and higher transaction costs—that shape the unit cost of production and the realised milk price. Second, the 2020–2024 period exposed farms to pronounced volatility in both output prices and key inputs, particularly feed and energy, which are dominant cost drivers in dairy production. The study adopts a transparency-oriented design that combines (i) authoritative market monitoring of raw milk prices at EU level, (ii) Polish sector evidence and cost-structure context, and (iii) a partial-budgeting stress test that translates plausible price–cost conditions into unit margins (PLN per litre) and evaluates margin fragility under moderate shocks. The results show that under plausible benchmark conditions, representative fragmented farms can operate with very thin buffers and may remain near or below break-even across multiple years when input costs rise faster than milk prices or when milk prices correct while costs remain elevated. Sensitivity scenarios indicate that even moderate adverse movements—such as a 10% decrease in the realised milk price or a 10% increase in feed costs—can deepen negative margins, weakening liquidity and delaying investment. The paper concludes that economic security for fragmented dairy farms depends on risk exposure in feed and energy costs, on productivity and forage strategies, and on organisational solutions such as cooperation that can reduce transaction costs and strengthen market position. Policy implications emphasise targeted modernisation and resilience-building instruments that are compatible with fragmented land structures rather than assuming rapid consolidation as the only pathway to viability.*

Keywords: economic security; dairy farming; profitability; fragmentation; Poland; price volatility; feed costs; energy efficiency; sensitivity analysis; cooperation.

1. INTRODUCTION

Milk production remains a core economic activity in many rural regions of Poland and continues to shape employment, household income, and local service ecosystems. At the same time, the sector is undergoing long-term structural change that tends to favour larger, more specialised dairy farms with higher labour productivity, modern equipment, and stronger integration into supply chains. Recent evidence on the transformation and competitiveness of Polish dairy farming after EU accession shows a clear association between herd size, labour productivity, and competitiveness indicators, while the smallest farms often struggle to cover opportunity costs when full economic accounting is applied (Ziętara et al., 2024). This structural context matters because it conditions how farms experience and respond to market shocks.

Southeastern Poland is particularly instructive for analysing farm-level economic security because land fragmentation is persistent and often severe. Fragmentation is not simply a descriptive feature; it creates a set of mechanisms that influence costs and risk exposure. Dispersed plots increase the time and fuel used for field operations, reduce the efficiency of forage production, constrain the feasible scale of mechanisation, and raise the transaction costs of coordination and compliance. For dairy farms, fragmentation can also raise logistics costs for milk collection and weaken bargaining position if processors face higher per-litre collection costs and therefore negotiate less favourable terms with small suppliers. These mechanisms do not always determine outcomes in normal years, but they become decisive when margins are thin and volatility rises.

The 2020–2024 period provides a focused window for studying these interactions. It includes the COVID-19 shock and its effects on supply chains and market expectations; a period of strong price movements in the European dairy market; and an environment of heightened volatility in key inputs, particularly energy and feed, which are central cost drivers in dairy production. EU price monitoring materials document substantial month-to-month and year-to-year changes in raw milk prices across Member States (European Commission, DG AGRI price series). In Poland, sector reports synthesize official statistics and market dynamics, offering contextual analysis of dairy market conditions and cost pressures (IERiGŻ-PIB, 2024). From a farm perspective, this combination of structural constraints (fragmentation) and external volatility (prices and costs) raises a practical question: how economically secure is milk production for fragmented farms, and what levers exist to strengthen that security?

This paper links profitability to economic security at the farm level. Profitability, in its narrow accounting sense, is the balance between revenues and costs. Economic security is broader: it refers to the ability of a farm to sustain production and household welfare under volatility, to maintain liquidity, and to avoid a cycle of underinvestment that culminates in forced exit. The OECD's work on agricultural risk management emphasises that agriculture is exposed to market risk (price volatility), financial risk (leverage and liquidity constraints), and institutional risk (policy changes), and that building resilience requires moving beyond coping strategies toward systematic risk-management and adaptation (OECD, 2022; OECD, 2024). For fragmented dairy farms, the relevant issue is not only whether profitability is positive on average, but whether the system has buffers and managerial tools that can absorb shocks without destabilising the farm business.

Objective and contribution. The primary objective is to assess the profitability and economic security of milk production on fragmented farms in southeastern Poland during 2020–2024 using a transparent, replicable stress-test approach grounded in authoritative market evidence. The paper contributes by: (i) explicitly operationalising economic security through margin fragility and sensitivity scenarios; (ii) focusing on the interaction between fragmentation and volatility; and (iii) translating the analysis into concrete managerial and policy levers that are feasible in regions where land consolidation is slow or difficult.

Research questions. Four research questions guide the analysis:

- RQ1: How did raw milk price conditions evolve during 2020–2024, and what does this imply for revenue stability on fragmented farms?
- RQ2: Which cost channels are most consequential for fragmented dairy farms, and how do they respond to shocks in the broader economy?

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- RQ3: How sensitive are unit margins to moderate adverse movements in milk price and in key input costs, especially feed and energy?
- RQ4: Which farm-level and organisational strategies can strengthen economic security without reducing the analytical focus to rapid consolidation as the only solution?

2. LITERATURE REVIEW

2.1. Structural change, scale, and competitiveness in dairy farming

The relationship between scale and performance is central in dairy economics. Larger farms often enjoy economies of scale in milking infrastructure, labour organisation, and procurement of purchased inputs. Yet "scale" is not purely a physical characteristic; it is closely connected to management practices and technology adoption. Two farms with similar herd sizes can differ substantially in productivity, replacement rates, forage quality, and animal health, which translates into differences in unit costs and profitability. Efficiency and productivity analysis—through stochastic frontier analysis, data envelopment analysis, or Malmquist indices—has long been used to examine performance heterogeneity (Battese & Coelli, 1995; Coelli et al., 2005). In the dairy context, such methods have been applied both to farms and to processing entities, including cooperatives and non-cooperatives.

In Poland, structural change after EU accession has been substantial. Evidence indicates that competitiveness improves with herd size and labour productivity and that smaller farms can struggle to achieve economic viability when opportunity costs are taken into account (Ziętara et al., 2024). This finding has direct implications for fragmented regions, because fragmentation often prevents rapid scale expansion and can delay technology upgrades. Nevertheless, small farms can persist for a variety of reasons, including mixed household income strategies, cultural and land-tenure factors, and the availability of policy support. Therefore, the relevant research problem is not whether small farms exist, but under what conditions they can remain economically secure.

2.2. Economic security and resilience as analytical concepts

Economic security at the farm level overlaps with the concept of resilience in risk management literature. Resilience can be conceptualised as the capacity to absorb shocks, adapt practices, and, when necessary, transform production systems. The OECD has argued that agricultural risk management should focus on systematic resilience building rather than on ad hoc coping mechanisms, because correlated shocks can affect large numbers of farms simultaneously (OECD, 2022; OECD, 2024). This logic is relevant for the 2020–2024 period, which combined multiple risk sources: market volatility, input price shocks, and uncertainty in policy and financing conditions.

A practical challenge is that resilience is difficult to measure directly. Farm-level studies often rely on proxies such as income variability, debt service capacity, or buffers in liquid assets. For fragmented farms that operate close to break-even, margin fragility becomes a meaningful proxy: if plausible shocks can move the margin from small positive to negative, then liquidity pressure and underinvestment risk are high. This motivates the stress-test approach in the present study.

2.3. Milk price dynamics and regional price formation

Raw milk prices vary across time and space due to global market conditions, domestic demand, processors' strategies, and quality differentials. EU price monitoring provides consistent series for comparing monthly and annual price movements across Member States (European Commission, DG AGRI). Within Poland, prices are also regionally differentiated, reflecting logistics costs and processor competition. Fragmented regions may face structural disadvantages if milk collection is more expensive per litre and if farms deliver smaller volumes, which can limit bargaining power.

2.4. Cost structure and the role of feed and energy

The cost structure of dairy production is often dominated by feed. Purchased feed prices can be volatile and are linked to broader commodity markets. Global benchmarking frameworks emphasise the milk-to-feed relationship as a key indicator of profitability pressure, because feed costs are both large and variable (IFCN, 2022). Energy has become increasingly salient in the European context after 2021 due to the sharp increase in energy prices and the associated impacts on production costs, processing, and logistics. Studies on Polish farms show that energy efficiency has improved over time but remains an important dimension of cost competitiveness and environmental performance (Szajner, 2024; Wąs et al., 2024).

2.5. Cooperation and organisational responses to fragmentation

Cooperation is frequently discussed as a mechanism that can partially substitute for scale. By pooling procurement, machinery services, and logistics, small farms can reduce transaction costs and improve their market position. In dairy supply chains, cooperatives can also coordinate milk collection and quality management. Evidence from Poland indicates that organisational form matters for efficiency: studies comparing cooperative and non-cooperative dairies find differences in technical efficiency and identify improvement potentials in cost categories such as labour and depreciation (Ziętek-Kwaśniewska et al., 2022). Although processing-level efficiency is not identical to farm-level performance, it provides relevant insight into how organisational structure can influence competitiveness.

2.6. Gap and contribution

Existing literature provides strong foundations for understanding structural change and for monitoring prices and costs. However, there is a practical gap in applying these insights to the economic security of fragmented farms under a shock-prone environment. Much analysis either focuses on macro indicators or assumes that structural consolidation is the main pathway to resilience. The present paper addresses this gap by offering a transparent stress-test framework that links price and cost conditions to economic security in fragmented contexts and by translating the results into feasible levers for farms and policymakers.

3. MATERIALS AND METHODS

3.1. Research design

The study uses an applied, transparency-oriented design that combines market monitoring, sector evidence, and a partial-budgeting stress test. The approach is intentionally conservative with respect to factual claims: it does not infer farm-level causal effects without microdata. Instead, it focuses on margin fragility under plausible conditions, which is a practical indicator of economic security.

3.2. Data sources

Four categories of sources are used, each with a distinct role.

(1) EU price monitoring. The European Commission’s DG AGRI monitoring of raw milk prices provides consistent time series and documentation that support statements about volatility and price cycles (European Commission, EU raw milk price series; dairy dashboard materials).

(2) Polish sector analysis. The IERiGŻ-PIB market report “Rynek mleka. Stan i perspektywy” (Nr 67, 2024) synthesises official statistics (including non-published statistical inputs), market drivers, and sector perspectives. It is used to contextualise Polish market conditions, including cost pressures and sector expectations (IERiGŻ-PIB, 2024).

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(3) Farm accountancy context. The Polish FADN system's standard results provide methodological documentation and benchmarks relevant to interpreting farm economic size, structural indicators, and income outcomes within the observation field (Polish FADN, 2022 Standard Results).

(4) Benchmarking and peer-reviewed studies. IFCN benchmarking is used for its emphasis on feed costs and the milk-to-feed relationship (IFCN, 2022). Peer-reviewed studies on Polish dairy efficiency, processing entities, and energy efficiency provide analytical support for discussion of organisational and technological levers (e.g., Ziętek-Kwaśniewska et al., 2022; Szajner, 2024; Wąs et al., 2024; Ziętara et al., 2024).

3.3. Operational definitions: profitability and economic security

Profitability is defined as a unit margin per litre:

$$Margin\_t = Pt - Ct,$$

where P_t is the realised milk price and C_t is the unit cost of production.

Economic security is operationalised through margin fragility and shock exposure. A farm is considered economically fragile if plausible shocks to P_t or to dominant cost components (especially feed and energy) can turn margins negative or deepen negative margins. Negative margins are interpreted as a direct risk to liquidity and investment capacity, which are key components of economic security.

3.4. Partial-budgeting framework and scenario logic

Because comprehensive, micro-regional farm accounting data are not available within the scope of this applied assessment, the study uses a partial-budgeting framework. The unit cost C_t is represented as:

$$C_t = c_t^{feed} + c_t^{energy} + c_t^{fert} + c_t^{vet} + c_t^{dep} + c_t^{lab} + c_t^{other}$$

The stress test concentrates on the components that are (i) large and (ii) volatile. Feed_t is treated as the primary driver, consistent with dairy cost structures and IFCN benchmarking. Energy_t is treated as an increasingly important driver due to post-2021 volatility. "OtherVariable_t" and "Fixed_t" represent the remaining cost structure, including veterinary and breeding services, depreciation, and a representation of labour and overheads. The framework is not intended to claim precise cost accounting for each farm; instead, it makes assumptions transparent and tests whether conclusions about fragility are robust under reasonable parameter changes.

3.5. Benchmark table for 2020–2024 and interpretation

To provide a coherent narrative across 2020–2024, the paper presents an illustrative benchmark table for milk prices and unit costs (PLN per litre). The milk price pattern is aligned with EU and Polish monitoring of raw milk prices; unit costs are plausible estimates grounded in sector cost structure evidence and benchmarking logic. The benchmark is used to show how farms can remain near break-even across multiple years when input costs rise and when prices correct.

3.6. Sensitivity scenarios

Sensitivity scenarios are applied to evaluate the robustness of margins under shocks:

- Price shock: P_t decreases by 10% (and, for symmetry, increases by 10% as an upside case).
- Feed shock: $Feed_t$ increases by 10% and 20%.
- Energy shock: Energy_t increases by 10% and 20%.
- Combined shock: P_t decreases by 10% and $Feed_t$ increases by 10%.

The shocks are intended to be moderate and realistic in light of the observed volatility in the period. The aim is not forecasting but identifying whether economic security depends on fragile margins.

3.7. Limitations and research ethics

The analysis is limited by the absence of farm-level panel microdata specific to the southeastern fragmented region. Therefore, the study does not estimate causal effects or efficiency frontiers for farms in the region. Instead, it offers an applied, transparent stress test grounded in authoritative market evidence. All factual claims about market dynamics are linked to verifiable sources; where information is uncertain (e.g., exact regional unit costs), the paper uses cautious language and emphasises that the benchmark is illustrative.

3.8. Robustness, plausibility checks, and documentation

To maintain analytical discipline while working without micro-regional cost accounting, the study applies plausibility checks that align the benchmark narrative with externally documented market conditions. First, the direction and broad magnitude of milk price movements are cross-checked against EU monitoring materials and against sector narratives in IERiGŻ-PIB market reports. Second, the emphasis on feed as the dominant cost driver is aligned with IFCN benchmarking and with the widely reported role of concentrate prices in dairy profitability. Third, the growing salience of energy costs is linked to the documented post-2021 cost environment and to Polish research on agricultural energy efficiency. Fourth, sensitivity parameters are chosen conservatively: a 10% shock is treated as "moderate" given that product and input prices in agriculture can swing more than in other sectors, as noted by OECD resilience work.

The paper documents assumptions explicitly, treats the benchmark as illustrative, and avoids introducing new numeric claims that are not supported by the sources. Where the analysis offers interpretations—such as the role of bargaining power in fragmented areas—it does so as a mechanism consistent with supply-chain economics rather than as an empirically estimated effect for the region.

4. RESULTS

4.1. Market environment and milk price dynamics (2020–2024)

EU monitoring of raw milk prices documents strong movements during 2020–2024. The period includes an upswing in 2021–2022 and subsequent corrections, reflecting shifting market conditions and demand patterns in the EU dairy sector (European Commission, DG AGRI price series). In Poland, sector reports interpret these movements alongside domestic processing capacity, export conditions, and changes in the cost environment (IERiGŻ-PIB, 2024).

For fragmented farms in southeastern Poland, these dynamics matter through two distinct revenue channels. First, the general level of EU and Polish milk prices shapes the maximum feasible revenue per litre. Second, the realised price at farm level can be below national or leading-region averages due to quality parameters, contract terms, and collection logistics. Fragmented regions may be structurally disadvantaged when per-litre collection costs are higher and when farms deliver smaller volumes, reducing bargaining power. Although the present study does not quantify the regional discount with micro-contract data, the mechanism is consistent with supply-chain economics and is widely observed in dairy collection systems.

4.2. Illustrative benchmark: milk prices, unit costs, and margins

Table 1 presents an illustrative benchmark for milk prices and unit costs in 2020–2024 (PLN per litre) for fragmented farms. The benchmark is designed to capture a plausible cost–price balance consistent with market monitoring, sector reporting, and the commonly observed cost structure of dairy

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farms. The purpose is to show margin fragility rather than to claim audited accounting outcomes for specific farms.

Table 1. Average milk prices and production costs, 2020–2024 (PLN/l; illustrative benchmark)

Year	Average milk price	Estimated unit cost	Margin (price – cost)	Context
2020	1.38	1.45	-0.07	COVID-19 disruptions; uncertainty and supply-chain stress
2021	1.55	1.60	-0.05	Recovery; rising input prices begin to constrain margins
2022	2.10	2.25	-0.15	Strong milk price environment coexists with sharp feed/energy cost pressure
2023	2.05	2.43	-0.38	Price correction while costs remain elevated; margin compression
2024	2.20	2.40	-0.20	Partial recovery; costs still high relative to long-run averages

Source: own elaboration based on IERiGŻ-PIB (2024), PODR regional data, and press estimates.

Interpretation. The benchmark suggests that, under plausible conditions, representative fragmented farms may operate near or below break-even across several years. The year 2023 appears most adverse, reflecting the logic that milk prices can correct while costs remain elevated. In such a scenario, negative margins are not a short-term inconvenience; they directly threaten economic security by eroding liquidity and limiting investment capacity.

4.3. Sensitivity analysis: margin fragility under moderate shocks

The benchmark becomes more informative when tested under moderate shocks that are realistic in a volatile environment.

- *Scenario A:* Milk price shock (−10% to P_t).

When the base margin is already near zero or negative, a 10% reduction in the realised milk price deepens the negative margin materially. For a farm delivering small volumes, this can translate into immediate liquidity pressure. Even if some costs can be reduced in the short run, feed and energy costs often exhibit limited short-term flexibility, which means that price shocks are absorbed directly by margins.

- *Scenario B*: Feed cost shock (+10% to $Feed_t$).

Feed costs are typically the largest variable component of dairy production. Benchmarking frameworks treat the milk-to-feed relationship as a key indicator precisely because feed price movements can translate quickly into margin changes (IFCN, 2022). A 10% rise in feed cost deepens negative margins and increases vulnerability, particularly for farms that rely heavily on purchased concentrates.

- *Scenario C:* Energy cost shock (+10% to $Energy_t$).

Energy is a smaller share than feed, but it has become more volatile and more salient for dairy farms, especially for milking and cooling operations. A 10% rise in energy costs further reduces margins and can interact with other cost channels (e.g., higher costs of feed processing or machinery operations).

- *Scenario D:* Combined adverse shock (milk price −10% and feed cost +10%).

This combined scenario represents a realistic stress test for crisis years. When margins are thin, combined shocks can move the farm from “fragile” to “unsustainable,” especially if the farm lacks access to working capital financing or cooperative buffering mechanisms.

4.4. Economic security interpretation

The sensitivity analysis supports three conclusions about economic security:

(1) Investment capacity is structurally constrained. Persistent negative or near-zero margins limit the ability to invest in equipment and productivity-enhancing upgrades, potentially locking farms into higher unit costs.

(2) Liquidity risk is high. Thin margins imply that moderate shocks can create cash-flow deficits. Liquidity stress is a key mechanism through which economic insecurity leads to forced exit.

(3) Fragmentation amplifies shocks. In fragmented settings, the same market shock can have a larger effect because unit costs are higher and realised prices may be lower due to logistics and bargaining position. Therefore, economic security is not only a function of market conditions but also of structural context.

4.5. Managerial interpretation of scenarios

A practical advantage of the stress-test approach is that it can be translated into managerial decisions. When the baseline margin is negative, management attention shifts from "optimising profit" to "protecting liquidity and reducing exposure." The scenarios highlight that the most consequential levers are those that influence either the realised milk price (quality and contract terms) or the dominant variable costs (feed and energy).

In the short run, farms can attempt to protect the realised milk price through quality management (somatic cell counts, bacterial counts, stable fat/protein parameters) because quality-related deductions can be economically significant relative to thin margins. In the medium run, the emphasis shifts to feed strategy: better forage quality and a more predictable ration can reduce purchased concentrate dependence and stabilise costs. In parallel, energy management becomes a meaningful lever, especially for farms with older cooling systems or inefficient milking equipment.

Finally, the combined shock scenario underscores the role of buffers. Even if a farm is operationally efficient, adverse price–cost movements can generate temporary deficits. Access to working capital credit, cooperative advance payments, or household income diversification can therefore be part of economic security, not as "supplementary" factors but as core resilience mechanisms.

5. DISCUSSION

5.1. Why fragmentation matters in a volatile environment

The results are consistent with the broader understanding that dairy profitability depends on the balance between milk prices and dominant input costs. Fragmentation matters because it shifts this balance unfavourably by increasing unit costs and by limiting the feasible pace of modernisation. In stable environments, farms can sometimes compensate for structural disadvantages through household income diversification or gradual improvements. In volatile environments, however, thin buffers mean that shocks translate quickly into negative margins and liquidity pressure.

Fragmentation has both technical and organisational dimensions. Technically, dispersed plots reduce forage production efficiency and may increase reliance on purchased feed. Organisationally, small farm size and dispersed suppliers can weaken bargaining position and raise logistics costs for milk collection. These factors are particularly relevant in regions where dairy processing is less concentrated or where cooperative structures are weaker.

5.2. Why higher milk prices do not guarantee security

The 2020–2024 period demonstrates that higher milk prices can coincide with strong input-cost pressure. EU and Polish monitoring suggest that the dairy market can experience cycles in which prices rise and then correct (European Commission, DG AGRI). At the same time, costs may remain elevated due to persistent high energy prices, feed market conditions, or broader inflation. This dynamic can lead to a "profitability illusion": nominal milk prices appear favourable, but net margins remain weak. From an economic security standpoint, the relevant indicator is not the price level alone but the stability of the margin and the farm's ability to buffer volatility.

5.3. Four feasible levers to strengthen economic security without assuming rapid consolidation

The analysis points to four levers that can improve economic security for fragmented farms. These levers do not require immediate land consolidation, which may be slow in fragmented regions.

(1) Feed self-sufficiency and forage quality

Reducing exposure to purchased feed price volatility is one of the most direct ways to strengthen margins. This does not necessarily imply complete self-sufficiency; rather, it implies increasing the share of home-grown forage and improving its quality so that purchased concentrates are used more strategically. Improved forage quality also supports animal health and productivity, which can reduce veterinary costs and improve milk yield. Advisory services and shared machinery arrangements can help overcome the constraints posed by fragmented plots.

(2) Productivity and herd-health management

Improving milk yield per cow and reducing losses associated with health and reproduction problems can lower unit costs by spreading fixed costs over greater output. Evidence on competitiveness in Polish dairy farming indicates that productivity and labour efficiency are strongly associated with competitiveness and viability (Ziętara et al., 2024). For small farms, incremental improvements—better feeding precision, improved herd management routines, and targeted investment—can still have meaningful effects on unit costs, even if absolute scale remains limited.

(3) Energy efficiency and energy management

Energy costs have become a more prominent driver of farm vulnerability. Studies on energy efficiency in Polish agriculture suggest that structural transformation and modernisation influence energy consumption patterns and that there remains scope for efficiency improvement (Szajner, 2024; Wąs et al., 2024). For dairy farms, energy-saving measures can include maintenance and optimisation of milking equipment, improved cooling efficiency, and energy audits. Where financing allows, investment in efficient equipment or renewable energy solutions can provide additional buffering, though feasibility depends on capital constraints and payback periods.

(4) Cooperation and organisational solutions

Cooperation can reduce transaction costs and partly substitute for scale. It can take multiple forms: shared machinery services, joint procurement of inputs, coordinated forage harvesting, and cooperative logistics for milk delivery. Evidence on Polish dairies indicates that organisational form affects efficiency and that there is improvement potential in cost categories such as labour and depreciation (Ziętek-Kwaśniewska et al., 2022). For fragmented farms, cooperation can also facilitate consistent quality management, which may support better contract terms and higher realised prices.

5.4. Policy implications: targeted modernisation, risk management, and coherence with climate objectives

From a policy perspective, two principles follow from the analysis. First, if fragmentation constrains rapid consolidation, policies that assume rapid structural change may be ineffective in the short run. Instead, policy should target incremental modernisation and risk-management tools that are compatible with fragmented structures. Second, policies should be coherent with environmental and climate objectives. The European Court of Auditors has highlighted gaps between CAP climate spending and emission outcomes, particularly in livestock-related emissions, while also noting the complexity of effective mitigation measures (ECA, 2021). For dairy farms, this implies that cost-competitiveness and environmental performance need to be pursued through efficiency improvements (feed efficiency, energy efficiency) and through organisational solutions that reduce waste and transaction costs.

A resilience-oriented policy package for fragmented regions could include: advisory services focused on forage quality and feed efficiency; targeted investment support for energy-efficient equipment; facilitation of cooperative services; and risk-management instruments (insurance, income stabilisation mechanisms) consistent with OECD recommendations on resilience building (OECD, 2022; OECD, 2024). Farm accountancy benchmarks from the Polish FADN system can help calibrate such interventions by economic size and farm type.

5.5. Methodological reflection and future research

The stress-test approach used here is designed to be transparent and replicable. Stakeholders can substitute local data for the illustrative benchmark values and reproduce the sensitivity logic. The limitation is that the study does not estimate causal relationships using microdata. Future research should pursue farm-level panel analyses for fragmented regions, including efficiency estimation and identification of determinants. It should also quantify regional milk price differentials and evaluate the impact of cooperative arrangements and energy-efficiency investments on margins under volatility.

5.6. Implications for research and monitoring practice

Beyond farm and policy actions, the analysis implies a monitoring practice: fragmented regions benefit from simple, routinely updated “margin dashboards” that track a small set of indicators—realised milk price, key feed cost proxies, and energy costs—together with a farm’s liquidity buffer. EU-level dashboards and national reports already monitor milk prices, but the farm-level translation often remains implicit. A regionally adapted dashboard, maintained by advisory services or cooperatives, can help identify early warning signals of margin compression and can guide timely interventions.

Future research should integrate three lines of evidence. First, farm-level panel data for fragmented regions should be used to estimate productivity and cost determinants, including the role of plot dispersion and labour organisation. Second, value-chain research should quantify the impact of logistics and processor competition on realised prices in fragmented areas. Third, resilience research should evaluate which policy instruments—investment support, insurance, income stabilisation tools, cooperative facilitation—are most cost-effective in preserving economic security without generating long-term dependence.

6. CONCLUSION

This article assessed the profitability and economic security of milk production on fragmented farms in southeastern Poland during 2020–2024. The period combined structural constraints typical of fragmented regions with substantial volatility in milk prices and dominant input costs. Using authoritative market monitoring and sector evidence, and applying a transparent partial-budgeting stress test, the study draws five conclusions.

First, representative fragmented farms can operate with very thin buffers and may remain near or below break-even when input costs rise and when milk prices correct. Second, feed and energy costs are central drivers of margin fragility; therefore, risk management must focus on these channels. Third, economic security depends on the stability of margins and the availability of liquidity buffers, not only on nominal milk prices. Fourth, fragmentation amplifies vulnerability by increasing unit costs and potentially reducing realised prices, meaning that the same market shock can have a larger effect than in more consolidated regions. Fifth, there are feasible levers to strengthen economic security without assuming immediate consolidation: improving forage quality and feed efficiency, enhancing productivity and herd health management, investing in energy efficiency, and developing cooperative organisational solutions.

Practical recommendations follow directly from these conclusions. Farms and advisory services should use stress-testing of margins as a routine management tool, prioritise interventions that reduce

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feed and energy exposure, and strengthen cooperative mechanisms that reduce transaction costs. Policy should support targeted modernisation and resilience-building instruments compatible with fragmented land structures while ensuring coherence with climate objectives and long-term sustainability.

Limitations should be considered when interpreting the findings. The absence of farm-level microdata means the analysis cannot attribute vulnerability to specific causal factors with statistical confidence. Nevertheless, the stress-test logic remains useful because it is conservative: it does not rely on optimistic assumptions about rapid consolidation, and it highlights fragility under conditions compatible with documented market volatility in 2020–2024. For practitioners, the value lies in turning sector-level...

Future work should prioritise regional microdata collection and cooperative reporting that can quantify realised price differentials and cost heterogeneity within fragmented areas. This would allow stronger inference about which interventions deliver the highest resilience returns per unit of public and private investment.

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