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Effects of CAP on greening and sustainability in CEE countries

Report

Deliverable 1 within project:

FOODAGRI

**Food security and sustainability of agricultural production:
the role of institutions and policies**

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The deliverable D1 consist of and summarizes 3 scientific papers published within WP1 of the project:

1. Can the CAP Deliver a Green Transition in Baltic, Central and Eastern Europe? by Štefan Bojnec, Marián Tóth and Jan Pokrivcak
2. Generational renewal in the European Union agriculture: Evidence from Slovakia on start-up grants, land, credit, and administrative constraints by Jan Pokrivčák, Štefan Bojnec, Marián Tóth and Jozef Palkovič
3. Impact of the adoption of chemical inputs on crop yield downside risk by Olha Aleksandrova and Štefan Bojnec

The three studies jointly examine how the design and implementation of the Common Agricultural Policy (CAP), institutional conditions and farm-level production decisions affect environmental sustainability, structural resilience and food security in Baltic, Central and Eastern European countries.

The first paper, *Can the CAP Deliver a Green Transition in Baltic, Central and Eastern Europe?*, by Štefan Bojnec, Marián Tóth and Ján Pokrivčák, was accepted for publication in *EuroChoices*. It evaluates the capacity of the CAP 2023–2027 to translate the environmental ambitions of the European Green Deal into measurable changes in the Baltic, Central and Eastern European region. The analysis shows that the environmental effectiveness of the CAP depends strongly on national Strategic Plans, administrative capacity, farm structure and the accessibility of support measures. Area-based payments and administratively demanding schemes often favour larger and better-resourced farms, while small farms face proportionally higher compliance costs and more limited access to eco-schemes and investment support. A more effective and inclusive green transition therefore requires simpler and better-targeted eco-schemes, stronger advisory services, improved monitoring of biodiversity and soil outcomes, and fairer access to support for small, young and women farmers.

The second paper, *Generational Renewal in the European Union Agriculture: Evidence from Slovakia on Start-up Grants, Land, Credit, and Administrative Constraints*, by Ján Pokrivčák, Štefan Bojnec, Marián Tóth and Jozef Palkovič, is under review in the *Journal of Rural Studies*. The study combines Slovak farm-level microdata for 2014–2022 with propensity-score matching and difference-in-differences estimation, complemented by a



survey of young farmers. The results indicate that CAP start-up grants significantly improve labour productivity when supported young farmers are compared with the broader farm population. However, no statistically measurable effects are identified for income or employment. Survey findings help explain these limited impacts: fragmented land ownership, restricted access to land, credit and collateral, irregular calls for applications, lengthy evaluation procedures and excessive administrative requirements can offset the benefits of financial support. The study concludes that stand-alone grants are insufficient to achieve generational renewal. They should form part of integrated support packages combining financial assistance with improved access to land, tailored financial instruments, advisory services and administrative simplification.

The third paper, *Impact of the Adoption of Chemical Inputs on Crop Yield Downside Risk*, by Olha Aleksandrova and Štefan Bojnec, was published in *Agricultural Economics – Czech* in 2025. Using FADN data from Estonia and Slovenia, the study applies propensity-score matching and inverse-probability-weighted regression adjustment to estimate the effects of adopting fertilisers and/or crop-protection products. The adoption of at least one chemical input reduces crop-yield volatility and downside risk in both countries. Its effect on expected crop yield nevertheless differs considerably: adoption increases expected yield by approximately 10% in Estonia but reduces it by 16.2% in Slovenia. These contrasting results demonstrate that the effects of agricultural inputs depend on climatic, structural and production conditions and that uniform policy conclusions should be avoided. Policies should promote efficient and carefully managed input use combined with crop rotation, diversification, irrigation where appropriate, precision technologies and environmental safeguards.

Papers show that policy instruments alone do not guarantee a green, resilient and socially inclusive agricultural transition. Their effects are mediated by national implementation, farm structure, access to land and finance, administrative quality, technology use and exposure to climate risks. The papers therefore directly contribute to WP1 by assessing the environmental and structural effects of the CAP and related production decisions. Their synthesis fulfils the purpose of D1 by providing evidence-based and territorially differentiated policy implications for agricultural sustainability and food security in Central and Eastern Europe.



Can the CAP Deliver a Green Transition in Baltic, Central and Eastern Europe?

By: Štefan Bojnec, Marián Tóth and Jan Pokrivcak

This working paper has been accepted for publishing in scientific journal *EuroChoices*, a peer reviewed outreach journal of the Agricultural Economics Society and the European Association of Agricultural Economists (ISSN 1746-692X).

Summary

The 2023–2027 Common Agricultural Policy (CAP) is presented by the European Commission as a key instrument for supporting the green transition in agriculture across the Baltic, Central and Eastern European (BCEE) region. However, its effectiveness remains uneven. While CAP instruments can support biodiversity conservation, nutrient management, and rural sustainability, their impact is constrained by fragmented farm structures, administrative complexity, differences in national implementation. In practice, area-based payments continue to favour larger farms, limiting smaller farms' participation in green measures. As a result, the CAP serves not only as an environmental policy but also as a significant distributional instrument. Achieving a more effective transition will require simpler eco-schemes, stronger advisory support, and more targeted measures to improve smallholders' access to CAP support.

Keywords: CAP; greening; eco-schemes; sustainability; Baltic, Central and Eastern Europe



From ambitious greening goals to implementation gaps in CEE countries

Greening agriculture in Baltic, Central and Eastern Europe (BCEE) has shifted from aspiration to implementation. The core policy question is whether the Common Agricultural Policy (CAP) can convert environmental ambition into measurable change in a context where outcomes are heavily shaped by fragmented land holdings, the prevalence of small farms, uneven productivity, diverse environmental pressures and varying institutional capacity (...). The key issue is therefore not only whether CAP instruments are green in design, but whether they can effectively change farmer behaviour and sustainability outcomes under the structural constraints in particular in the BCEE countries.

The Farm-to-Fork and Biodiversity Strategies have raised EU-level ambitions to reduce pesticide and fertiliser use, expand organic farming and restore ecosystems. In practice, however, outcomes depend on national CAP Strategic Plans, whose environmental ambition, administrative capacity and efficiency of implementation and control mechanisms differ significantly across BCEE countries. In several of them, this contributes to weaker uptake of more demanding environmental measures.

The European Green Deal and the reformed CAP have raised environmental expectations, but the CAP continues to shape far more than environmental performance alone. It also influences income stability, investment incentives, production choices and the territorial distribution of support. National implementation of the CAP strongly affects all these dimensions and thus plays a decisive role in determining whether higher environmental ambition is translated into tangible change on the ground in BCEE.

The CAP's green architecture operates through three main levers. First, eco-conditionality is a compulsory baseline requirement linked to compliance with GAEC (good agricultural and environmental conditions) standards and relevant SMRs (statutory management requirements), as defined and implemented by Member States or regions within the EU framework. It establishes the baseline standards farmers must meet to receive support.



Their non-compliance may result in administrative reductions of direct payments. The exemption or simplified treatment of small farmers is relevant not only from a compliance perspective but also because of the administrative cost and proportionality issues associated with monitoring and enforcement. Second, eco-schemes provide additional payments to farmers who undertake eligible environmental and climate-related voluntary practices that go beyond the compulsory baseline. Third, rural development measures support longer-term environmental and structural investments.

Gap between EU Ambition and National Implementation

Table 1 shows a persistent gap between EU-level environmental ambition and national implementation. Most BCEE countries have experienced weaker uptake of more demanding eco-schemes and continue to face limitations in monitoring and evaluation capacity (European Commission 2024; EU CAP Network 2024; BirdLife Europe and NABU 2024).

**Table 1. Gap between EU ambition and national implementation across selected BCEE countries**

Country	EU ambition	Implementation gap	Implication
Bulgaria	Stronger biodiversity protection and better-targeted eco-schemes.	EU biodiversity ambition is weakened by low attractiveness and difficult implementation of biodiversity-focused eco-schemes.	Limited biodiversity gains despite formal compliance.
Croatia	Wider eco-scheme uptake among small and fragmented farms.	EU greening ambition is constrained by small-farm fragmentation and complex access conditions for eco-schemes.	Environmental effects depend heavily on farmer uptake and support.
Czechia	Stronger biodiversity, soil, and landscape outcomes.	EU biodiversity and landscape goals are constrained by administrative complexity and demanding compliance requirements.	High-value eco-payments remain underused.
Estonia	Better climate, carbon, grassland, and biodiversity delivery.	EU climate, carbon, biodiversity, and grassland priorities depend on stronger uptake, advisory support, and monitoring to become effective.	High ambition may still yield uneven results.
Hungary	Incentives aligned with biodiversity, soil, and water benefits.	EU green objectives are only partly reflected in farmer incentives, limiting uptake of higher-value environmental practices.	Selective uptake weakens environmental effectiveness.
Latvia	Simplified eco-schemes with high environmental ambition.	EU environmental ambition has exceeded early administrative capacity, requiring simplification to improve eco-scheme uptake.	Wider delivery depends on continued simplification.
Lithuania	Better biodiversity targeting and organic farming expansion.	EU biodiversity and organic farming goals are constrained by small-farm feasibility and weak targeting.	Stronger targeting and monitoring are still needed.
Poland	Greater uptake of demanding environmental practices.	EU greening ambition is weakened by limited uptake of more demanding biodiversity, nutrient, and soil measures.	Greening effects remain concentrated in selected measures.
Romania	Stronger capacity for farm-level green delivery.	EU environmental priorities are not fully translated into farm-level delivery because of administrative and institutional capacity constraints.	Monitoring and implementation capacity remain bottlenecks.
Slovakia	Broader uptake of innovative eco-schemes.	EU ambition for innovative eco-schemes is diluted by preference for administratively simpler, less demanding options.	Good practice remains isolated.
Slovenia	Wider biodiversity, grassland, and organic farming gains.	EU green objectives are supported by targeted measures, but limited scale and farmer engagement reduce systemic impact.	Local success has not yet translated into systemic change.

Source: authors' synthesis from European Commission (2024), EU CAP Network (2024), BirdLife Europe and NABU (2024), and selected national CAP factsheets.



CAP implementation varies widely across BCEE countries, and its effects depend on how Member States – or, in some cases, regions – translate EU-level rules into national priorities, instruments, and administrative practices. Bulgaria, Hungary, Poland, and Romania continue to prioritise income support over stronger environmental measures, whereas Estonia, Latvia, and Slovenia display greater ambition but still face uptake, monitoring, and administrative constraints.

Fragmented Land Holdings

BCEE agriculture is characterised by fragmented land holdings, numerous small farms, uneven productivity, and variable institutional capacity (Figure 1). These conditions shape both the implementation of CAP instruments and farmers' responses to income support, eco-schemes, conditionality, and rural development incentives. The BCEE therefore offers a particularly revealing setting for assessing how policy design translates into economic adjustment and sustainability outcomes under heterogeneous structural conditions.



Figure 1. Farm size composition in selected BCEE agriculture: number of farms vs. utilised agricultural area (UAA), in % (2023)



Source: Authors' calculations based on Eurostat (2026).

Smallholders in BCEE countries face disproportionately high compliance and reporting burdens under conditionality and eco-schemes, which can reduce participation in greener practices. Limited advisory capacity, unclear rule interpretation, and new requirements such as carbon accounting and deforestation-free standards further weaken implementation. Where measures are well designed and adequately funded, however, the CAP can still support nutrient management, biodiversity, and rural sustainability, including



through Smart Villages and LEADER initiatives in lagging rural areas (European Commission 2019, 2024; EU CAP Network 2025).

Do CAP Subsidies Favour Bigger Farms in BCEE?

In BCEE, the CAP has the potential to support the green transition, yet its current implementation continues to favour larger farms over smallholders despite the EU's stated objective of strengthening the position of smaller farms. Area-based direct payments tend, by design, to allocate larger absolute amounts of support to larger farms. This has important implications for both equity and efficiency of support of farms. On the one hand, area payments may support income stability, land management, and continuity of production, especially where larger farms account for a significant share of agricultural output. On the other hand, they may reinforce unequal distribution of support, limit the inclusiveness of CAP benefits, and provide weaker targeting toward smaller or more vulnerable farms. In BCEE countries, CAP subsidies continue to display a strong size bias, with larger farms capturing a disproportionate share of support.

The current EU legislative framework does not oblige Member States or regions to rely exclusively on uniform area-based support (Testa et al., 2025). Within the CAP Strategic Plan framework, Member States have several corrective or redistributive instruments available, including capping, degressivity, redistributive income support, coupled support, and specific schemes for small farmers or young farmers. However, these options are implemented unevenly because they involve political trade-offs, administrative complexity, budgetary redistribution among farm groups, and different national priorities.

Under the CAP 2023–2027, one of the specific objectives is to ensure a fairer distribution of income support through instruments such as degressivity and capping, a priority that has also been maintained in the European Commission's proposals for the post-2027 CAP.

A substantial body of empirical evidence shows that area-based direct payments are capitalised into agricultural land values, with the highest rates of capitalisation occurring when payments are implemented uniformly as fixed payments per hectare without degressivity or payment capping



(Ciaian and Kanacs, 2012; Baldoni and Ciaian, 2023). By increasing land prices and rental values, such payment schemes create barriers to entry for young and beginning farmers (Vranken et al., 2021) while concentrating public support among large farms and reinforcing land concentration. At the same time, evidence suggests that these payments have little effect on investment in large farms, which generally do not face the credit constraints that limit investment (Ciaian et al., 2012, Pokrivcak and Toth, 2020, Fi-Compass, 2020).

To mitigate these effects, the CAP allows Member States to apply degressivity and capping. However, these instruments have been used only to a limited extent, largely because of political economy factors, including the influence of large farm interests and domestic policy preferences (Pokrivčák et al., 2020). Evidence from Slovakia illustrates this pattern: farms that would be affected by capping or degressivity exhibit, on average, lower employment, lower production per hectare, and lower profitability than farms that would remain unaffected. These findings suggest that concentrating support on the largest beneficiaries does not necessarily improve the efficiency of CAP expenditure. Recent evidence further for Saxony and Europe highlights that capping and degressivity involve important trade-offs between redistribution, structural change, environmental ambition and administrative feasibility, particularly when combined with the CAP's new green architecture (Balman et al., 2026).

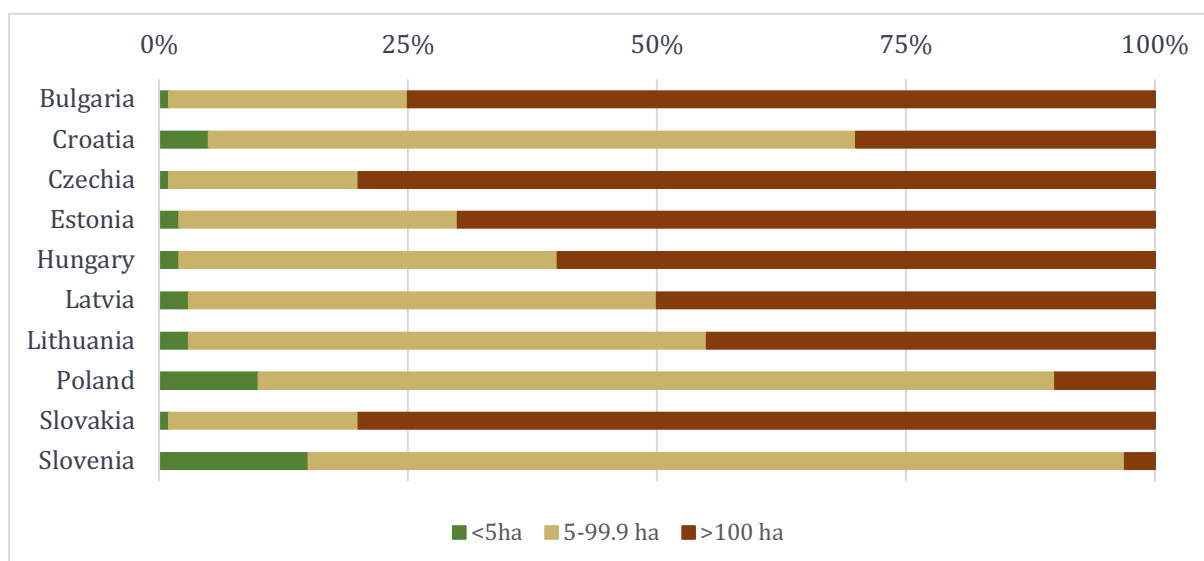
The distribution of agri-environmental payments (payments under Agri-Environment-Climate (AEC) measures, organic farming support, Natura 2000 schemes, etc.) across farm sizes in the EU is highly uneven and generally mirrors the broader structure of the EU's CAP: larger farms receive a disproportionately large share of payments because most environmental schemes are area-based.

Why AEC payments favour larger farms?

Most AEC measures pay farmers per hectare enrolled. Consequently: A 500-ha farm entering an AEC scheme often receives much more than a 20-ha farm implementing similar practices. AEC payments tend to scale with land area. Small farms are often underrepresented in total payment amounts despite making up a large share of beneficiaries.



Figure 2. Distribution of AEC payments by farm size groups in selected BCEE countries, 2023 (share of farms by size category in %)



Source: Authors' extracted from European Commission (2026a)

BCEE countries do not have identical holding structures and therefore do not face the area-payment issue in the same way. Some countries are characterized by a dual structure with very large corporate farms alongside many small or semi-subsistence holdings, while others have more fragmented family-farm structures. Consequently, the distributional effects of area-based payments, and the willingness to correct them through redistributive instruments, differ across BCEE countries. Figure 2 indicates that AEC payments are more concentrated among larger holdings in countries with corporate or cooperate farm structures, such as Czechia, Slovakia, Bulgaria and Estonia. In countries with more fragmented farm structures, including Poland and Slovenia, payments are more widely distributed across small and medium-sized farms, although individual payment amounts are typically lower. The broader regional pattern suggests that the CAP functions not only as an environmental policy but also as a distributional mechanism with substantial structural effects (...; Castaldo et al. 2026).

Country comparisons reinforce this pattern. In Slovakia, the concentration of larger corporate farms channels CAP support through a structure already dominated by large



beneficiaries. In Poland and Romania, where small and medium-sized farms remain far more numerous, the same area-based logic can deepen disparities between farm types and regions (...; Castaldo et al. 2026). Hungary and Bulgaria show a similar tendency, as area-based support and uneven participation in more demanding eco-schemes can still concentrate benefits among better-resourced farms. By contrast, Slovenia combine smaller farm structures with somewhat stronger targeting, but even their limited uptake capacity and administrative frictions can prevent smaller farms from capturing the full benefits of greener measures. Across these settings, better-capitalised holdings are generally better placed to capture CAP advantages unless monitoring, targeting, and advisory support are strengthened. A greener and more inclusive CAP in CEE requires stronger redistributive targeting, simpler access conditions for smaller farms, and advisory support that enables smallholders to participate more fully in environmental and investment measures.

Competitiveness, Policy Trade-offs and Risks

Greening agriculture is not cost-free, and this is where the policy debate becomes most difficult. For European farmers, the transition will gain credibility only if stricter environmental requirements are matched by investment support, advisory services and realistic adjustment pathways. The question is no longer whether to green, but how to do so without undermining resilience, competitiveness and farm viability. This is perhaps even more relevant in the case of BCEE farmers.

The CAP is thus not only a source of environmental opportunity, but also a key arena of policy trade-offs. Well-designed and adequately funded measures can improve nutrient management, enhance biodiversity and support rural sustainability through European Agricultural Fund for Rural Development investments in digitalisation, energy efficiency and diversification. Smart Villages and LEADER initiatives can also strengthen social sustainability in lagging rural areas, but their broader impact depends on local



implementation capacity and on how effectively project-based support is linked to wider territorial development strategies.

CAP can introduce clear distributional biases when area-based payments, co-financing requirements and administrative complexity favour better-resourced farms (Ciaian and Kanacs, 2012; Pokrivcak et al., 2020; Baldoni and Ciaian, 2023). This is already possible, even if a limited extend, in the current legal framework, optional for the Member States.

This is particularly consequential in most BCEE countries, where small farms remain predominant, even if Slovakia stands out structurally with its large corporate holdings (...). In Slovakia, this leads to a disproportionate share of support flowing to already large beneficiaries, while in Poland and Romania the same payment logic restricts many small and semi-subsistence farms' access to investment-oriented measures. In Bulgaria and Hungary, uneven uptake of more demanding eco-schemes can likewise concentrate environmental payments among better-capitalised farms, reinforcing inequalities in both income support and access to green transition funding.

These effects go beyond income distribution. The CAP's environmental and redistributive reforms need to be considered alongside potential implications for agricultural production and the CAP's production-policy dimension as it also continues to shape agricultural production incentives and, consequently, overall production levels. Although the paper does not aim to provide a full assessment of the production effects of decoupled direct payments, we acknowledge that their possible reduction or cancellation may influence farm production decisions, income stability, land use, and the sector's capacity to maintain output, particularly in CEE countries where farm structures, income dependence on direct payments, and adjustment capacities differ considerably. They shape generational renewal, land market dynamics and access to sustainability-oriented investment. Such constraints are particularly acute for young and women farmers, who often face weaker access to land, credit, advisory services and investment finance, limiting their ability to participate fully in greener transitions. Gender impacts are also likely to be uneven: women remain under-represented among farm managers and typically operate smaller farms,



while younger women still account for only a small share of new farm holders. Compliance-intensive support systems therefore risk entrenching existing barriers to land, finance and participation unless advisory and investment support are more effectively targeted (European Commission 2024, 2026b; Eurofound 2025; Dodsworth et al., 2025).

What Should Happen Next?

Although the CAP offers a crucial framework for advancing environmental sustainability in BCEE countries, its real impact is shaped by national priorities, administrative capacity and farm structures. Greening effects are strongest where eco-schemes are ambitious and adequately funded, and weaker where administrative burdens discourage participation or where policy priorities still favour income support over environmental performance (Anoumar et al., 2025). Looking towards 2030 and the next CAP, a more effective green transition will require stronger implementation capacity, closer alignment of CAP instruments with Green Deal targets, improved monitoring of biodiversity and soil outcomes, and simpler, better-targeted eco-schemes backed by advisory services, particularly for smallholders (Dodsworth et al., 2025; Röder 2025; Latacz-Lohmann et al., 202; Pokrivcak et al. 2025).

Policy priorities

- Target CAP support more inclusively so young and women farmers can participate fully in the green transition.
- Target CAP support more fairly, so smaller farms can access green and investment measures.
- Simplify eco-schemes and compliance rules to raise uptake in structurally fragmented farm systems.
- Strengthen advisory and monitoring capacity so green objectives translate into measurable outcomes.

Taken together, these policy priorities underline the paper's conclusion: the CAP can support a greener transition in BCEE only if implementation focuses on specific areas where implementation could be improved while maintaining policy effectiveness. Fairness



and simplification should not weaken the CAP's capacity to support viable agricultural production, income stability, and environmental delivery.

The CAP can support a green transition in BCEE, but it will not deliver one fully under current conditions. Uneven national ambition, weak administrative and advisory capacity, limited monitoring, and subsidy patterns that favour larger farms all constrain its impact. The European Commission's (2025) proposal for the CAP 2028–2034 moves partly in the direction proposed here: it emphasises of payments fairer and more targeted income support, introduces degressive area-based income support and capping, simplifies the delivery model, and gives Member States greater flexibility to adapt measures to national and regional needs. However, the proposal also raises important concerns. Greater flexibility may improve feasibility and reduce simplified administrative burdens, especially procedures for smaller farms, but it may also weaken common clearer eligibility rules for eco-schemes, stronger advisory support, improved monitoring of environmental outcomes ambition if not accompanied by clear safeguards, reliable funding for environmental and climate actions, and stronger monitoring of outcomes. In this sense, the proposed CAP appears to offer more simplification and more Member State discretion, but not necessarily stronger environmental commitments. Real progress will therefore depend on whether flexibility is used to design simpler, better-targeted and more attractive environmental measures than to dilute obligations. For BCEE countries, this makes simplified administrative procedures for smaller farms, clearer eligibility rules for eco-schemes, stronger advisory capacity, transparent targeting, improved monitoring and stronger institutional capacity to convert policy ambition into measurable economic, environmental and social sustainability outcomes even more important.



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Generational renewal in the European Union agriculture: Evidence from Slovakia on start-up grants, land, credit, and administrative constraints

By: Jan Pokrivčák, Štefan Bojnec, Marián Tóth and Jozef Palkovič

This working paper is under 3. review in the scientific Journal of Rural Studies, a peer reviewed academic journal published by Elsevier.

Abstract

This paper examines how generational renewal in the European Union is affected by subsidies from the Common Agricultural Policy, land and credit market imperfections, as well as by institutions related to excessive bureaucracy. The study employs quantitative techniques to provide a comprehensive analysis of the research questions. First, we employed counterfactual analysis to assess the impact of start-up grants for young farmers based on a national panel micro-level data in the 2014-2022 period from Slovakia to rigorously evaluate the effectiveness of these support measures. Second, a voluntary online survey of young farmers was conducted to evaluate their experiences and perspectives regarding land and credit markets, administrative constraints and financial support. Start-up grants are associated with significantly higher labor productivity among supported young farmers compared with the overall farm population, but no measurable effects are found on income, employment, or other farm performance indicators. The effects of start-up grants depend heavily on the quality of their management and administration. In Slovakia, persistent land and credit market inefficiencies pose a significant barrier for young people to enter farming. Moreover, the negative effects of land and credit market constraints, along with excessive bureaucratic red tape hurdles, often counterbalance the limited positive effects of start-up grants, ultimately hindering generational renewal in farming.

Keywords: Young farmers, Common Agricultural Policy, subsidies, land market, credit market, institutions

JEL Classification: Q12, Q16, P26



1. Introduction

Generational renewal in agriculture is a critical challenge across European countries (Bertoni and Cavicchioli, 2016; Meijers and van der Wouw, 2019; Coopmans et al., 2021; Llorent-Bedmar et al., 2021; Sutherland, 2023; Mattas et al., 2024; Garner et al., 2025). We examine Slovakia, the European Union (EU) member state, where the average age of farmers is rising, and youth participation is declining (European Court of Auditors, 2017; Jepsen et al., 2015; Eurostat, 2023). With young farmers – typically defined under 40 years old – forming a shrinking share of farm holders, the sector's long-term sustainability, innovation capacity, and socio-economic vitality of rural areas are at risk (Borda et al., 2023; González and Soler-Vaya, 2024; Zorn, 2025).

The young farmer's concern in the EU refers to the persistent obstacles to entry and succession that challenges generational renewal in the agricultural sector (Zagata and Sutherland, 2015; Zagata et al., 2017; Adam et al., 2025). Generational renewal has already been one of the serious concerns of the Common Agricultural Policy (CAP) of the EU (Balezentis et al., 2020). To reverse the ageing of farmer population the CAP relied on providing financial incentives that support start-ups or intergenerational transfer of farms from older generation – parents (Pietola et al., 2003; Milone and Ventura, 2019). Despite targeted policies and funding, the proportion of farmers under 40 remains low at around 11% of EU farm holders (Eurostat, 2023).

In the programming period 2007–2013 EU allocated to support young farmers 3.23 billion EUR in the rural development pillar of the CAP, while in the programming period 2014–2020 6.42 billion EUR was earmarked for young farmers, 3.8 billion EUR from the rural development pillar and 2.62 billion EUR from the CAP direct payments pillar. This expansion underpins the CAP 2023–2027 approach, where EU member states should program young-farmer support in their CAP Strategic Plans, including a minimum 3% of direct payments (e.g., complementary income support) alongside start-up and investment aid; post-2027 discussions increasingly emphasize more integrated generational renewal packages that also tackle land access, finance, skills and succession.

Support for young farmers was introduced in the EU in 1980s. From the year 2000 young farmers were supported within the rural development pillar of the CAP, which financed measures on establishing farms. In the programming period 2014–2020 92 of 118 rural development programs adopted in EU member states contained a measure supporting young farmers. Although financial subsidies have been allocated to support young farmers, the challenge of an ageing farmer



population in the EU persists. The share of young farmers in the total farmer population has remained literally unchanged, indicating that current policy measures have yet to produce a significant generational renewal in the sector.

This paper examines generational renewal in Slovak agriculture as shaped by CAP support and the rural conditions that determine whether new entrants can establish viable farms. Slovakia is selected as an analytically informative EU case because it combines the CAP policy framework with unusually binding entry constraints such as highly fragmented land ownership alongside concentrated land use (often via long-term leases), limited collateral and rural credit, and sizeable administrative frictions in program delivery. These features are not unique to Slovakia but are characteristic (to varying degrees) of several post-socialist EU member states; they therefore provide a useful setting to study how EU-wide CAP instruments translate into outcomes under weak factor markets and constrained institutional capacity. We use Slovak start-up grant microdata together with survey evidence to identify mechanisms through which land, finance and implementation frictions can offset financial incentives, helping to explain why CAP young-farmer measures deliver heterogeneous – and often modest – effects across the EU member states.

The primary objective is to assess whether CAP start-up grants for young farmers in Slovakia lead to measurable improvements in farm economic performance and thus contribute to generational renewal. Using farm-level microdata, we estimate effects on income related indicators, employment and productivity, and interpret the results considering the contextual constraints in an inefficient land market, an underdeveloped financial market particularly for small firms and suboptimal functioning of government institutions.

The paper has two objectives. First, we quantify the effect of CAP start-up grants for young farmers in Slovakia on farm economic performance using counterfactual methods and farm-level microdata. Second, we document the implementation context in which these start-up grants operate – coverage, timing and administrative processes – and link it to young farmers' reported constraints to interpret why estimated effects may be modest. The analysis is guided by four research questions (RQ) that map directly onto the empirical components and the results presented:

RQ1 (program implementation): How were CAP start-up grants for young farmers implemented in Slovakia in 2014–2022 in terms of uptake, acceptance rates, and administrative timing (calls, approvals, and payments)?



RQ2 (average impacts): What is the average treatment effect of receiving a start-up grant on supported young farms' economic outcomes – income/profit indicators, revenues, labor input/employment, and labor productivity – relative to comparable non-supported farms?

RQ3 (heterogeneity and robustness): Are estimated impacts robust to alternative comparison groups and matching specifications, and do effects differ depending on the available control pool (young-farmer controls versus all-farm controls)?

RQ4 (mechanisms and constraints): Which constraints reported by young farmers – especially access to land, access to finance, and administrative burden – help explain the magnitude and direction of the estimated impacts?

This paper contributes to rural-studies debates on generational renewal by integrating together evidence on how policy support, rural factor markets and institutional arrangements shape young farmers' entry and early trajectories. First, focusing on Slovakia as a post-socialist context characterized by fragmented land ownership and uneven access to finance, we provide a counterfactual assessment of the farm-level effects of CAP start-up grants using linked administrative and financial microdata for 2014–2022. Second, we complement the quantitative econometric evaluation with a survey of young farmers (2024), allowing us to connect measured outcomes to the everyday constraints that mediate policy effectiveness, i.e., land access, credit-market constraints and administrative burden. Third, by analyzing both impacts and mechanisms, the article offers policy-relevant insights for designing more enabling rural environments for new entrants, highlighting that generational renewal is unlikely to be achieved through financial incentives alone without complementary measures that improve access to land and finance and reduce transaction costs in program delivery.

The paper is organized as follows: The next section provides a literature review on the impacts of young-farmer support measures – especially CAP start-up grants and related instruments – on farm economic performance, and discusses how land access, credit constraints, and administrative burden shape these impacts. This is followed by an overview of the situation of young farmers in Slovakia and the EU, with particular attention to the state of land and credit markets in Slovakia from the perspective of young and small-scale farmers. Subsequently, methodology is described, and the results are presented and discussed. Finally, the paper concludes with a summary of key findings and implications.



2. Literature Review

2.1. Analytical framing and research gaps in generational renewal in EU agriculture

The literature highlights that the challenges facing young farmers in the EU are multifaceted, reflecting a complex interplay of policy, structural, financial, administrative, and socio-cultural factors (Vaishar et al., 2020; Giannakis and Bruggeman, 2020; Castillo et al., 2024). These issues contribute to pronounced regional and rural disparities in economic resilience, making generational renewal in agriculture a persistent concern across the EU (Coopmans et al., 2021). Targeted CAP measures such as start-up aid and Rural Development Programs (RDP) have achieved mixed or only limited success in overcoming persistent structural barriers within the agricultural sector (Pechrová and Šimpach, 2020; Licciardo et al., 2022; Sutherland, 2023; European Parliament, 2023).

Research on generational renewal increasingly treats low entry and succession rates as the outcome of interacting constraints with three strands that are often examined in parallel (Zagata et al., 2017; Mattas et al., 2024; Carbone et al., 2024): (i) the design and targeting of CAP young-farmer instruments (e.g., start-up aid, top-ups, and rural development measures), (ii) structural conditions in factor markets – especially access to land and finance – and (iii) the enabling institutional environment, including administrative capacity and the transaction costs created by complex procedures. For the purposes of this paper, the key implication is that the effectiveness of financial incentives cannot be inferred from program design alone: estimated impacts depend on how support is implemented (selection, timing, and administrative frictions) and on whether land and credit markets allow beneficiaries to translate subsidies into viable investment and productivity gains.

Building on this framing, two gaps are particularly relevant for post-socialist EU member states such as Slovakia. First, there remains limited *micro-level, counterfactual* evidence on whether start-up grants measurably improve young farms' economic performance under markedly different farm structures and factor-market conditions. Second, while land access, credit constraints, and administrative burden are frequently identified as barriers, they are less often integrated into a single explanation of *why* program effects are heterogeneous or modest – i.e., whether outcomes reflect binding land/finance constraints that offset the subsidy, implementation bottlenecks that reduce its real value, or both. The next subsections therefore review evidence on young-farmer support instruments and their impacts, land and finance constraints, and institutional quality, before



synthesizing how these strands motivate the paper's empirical design and research questions for Slovakia.

2.2. Support measures for young farmers

CAP support for young farmers combines recurring payments (e.g., Pillar I top-ups) with one-off start-up/installation aid and, in some countries, national schemes (Zagata et al., 2017; Mattas et al., 2024; European Commission, 2025). These instruments aim to relax short-run liquidity constraints and support entry and early investment, but effects on medium-term performance (income/profit, employment, productivity) are typically modest and heterogeneous, depending on program design and targeting, selection rules, and the local context in which beneficiaries operate, especially access to land and credit and the administrative burden that shapes uptake and the real value/timing of support (Zagata et al., 2017; Mattas et al., 2024; Carbone et al., 2024; European Commission, 2025).

In Slovakia, existing assessments similarly stress that implementation frictions (irregular calls, slow processing, complex administration) and binding land/finance constraints can dilute the effectiveness of young-farmer support (European Court of Auditors, 2017; Fi-Compass, 2020; European Commission, 2022; EU CAP Network Evaluation Helpdesk, 2025), motivating the closer focus on these mechanisms.

2.3. Rural factor markets: access to land and capital

A recurring finding across systematic and policy reviews is that the core constraints for new/young farmers are access to land, access to capital/finance, fragmented land ownership, low profitability of small farms, inadequate training and skills / managerial capacity (Williams, 2006; Hamilton et al., 2015; Nolan et al., 2024). In addition, rural demographic decline and social perceptions are that farming is unattractive (Fi-Compass, 2020; European Commission, 2022; Da Silveira et al., 2023; Zorn, 2025). These barriers are repeatedly found in cross-country analyses and policy evaluations (European Parliament, 2023; European Commission, 2025). These barriers are particularly acute in Slovakia due to its post-socialist land restitution legacy and regional disparities (Jepsen et al., 2015). The land restitution process in Slovakia fundamentally reshaped post-socialist rural space by reallocating agricultural and forest land back to pre-1948 owners or their heirs. Restitution profoundly affected rural land ownership structures, farm consolidation, and



the re-emergence of family farming, but was constrained by strict deadlines and numerous exclusions that left many rural properties unresolved (Sudzina, 2025). Replacement land and compensation mechanisms – often insufficient or poorly matched – created fragmented landscapes and uneven rural development outcomes. The transformation of cooperatives further redefined rural economies: individuals who resumed farming gained tangible assets, while holders of share certificates were disadvantaged. These processes have reinforced rural inequalities, affected land markets, and contributed to the socio-spatial reconfiguration of rural areas in post-socialist Slovakia.

According to the literature, young farmers can better fulfill strict requirements of the EU on agricultural and food production than older generations of farmers (Defrancesco et al., 2008; Sponte, 2014, Hamilton et al., 2015). Main contributions of young farmers are introducing innovations and new technology to agricultural production and marketing (Jansuwan and Zander, 2022, Gkatsikos et al., 2022, Elbasi et al., 2023, USDA, 2024).

McDonald et al. (2013; 2014), Caputo (2018), and others conclude that RDP support helped young farmers to enter the sector and was crucial for introducing innovative forms of farming (Kontogeorgos et al., 2014; De Rosa and McElwee, 2015; Adamowicz and Szepeluk, 2016; ENRD, 2017) and increased income (Buysse et al., 2011). However, Carbone and Subioli (2008) argue that support was distributed inefficiently, while CEJA (2010) concludes that a stricter definition is needed for young active farmers. Despite some deficiencies, RDP support measures can help to create more resilient farms among young farmers, particularly when complemented by effective targeting and additional support mechanisms (DG AGRI, 2012; Davis et al., 2013).

European Court of Auditors (2017) and others found that RDP support measures were not fully efficient because of the existence of other constraints in land and credit markets or in the form of prohibitive bureaucracy. DG AGRI (2012), Rovný (2016), and others contend that support is too low to make a significant contribution to the economic parameters of young farmers.

Financial constraints and credit access limitations are key barriers. Young farmers in Slovakia often lack the collateral needed for traditional bank loans due to small farm sizes and limited personal wealth (Fi-Compass, 2020). This constraint reduces their ability to invest in machinery, inputs, or diversification strategies essential for competitiveness. While CAP provides direct payments and installation aid for young farmers, financial support alone is often insufficient or accompanied by complex administrative hurdles that limit accessibility (European Commission,



2022). The European Court of Auditors (2017) emphasizes that financial instruments must be complemented with targeted advisory and mentoring support. For example, participatory extension can reshape a farming culture and influence improvements in the quality of institutions (Knook and Turner, 2020). Farm advisors can help to improve farm business performance (Moojen et al., 2023), and efforts should be made to encourage farmers' participation in agricultural education and training programs (Ashfield et al., 2020; Charatsari et al., 2025). Emerging research in EU countries suggests that innovative financial mechanisms such as public loan guarantees and blended finance models can improve young farmers' credit access (Borda et al., 2023). Integrated support models combining financial aid, business training, and mentorship show promise in other EU contexts, improving both farm viability and farmer confidence (European Commission, 2025). However, there is limited empirical evidence evaluating such integrated approaches in Slovakia, and such solutions remain underexplored.

Structural barriers with insufficient access to land are considered the biggest obstacle to generational renewal in farming (ADAS, 2004; Williams, 2006; Carbone and Subioli, 2008; CEJA, 2010; EC, 2012; Carillo et al., 2013; DG AGRI, 2015; Adamowicz and Szepeľuk, 2016; Zagata et al., 2017). Access to land is widely identified as a core obstacle for young farmers in Slovakia. The restitution process following the fall of socialism led to highly fragmented and parceled land ownership, often limiting the ability of new entrants to accumulate viable farm sizes (Jepsen et al., 2015; Lazíková et al., 2017; Izakovičová et al., 2022). Land prices, especially in fertile areas, have risen sharply, exacerbating entry barriers for youth without inherited land (Fi-Compass, 2020). Several studies highlight that young farmers in Slovakia typically operate smaller farms with less productive capacity, which reduces profitability and inhibits investment in modernization (European Court of Auditors, 2017). This small farm-size trap creates a cycle where low returns discourage expansion and innovation. Comparative research from other EU countries, like Portugal, shows similar challenges but also innovative policy responses such as land banks or long-term leasing programs, which are largely absent or underdeveloped in Slovakia (Eistrup et al., 2019). This highlights a critical knowledge gap and policy opportunity.

2.4. Quality of institutions and enabling environment

Excessive bureaucracy reduces the efficiency of support to young farmers (Carbone and Subioli, 2008; Adamowicz and Szepeľuk, 2016; EIP-AGRI, 2016; Zagata et al., 2017) and increases



operational costs and expenditures of young farmers on consulting services (Carbone and Subioli, 2008; ENRD, 2017). Administrative burdens, training, and advisory services represent additional constraints. Complex CAP application procedures and eligibility criteria present non-trivial barriers, particularly for new and young farmers unfamiliar with bureaucratic processes (European Commission, 2022). In Slovakia, advisory services and training opportunities for young farmers remain fragmented and insufficiently linked to financial support programs (Fi-Compass, 2019).

Beyond economic and administrative factors, social, cultural, rural infrastructure and lifestyle considerations significantly influence youth engagement in agriculture (Chmielinski and Karwat-Woźniak, 2015; Hammersley et al., 2023). Studies indicate that young people perceive farming as a high-risk, low-status occupation with limited social amenities, which discourages rural residency and entrepreneurship (Jepsen et al., 2015; Heaberlin and Shattuck, 2023; Garner et al., 2025). Rural depopulation, limited healthcare, education, and leisure facilities compound these challenges (Riethmuller et al., 2025). Research points to the importance of critical issues of the social security and pension provision system for the self-employed farmers, balancing work-social security-pension life balance as a critical factor for young farmers' retention (Hayden et al., 2025; Hlochova et al., 2025). Motivation, perceptions, and non-economic factors (family background, cultural image of farming, expectations for quality of life) strongly affect youth decisions to enter or stay in agriculture. Studies show that youth from farming families are more likely to enter farming, while others emphasize the role of entrepreneurship education and non-farm rural opportunities (Li et al., 2019; Unay-Gailhard and Bojnec, 2019; Angioloni et al., 2024; Holmes et al., 2025).

3. Slovak agriculture and the main challenges facing young farmers

3.1. Contextual background and conceptual definitions

Structure of Slovak agriculture and rural context. Slovak agriculture is shaped by a post-socialist dual structure in which land ownership is highly fragmented while land use is comparatively concentrated through large corporate farms and long-term lease arrangements. This structure influences both factor markets and the feasibility of entry for new farm holders. At the same time, rural areas face demographic ageing and out-migration of younger cohorts, which reduces the pool of potential successors and reinforces the policy relevance of supporting generational renewal.

Key concepts used in this paper. To avoid definitional ambiguity, we use the following terms consistently throughout the paper.



Young farmer refers to a farm holder/manager who meets the CAP legal age criterion (≤ 40 years in the year of application) and is establishing for the first time as head of holding; where descriptive statistics rely on Eurostat age brackets, we operationalize young farmers as managers aged ≤ 39 in line with available categories.

Land market denotes both the market for ownership transfers (sales) and, crucially in Slovakia, the market for land use rights (rental and long-term leases), including access to land administered by the Slovak Land Fund (SLF).

Credit market refers to the supply of and demand for loans for farm establishment and investment, mediated by commercial banks and public financial instruments; we use *financing gaps* to describe the shortfall between young farmers' viable demand for credit and the credit actually supplied (e.g., due to collateral constraints, risk perceptions, and product design).

Institutions refer to the public bodies and rules that govern access to CAP support and to land and finance (notably the Agricultural Paying Agency or APA and the SLF), as well as the administrative procedures that create transaction costs, delays, and compliance burdens for applicants.

Young farmers in Slovakia (incidence and typical farm size). Based on Eurostat (2023), young farm managers (≤ 39) represented about 20% of farm managers in Slovakia (3,850) in 2020 (EU average: 11.9%). Administrative data from the APA show that 726 of the 17,056 direct-payment applicants in Slovakia received Complementary Income Support for Young Farmers (CIS-YF) in 2023, equivalent to approximately 4.3%. Most of these CIS-YF beneficiaries operated holdings below 100 ha, including many micro- and small holdings, which limits collateral availability and their capacity to expand through land purchases.

Land access and the land market. The Slovak land market is characterized by extreme fragmentation of ownership, which raises transaction costs and complicates consolidation for new entrants. The total agricultural area is about 2.39 million ha and is split across a very large number of owners and parcels; parcels are often small and co-owned by multiple individuals, including absentee and unknown owners, which increases coordination costs and legal uncertainty. In this setting, access to land is often mediated through rental and long-term lease arrangements rather than purchase, and entry is further shaped by the functioning of the SLF, which manages state land and land of unknown owners and allocates land through administrative procedures.



Land fragmentation has historical roots (inheritance practices, socialist-era separation of ownership from use, and post-1990s restitution) and persists through complex co-ownership, unresolved inheritance, and incomplete records. These features contribute to thin local land markets, long negotiation chains, and high legal/administrative costs, which particularly disadvantage young farmers without inherited land or established local networks.

The SLF manages state land and land of unknown owners and rents it out to farmers. Although SLF rules formally prioritize young and small farmers, evidence and stakeholder accounts suggest that only a limited area has been effectively channeled to these groups, while long-term leases and incumbent users can constrain entry. As a result, young farmers often face long waiting times, limited availability of suitable plots, and substantial administrative burdens when seeking land through SLF.

The land owned by the state is managed by the SLF, which also manages the land of unknown owners. SLF manages about 20.5% of agricultural land (6.4% state land and 14.1% of land of unknown owners) (SLF, 2022), which it rents out to farmers. SLF is obliged by the law to give preference to young farmers and small farmers. However, the SLF rented only a very small area to small farms or young farmers.

Access to finance and the financing gap. Young farmers' financing constraints in Slovakia reflect limited access to loans, insufficient collateral (linked to small farm size and limited asset endowments), and lenders' risk perceptions. Following the European Investment Bank (EIB, 2020), the overall financing gap in Slovak agriculture is estimated at about EUR 140–316 million, with a large share concentrated among small farms (up to 20 ha) and a substantial portion attributed to young farmers; the gap is particularly pronounced for long-term investment loans that are critical for modernization and growth.

Survey evidence from the EIB (2020) further indicates that a high share of rejected (yet potentially viable) loan applications in Slovak agriculture comes from farmers under 40, and that discouragement from applying is non-trivial. These patterns are consistent with a credit environment where collateral requirements, limited credit history, and product design restrict young farmers' ability to finance investment even when subsidies are available.

3.2. Slovakia: design and implementation of young-farmer support (policy context)



Because Slovakia is the empirical focus, this section provides the policy context needed to interpret the empirical results. Young-farmer support in 2014–2022 combined (i) Pillar II RDP start-up aid (sub-measure 6.1), allocated through discrete competitive calls and implemented by the APA under the Managing Authority (MARD SR), and (ii) a Pillar I young-farmer top-up payment to eligible hectares under the direct payments system (Regulation (EU) No 1307/2013). These design features matter for RQ1, which documents uptake, approval, and timing (calls–approval–payment), and for RQ2–RQ3, because eligibility, selection and payment timing shape the treated group and the comparison strategy.

The Slovak RDP sub-measure 6.1 (start-up aid) provided a flat-rate start-up grant of EUR 50,000 per supported young farmer, paid in two instalments conditional on a business plan (European Court of Auditors, 2017; European Commission, 2022). Eligibility requirements in call documentation include applicant age ≤ 40 ; first establishment as head of holding (and effective control/management for legal persons); and documentary verification of business history and farm economic size (standard output), including a stated range of EUR 10,000–50,000 in the 2022 call (APA call notice, 2020; MARD SR notice, 2022). For RQ1, these rules define the pipeline from application to contracting and payment; for RQ2–RQ3, they motivate careful construction of comparable non-supported farms and robustness checks given non-random selection.

Implementation relied on a small number of calls, with indicative budgets that constrain coverage (e.g., EUR 24.5 million outside Bratislava and EUR 0.5 million for Bratislava in the 2015 call; eu-fondy.sk, 2015) and with processing times that can create sizeable lags between calls, approvals and payments. These features are central to RQ1 (administrative timing) and provide context for interpreting estimated impacts in RQ2–RQ3 when outcomes are measured relative to the timing of support.

Pillar I young-farmer payment in Slovakia is also applied as an annual *per-hectare* young-farmer top-up (typically for up to five years from first application) alongside the baseline direct payments (European Commission, 2016; Schwarcz, 2022). In this study, the Pillar I top-up is treated as part of the broader support environment: it may affect liquidity and interacts with land access (hectare-based eligibility), which is relevant when interpreting constraints and mechanisms in RQ4.

3.3. Integrated administration and control system (IACS) of start-up grants



In the programming period 2014–2022, young farmers in Slovakia were supported under the RDP through Measure 6.1: Aid for Starting Business Activities for Young Farmers (start-up grants). This support was provided to assist young farmers in starting their livestock and specialized crop production and implementing their business plans.

The aid consisted of a flat payment of 50,000 EUR per young farmer, distributed in two instalments over a maximum of five years. 70% of the support was paid upon signing the Agreement, and the remaining 30% was paid after the successful implementation of the business plan. The APA announced three calls under Measure 6.1.

According to IACS evidence for the 2014–2022 period, a total of 2,411 applications for start-up grants in Slovakia were submitted, requesting 120.55 million EUR. Of these, 952 applications were approved, amounting to 47.61 million EUR in funding.

Out of the 952 approved projects, 925 were implemented. As of January 2024, 24.92 million EUR had been paid. Young farmers primarily applied for support for small farms. The average farm size of successful applicants was 17 ha in the first call, 29 ha in the second call, and 24 ha in the third call.

The administration by the APA was slow, and the process from the call until signing contracts varied. For the 2015 call, the process took five years. The 2020 call required over 3.5 years, while the 2022 call was completed within 22 months. Slovakia prioritized projects in regions with high unemployment, self-employed farmers, and the level of standard output as a measure of economic firm size in each call.

Reviews and Slovak evidence among implementation challenges highlight recurring frictions – irregular calls, complex documentation/controls, and slow evaluation and payment processing – which can lower take-up and reduce the effective value of support through delays and compliance costs (European Court of Auditors, 2017; Fi-Compass, 2020; European Commission, 2022). These frictions are documented empirically in RQ1 (uptake, approvals, timing) and are used to interpret why estimated program effects may be modest or heterogeneous in RQ2–RQ4, particularly when land and credit constraints limit beneficiaries’ ability to convert the grant into sustained performance gains.

In sum, this section operationalizes the Slovak policy setting for the research questions: RQ1 draws on the call-based design and administrative pipeline; RQ2 estimates average effects of receiving the start-up grant; RQ3 tests robustness to alternative comparison groups under non-



random selection; and RQ4 interprets impacts using constraints that interact with these measures (land access, finance, and administrative burden).

Main challenges facing young farmers (and implications for this study). Taken together, the Slovak context suggests that generational renewal is shaped by interacting constraints: (i) limited and costly access to land under fragmented ownership and lease-based land use; (ii) restricted access to credit due to collateral and risk constraints, producing a persistent financing gap; and (iii) institutional and administrative frictions in land allocation and CAP program implementation that raise transaction costs and delay support. These conditions motivate our empirical strategy on how we measure young farmers' reported constraints through the survey and how we estimate the causal impacts of start-up grants using farm-level microdata. This paper follows an explanatory mixed-methods design. The core contribution is a counterfactual econometric evaluation of CAP start-up grants using farm-level administrative data to estimate causal effects on economic performance. Survey evidence is used as a complementary analytical component to interpret these estimates and to identify mechanisms—particularly land access, credit constraints, and administrative burden—that cannot be observed in secondary data but help explain the magnitude and heterogeneity of the econometric results.

4. Data and Methods

The empirical strategy combines a counterfactual econometric analysis with survey evidence in an explanatory sequence. The propensity score matching difference-in-differences (PSM-DiD) approach identifies the average treatment effects of start-up grants on farm performance. The survey of young farmers is not used for causal inference; instead, it serves to contextualize and interpret the econometric findings by documenting institutional constraints and farmers' experiences that may shape observed outcomes.

4.1. Survey

The target population comprised young farmers operating in Slovakia. The survey was administered through Microsoft Forms between 2 and 26 October 2024. The Association of Young Farmers in Slovakia (ASYF) distributed the invitation and questionnaire link through its network of young farmers, which covers all active young farmers across Slovakia. Participation was voluntary and anonymous. Eligibility was based on recruitment through the ASYF network and



respondents' self-identification as young farmers; identities were verified against ASYF database, but beneficiary status was not verified against administrative records. A total of 118 responses were obtained. To assess the representativeness of the sample, the farm-size distribution of respondents was compared with administrative data for the 726 recipients of CIS-YF in Slovakia in 2023 (Table 1). A goodness-of-fit test indicated no statistically significant difference between the two distributions ($p = 0.925$). The 726 CIS-YF beneficiaries were used solely as an external administrative benchmark and not as the survey sampling frame or denominator for calculating a response rate.

Table 1

Farm-size structure of CIS-YF beneficiaries (2023) and surveyed respondents (2024) in Slovakia

Farm size in ha	All CIS-YF beneficiaries		Surveyed YF	
	No.	Share in %	No.	Share in %
0 – 5	88	12.1	17	14.4
6 – 20	204	28.1	30	25.4
21 – 50	223	30.7	37	31.4
51 – 500	196	27.0	32	27.1
500+	15	2.1	2	1.7
Total	726	100.0	118	100.0

Source: APA, survey results

The survey consisted of 38 questions divided into four thematic sections. The first section focused on respondent characteristics, including legal form of the farm, farm size, type of agricultural production, farm origin (new entrant versus successor), educational background, and motivations for entering farming. The second section examined respondents' experience with CAP support in Slovakia, covering both direct payments and rural development measures, with particular attention to administrative burdens, timing of payments, and perceived effectiveness. The third section addressed access to land, investigating young farmers' land demand, key barriers to land acquisition, and the role of the SLF. The final section concentrated on access to loans, exploring demand for finance, major financial constraints faced by young farmers, and the role of commercial banks in supporting farm investments in Slovakia.

Information on farm origin was provided by 115 respondents. Of these, 85 respondents (73.9%) had established a new farm and were classified as new entrants, while 30 respondents (26.1%) had



taken over an existing farm and were classified as successors. Three respondents did not answer this question.

A Likert scale was employed to assess the level of agreement, with responses ranging from 1 (strongly disagree) to 5 (strongly agree). The significance of differences in evaluations of responses was assessed by the Friedman test with subsequent Nemenyi procedure.

Differences between new entrants and successors were explored using the Mann–Whitney U test for ordinal variables and the chi-squared or Fisher’s exact test for categorical variables. Three respondents with missing information on farm origin were excluded from these comparisons.

4.2. Counterfactual analysis

We use individual farm-level data on young farmers in Slovakia from two datasets:

First, an integrated administration and control system (IACS) from 2014 to 2022 for the identification of young farmers supported and not supported by start-up grants in Slovakia.

Second, the dataset of the Ministry of Agriculture and Rural Development in Slovakia (Information letters) on financial performance (revenues, costs, and profit), production structure and labor input. The years 2018 and 2021 were selected to reflect medium-term post-treatment outcomes following the main support calls under RDP Measure 6.1. Given that start-up grants are paid in instalments and tied to business-plan implementation, immediate short-term effects are not expected. Observations several years after approval better capture realized economic impacts. Using two distinct post-treatment years allows us to assess the stability of estimated effects over time and to distinguish between short-run adjustment effects and more persistent changes in farm performance. The analysis is constrained by the limited number of non-supported young farmers available as potential controls, which motivates the complementary use of a broader control pool consisting of all farms. While this increases statistical power, it introduces structural heterogeneity that we explicitly test for in robustness checks (RQ3).

Matching covariates were selected to reflect farm scale, production structure, asset endowment, and baseline performance, all of which influence both the probability of applying for support and post-treatment outcomes. They may be divided into four categories:

Size and assets: land (ha), assets, livestock units, (number of cattle, sheep, pigs and poultry)

Financial position: liabilities, baseline subsidies

Performance: revenues, profit, labor productivity



Labor input: employees

In counterfactual analysis were used 6 outcome variables to capture farm economic performance along three dimensions relevant for generational renewal (RQ2): income generation, labor use, and productivity. Outcome variables used in the econometric analysis are:

Revenues (EUR) – total farm output; proxy for market integration.

Profit (EUR) – net farm income after costs; indicator of economic viability.

Number of employees (persons) – labor demand created by supported farms.

Labor productivity (EUR per worker) – efficiency indicator relevant for competitiveness.

Revenues per hectare / profit per hectare – normalize performance for land constraints typical for young farmers.

The choice of econometric methods is driven by the institutional design of CAP start-up grants and the structure of the administrative farm-level data. Access to start-up grants is not randomly assigned but depends on eligibility criteria, self-selection into application, and administrative approval, implying systematic differences between supported and non-supported farms. Simple mean comparisons or cross-sectional regressions would therefore yield biased estimates of policy effects. To address this selection problem and to construct a credible counterfactual, we employ propensity score matching (PSM) combined with difference-in-differences (DID), which is a standard evaluation strategy in agricultural and rural policy analysis when randomized experiments are not feasible.

This approach directly addresses RQ2 by estimating the average treatment effect on the treated (ATT) of start-up grants on farm performance outcomes. The use of alternative control pools (young farmers only versus all farms) and repeated matching specifications respond to RQ3 by assessing the robustness of estimated impacts under different comparison scenarios. The available data do not constitute a fully balanced annual panel for all farms, but they provide consistent farm-level observations before and after treatment for comparable cohorts. This structure supports a DID framework that exploits within-farm changes over time while controlling for time-invariant unobserved heterogeneity, such as managerial ability or inherited land endowment. Combining DID with PSM, therefore allows us to reduce bias from both observable and time-invariant unobservable factors.

We analyze the impact of support to young farmers (treatment) on their performance as measured by the average treatment on the treated (ATT), a widely applied method in the literature



for counterfactual impact analysis of policies (e.g., Hoken and Su, 2015; Michalek et al., 2018). We estimate the average difference in outcome variables, farm productivity, employment, revenue or profits, Y , of young farmers that had received support ($D=1$) and those that had not received support ($D=0$). The causal effect of investment support is the difference between the potential outcome of farms of young farmers with support (treated farms), Y_1 , and the potential outcome of farms of young farmers without support (untreated farms), Y_0 : $Y_1 - Y_0$. The expected value of the potential outcome of young farmers without investment support is not directly observed. To use non-supported young farmers as a control group would result in a selection bias, because the selection in or out of the support scheme is not random, implying that means of Y_0 for farms with investment support ($D=1$) and Y_0 for these without investment support ($D=0$) may differ systematically, even in the absence of the support program (Heckman and Robb, 1985; Heckman, 1997; Smith, 2000; Smith and Todd, 2005). In the RDP, young farmers self-select to apply for the investment grant, which makes the selection bias particularly relevant. To deal with the selection bias, we define the average treatment on the treated (ATT) conditional on the probability distribution of observed covariates:

$$ATT = (Z) = E(Y_1 - Y_0 | X = Z, P(Z) = p, D = 1) \quad (1)$$

where X is a set of variables representing the pre-exposure attributes (covariates) of farms, Z is a subset of X representing a set of observable covariates, P is a probability distribution of observed covariance Z . However, the estimation of ATT is difficult due to the high dimensionality of the conditioning problem.

According to Rosenbaum and Rubin (1983) the dimensionality of the conditioning problem can be significantly reduced by implementing matching methods using balancing scores $b(Z)$ such as propensity scores. For random variables Y and Z and for a discrete variable D , the propensity score is defined as the conditional probability of receiving the treatment (i.e., receiving investment support) given pre-treatment characteristics, Z : $p(Z) = Pr(D = 1 | Z) = E(D | Z)$. Rosenbaum and Rubin show that if treatment is random conditional on Z , it is also random conditional on $p(Z)$:

$$E[D | Y, Pr(D = 1 | Z)] = E[E(D | Y, Z) | Y, Pr(D = 1 | Z)] \quad (2)$$

so that $E(D | Y, Z) = E(D | Z) = Pr(D = 1 | Z)$, which implies that $E[D | Y, Pr(D = 1 | Z)] = E[D | Pr(D = 1 | Z)]$, where $Pr(D = 1 | Z)$ is a propensity score. This implies that, when outcomes are *independent of receiving treatment* conditional on Z , they are also *independent of treatment* conditional on the



propensity score, $Pr(D = 1|Z)$. Hence, the conditional independence remains valid if we use the propensity score $p(Z)$ instead of covariates Z or X .

Estimating a conditional participation probability by employing a parametric method, such as *probit* or *logit*, or *semi-parametrically*, reduces the dimensionality of the matching problem substantially to one dimension only, i.e., univariate propensity score. An important feature of this method is that after individuals have been matched, the unmatched comparison individuals can be easily separated out and are not directly used in the estimation of treatment effects.

The Propensity Score Matching (PSM) estimator for the ATT can be written as:

$$\tau^{PSM} = E[p(Z)|D = 1][E(Y_1|D = 1), p(Z)] - [E(Y_0|D = 0, p(Z))] \quad (3)$$

which corresponds to the mean difference in outcomes over the common support, appropriately weighted by the propensity score distribution of farms (Caliendo and Kopeinig, 2008).

Whereas the PSM can be applied to control for selection bias on observables at the beginning of the program, a combination of the PSM with Difference-in-Differences (DID) methods (conditional DID estimator) allows for controlling of selection bias in both observable and unobservable (e.g., Heckman, 1997; Bratberg et al., 2002; Smith and Todd, 2005). The PSM-DID measures the impact of receiving support by using differences between comparable treated farms ($D=1$) and the control group (non-treated) ($D=0$) in the period before, t' , and after, t , the investment support implementation:

$$PSM-DID = \left\{ \sum_i [Y_{it}|(D=1) - Y_{it}|(D=0)] - \sum_i [Y_{it'}|(D=1) - Y_{it'}|(D=0)] \right\} / n \quad (4)$$

where $Y_{it}|(D=1) - Y_{it}|(D=0)$ is the difference in mean outcomes between i with investment support and i matched non-investment support farm *after* the access to investment support, and $Y_{it'}|(D=1) - Y_{it'}|(D=0)$ is the difference in the mean outcome between i with investment support and i matched with no investment support in *prior* period to the program implementation.

The PSM-DID estimator thus eliminates differences in the initial conditions (observable heterogeneity) and differences between both groups (receivers and non-receivers) of farms of young farmers. The first difference in the PSM-DID estimator, which is the change over time within farms, eliminates the influence of time-invariant unobserved individual heterogeneity. The second difference, between receivers of investment support and the control group, eliminates general changes common to all farms (receivers and non-receivers) (Michalek et al., 2018).



While the econometric analysis estimates causal effects under standard observational assumptions, administrative data alone cannot capture the constraints and transaction costs faced by beneficiaries. The interpretation of estimated treatment effects therefore draws on survey evidence collected from young farmers, which provides information on access to land, finance, and administrative processes. These factors are explicitly taken into account when discussing the magnitude and significance of the estimated impacts.

5. Results

5.1. Counterfactual analysis of farm-level data

Using combined secondary farm-level data from the IACS and from the Ministry Information letters, Tables A1 and A2 in the Appendix provide evidence on how PSM balances supported farms of young farmers and those from the control group. Balancing reduced the difference between the treated farms and non-treated farms in observed covariates.

The propensity score was based on 11 microdata variables investigated: assets, liabilities, revenues, subsidies, profit, employees, land, number of cattle, number of pigs, sheep and labor productivity. We matched 47 supported young farmers with not supported young farmers (control group) with similar propensity scores, which ensured similar characteristics of matched farms, to estimate the effect of support in a group of young farmers (results in Table 2). This analysis was limited to the small number of non-supported young farmers in the database. Subsequently, 137 supported young farmers were matched with a corresponding control group from a set of all other non-supported farms (not only young farmers).

Tables 2 and 3 report difference-in-differences estimates based on propensity score matched samples. For each outcome variable, we report average values for treated (supported) and matched control farms before and after treatment, followed by relative and absolute changes. The estimated ‘effect’ captures the net change attributable to receiving a start-up grant, i.e., the difference in post-treatment changes between treated and control farms. For each estimated effect we additionally report a 95% confidence interval (derived from the estimated effect and its t-statistic) in Tables 2 and 3, so that the precision of the estimates can be judged alongside the point estimates and the p-values.

Table 2 presents a conservative comparison in which supported young farmers are matched only with other young farmers who did not receive start-up grants. This specification minimizes



structural heterogeneity but substantially limits sample size and statistical power. At baseline (2018), supported young farmers operate at a smaller scale, with lower revenues and fewer employees than non-supported young farmers, consistent with policy targeting of new entrants and early-stage farms rather than established young operators.

The comparison of matched supported and non-supported young farmers in Table 2 shows that none of the estimated effects reaches conventional significance levels. Nevertheless, the point estimates are mixed in sign: they are positive for labor productivity, the number of employees, and revenues per hectare, but negative for revenues, profit, and profit per hectare. Because every effect is statistically insignificant and the associated confidence intervals include zero, these signs describe the direction of the matched differences only and cannot be interpreted as an effect of the start-up grant. Within this small young-farmer sample, therefore, no effect on any outcome can be established.

Given the small, matched sample of young farmers and high variability in income outcomes, the lack of statistical significance should be interpreted with caution.

Table 2

Effect of start-up grants: comparison of supported (treated) and non-supported (untreated) young farmers.

Year	Method	Revenues	Profit	Labor productivity	Number of employees	Revenues per ha	Profit per ha
2018	Not Treated	294813	2726.3	85700.5	3.79	1044.5	79.1537
	Treated	45173.8	4725.8	34440.4	0.4930	1051.6	103.0
	Difference	249639	-1999.5	51260.1	2.49	-7.0926	-23.8902
	p-value	0.0179	0.6028	0.0594	0.0760	0.9730	0.6252
2021	Not Treated	380460	32303.2	83247.1	3.18	1350.9	218.3
	Treated	83646.8	15521.5	41409.3	0.6806	1528.7	174.1
	Difference	296814	16781.7	41837.8	3.12	-177.8	44.1731
	p-value	0.0401	0.2864	0.0031	0.1107	0.6108	0.5862
Relative change	Not Treated	29%	1085%	-3%	-16%	29%	176%
	Treated	85%	228%	20%	38%	45%	69%
Absolute change	Not Treated	85647.00	29576.90	-2453.40	-0.61	306.40	139.15
	Treated	38473.00	10795.70	6968.90	0.19	477.10	71.10
Effect	Effect	-30125.10	1176.60	19837.10	0.05	387.40	86.19
	Significance of effect	0.0627	0.8792	0.5739	0.9180	0.4037	0.4419
	t-statistics	-1.95	0.15	0.57	0.1	0.85	0.78
	95% CI	(-61967.6; 1717.4)	(-14599.3; 16952.5)	(-51863.7; 91537.9)	(-0.87; 0.96)	(-556.0; 1330.8)	(-142.1; 314.5)

Note: Difference = Not Treated – Treated.

Source: Authors' calculations.



Table 2 presents PSM-DiD estimates comparing supported and non-supported young farmers. This within-cohort comparison represents a conservative test of program effects with strong comparability but limited statistical power. Supported farms exhibit directionally positive effects, though statistically non-significant, for labor productivity and revenues per hectare, while effects on profits and employment remain weak. This pattern suggests that start-up grants may support early efficiency improvements among young farmers without generating immediate income or scale effects. As discussed below, survey evidence indicates that persistent land and credit constraints among young farmers may limit the translation of efficiency gains into higher profits.

The directionally non-significant profit indicators show weaker and sometimes negative relative effects. This likely reflects short-term adjustment costs, repayment obligations, and the fact that early investments financed by the grant raise costs before generating returns. Within the cohort of young farmers, start-up grants appear to support early efficiency improvements but do not generate strong short-term income or employment effects. This suggests redistribution and stabilization rather than transformation.

Table 3 extends the analysis by comparing supported young farmers to a broader control group consisting of all non-supported farms, allowing assessment of whether start-up grants help young farmers close performance gaps relative to the overall sector. Estimated effects are larger in magnitude than in Table 2, indicating partial convergence of supported young farms toward the performance levels of established farms rather than overtaking them.

The comparison of matched supported young farmers and all farms in Table 3 shows that only the effect on labor productivity is statistically significant ($p = 0.042$), indicating that start-up grants had a positive impact on this indicator. Although statistically insignificant, the other indicators – revenues, profit, number of employees, revenues per hectare, and profit per hectare – show positive directional signs, but none of these five effects is statistically significant. The narrowing of the performance gap relative to established farms is therefore supported only for labor productivity.

Between 2018 and 2021, both treated and control farms experienced increases in revenues and profits, reflecting favorable market conditions and broader sectoral trends. However, growth rates differed across groups and outcomes, suggesting that start-up grants may have influenced specific dimensions of farm performance.

The most robust econometric result concerns labor productivity. In both comparison frameworks, supported farms experienced larger increases in labor productivity than matched



controls. Although the estimated effect is only statistically significant in the broader comparison with all farms, its magnitude suggests that start-up grants contributed to labor productivity improvements, likely by enabling limited capital investment or improved organization rather than large-scale expansion.

However, other differences, despite being large in absolute terms and directionally favorable, remain statistically insignificant. This lack of significance can be explained by high variability in farm performance and structural heterogeneity within the control group. For revenues and profits, the estimated treatment effects are small and statistically insignificant. While supported farms experienced higher relative growth rates, the DiD estimates indicate that these gains did not exceed those of comparable non-supported farms by a statistically meaningful margin. This suggests that start-up grants alone are insufficient to materially alter income trajectories within the observed period.

Especially, profit and profit per hectare recorded an insignificant effect despite their relatively large size. The reason was the exceptionally high variability of these variables in both matched groups. Employment effects are positive in direction but modest in magnitude and statistically insignificant. Supported farms increased the number of employees slightly more than controls; however, high variance and small sample sizes limit inference. These findings suggest that early-stage farms tend to prioritize efficiency gains in labor productivity and survival over labor expansion.

Comparison in Table 3 was more representative from a statistical perspective due to a larger sample size. Although most results are statistically insignificant, the comparison indicates a statistically significant positive effect on labor productivity, while the remaining indicators are positive in direction but statistically unconfirmed. This outcome reflects the relatively modest size of the grants compared to the capital requirements of farm modernization and the persistence of structural constraints such as fragmented land ownership, restricted access to credit, and complex administrative procedures.

**Table 3**

Effects of start-up grants: comparison of supported young farmers and all other farmers.

Year	Method	Revenues	Profit	Labor productivity	Number of employees	Revenues per ha	Profit per ha
2018	Not Treated	39446.6	3995.9	28926.5	0.5855	2481.5	228.4
	Treated	34383.3	3694.9	24561.2	0.7351	3137.5	158.8
	Difference	5063.3	301.1	4365.3	-0.1495	-656	69.5864
	p-value	0.348	0.7981	0.3426	0.331	0.2994	0.6911
2021	Not Treated	55888.4	4573.5	31891.3	0.44	2383.6	-41.9293
	Treated	53407	6168.8	31262.9	0.7208	3232.1	39.1034
	Difference	2481.4	-1595.3	628.4	-0.2808	-848.5	-81.0328
	p-value	0.8106	0.6408	0.9221	0.0127	0.367	0.7233
Relative change	Not Treated	41.68%	14.45%	10.25%	-24.85%	-3.95%	-118.36%
	Treated	55.33%	66.95%	27.29%	-1.95%	3.02%	-75.38%
Absolute change	Not Treated	16441.8	577.6	2964.8	-0.1455	-97.9	-270.329
	Treated	19023.7	2473.9	6701.7	-0.0143	94.6	-119.697
Effect	Effect	2581.9	1896.3	3736.9	0.1312	192.5	150.6327
	Significance of effect	0.1629	0.3326	0.0419	0.8950	0.4077	0.5156
	t-statistics	1.41	0.98	2.08	0.13	0.84	0.66
	95% CI	(-1116.6; 6280.4)	(-2056.5; 5849.1)	(148.1; 7325.7)	(-1.9; 2.2)	(-278.3; 663.3)	(-319.8; 621.0)

Source: Authors' calculations.

Table 3 compares supported young farmers with a broader control group of all non-supported farms, allowing assessment of convergence toward established farms. The statistically significant effect on labor productivity suggests that start-up grants help narrow the efficiency gap between young and established farms. However, weak and statistically insignificant effects for profit and employment indicate that broader structural barriers remain. Survey responses confirm that limited access to land and co-financing restricts expansion and income growth, helping to explain why productivity gains do not translate into broader performance convergence.

Comparing Table 2 (young-farmer controls only) with Table 3 (all-farm controls) reveals a consistent pattern: estimated effects are directionally similar but more precisely estimated in the broader control group. This reflects greater statistical power but also increased heterogeneity. The stability of coefficient signs across both specifications strengthens confidence in the qualitative conclusions despite limited statistical significance in some outcomes. Taken together, Tables 2 and 3 indicate that CAP start-up grants primarily improve young farmers' early labor productivity efficiency in comparison to all other farmers and contribute to partial convergence with established farms. However, in the absence of complementary measures, they do not generate statistically significant or substantively strong effects on income or employment.



Apart from labor productivity, the remaining estimated effects do not reach conventional level of statistical significance. This is primarily due to three factors: the relatively small number of supported young farmers available for matching, high variability in farm income and profit measures, and the modest size of the start-up grant relative to overall capital needs. Importantly, insignificance should therefore not be interpreted as evidence of no effect, but rather as evidence of limited, heterogeneous, and context-dependent impacts. The timing of observed outcomes is consistent with the design of the support measure. As start-up grants are disbursed gradually and subject to administrative delays, immediate income effects are unlikely. The statistically significant results for labor productivity relative to profits suggest that farms initially adjust internal efficiency rather than scale or market position.

Overall, the quantitative analysis indicates that start-up grants generate significant positive improvements in farm labor productivity performance among supported young farmers compared with the overall farm population (Table 3). No measurable effects are found on income or employment. These findings suggest that start-up grants function primarily as complementary liquidity support rather than as transformative instruments for generational renewal.

5.2. Survey

5.2.1. CAP support to young farmers

According to the results of a **survey** among young farmers, subsidies are crucial for young farmers, as stated by 88% of respondents in the survey.

Young farmers rated start-up grants in the 2014–2022 programming period negatively, highlighting poor timing and irregularity of calls, inadequately designed eligibility criteria, and a high level of complexity and bureaucracy when preparing and submitting applications (Table 4). More than 60% of respondents combined (“strongly disagree” + “disagree”) and thus expressed negative views: 63% rated the timing of calls poorly, 72% rated their regularity negatively, 60% considered financial limits inadequate, 60% viewed eligibility criteria as poorly designed, 60% found application submission difficult, and 73% perceived the associated bureaucracy as high. Significant differences were found in the review of individual statements, as determined by the Friedman test with a p-value of 0.0038. The majority of statements were evaluated as “strongly disagree”, with “the bureaucracy was low” as the worst. On the other hand, the most positively



evaluated, significantly better than the rest, was the statement “The financial limits of projects were adequate”.

The evaluation of the calls for projects and submitted proposals by young farmers was viewed especially critically with respect to speed, with 79.8% rating evaluation times negatively. In contrast, respondents were notably less critical of the transparency and objectivity of evaluations, which received more balanced assessments. According to result of the Friedman test, with p-value <0.001, speed was evaluated with significantly higher disagreement than the other two options.

Table 4

Opinions of young farmers on calls and evaluation (in %)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
How do you assess the calls for projects in the 2014–2022 period?					
The calls were well timed	49.0	14.0	26.0	2.0	9.0
The calls were regular	52.0	20.4	19.4	2.0	6.1
The financial limits of the projects were adequate	46.5	13.1	22.2	9.1	9.1
The eligibility criteria were well designed	47.5	13.1	22.2	10.1	7.1
Submitting an application was easy	43.8	16.2	26.7	5.7	7.6
The bureaucracy was low	57.3	15.5	12.6	6.8	7.8
How would you rate the evaluation of your application by the Paying Agency?					
Transparent	20.4	13.3	33.7	8.2	24.5
Objective	19.4	10.2	29.6	14.3	26.5
Fast	69.8	10.4	9.4	5.2	5.2

Source: Survey results, authors' calculations.

A total of 42 respondents (39%) hired consultants to draft their applications, while 25 respondents (23%) relied on advice from friends (Table 5). Only 7% of respondents received assistance from the APA. Furthermore, the complexity of the application process discouraged 12% young farmers from even applying.

Table 5

Opinions of young farmers on submission of a project application (in %)

Submitting a project was complicated, so I decided not to apply	12.1
Submitting a project was complicated, but the APA advised me	6.5
Submitting a project was complicated, but friends helped me	23.4
Submitting a project was so complicated that I paid a consultant	39.3
Submitting a project was simple and I managed everything myself	10.3



I don't know, I did not apply	8.4
-------------------------------	-----

Source: Survey results, authors' calculations.

Many young farmers encountered challenges during the project implementation, often due to complex administrative requirements and inefficient administrative processes. Respondents criticized the bureaucracy and slow payment processing by the APA during project implementation. Nevertheless, most respondents acknowledged that the funds they received significantly contributed to the development of their farms. Communication with the APA during project implementation was rated predominantly negatively by respondents.

5.2.2. Access to land

Based on the **survey**, young farmers have a high demand for land, with 91% of respondents expressing a desire to acquire more agricultural land. The main barriers (Table 6) to obtaining additional land identified by young farmers included long-term leases of state-administered agricultural land (23%), fragmented land ownership (28%), high rental rates or land prices (26%), and bureaucracy (21%).

Table 6

What are the biggest obstacles to buying/renting agricultural land in Slovakia? (in %)

High rent and high purchase price of land	25.7
Plots available for rent or purchase are small and have many owners	27.9
The land is already long-term leased by other farmers	22.6
Even when land is available, the bureaucracy is extensive	21.2
Other	2.7

Source: Survey results, authors' calculations.

Young farmers are aware of the option to acquire land through SLF. In fact, 62% of respondents attempted to obtain land from the SLF during the 2014–2022 period. However, young farmers reported negative experiences in acquiring land from the SLF (Table 7). According to respondents, the process was slow and burdened with excessive bureaucracy, as survey data reveal that 85.4% of young farmers found the process slow, while 64.6% did not perceive it as free of bureaucratic obstacles. Perceptions of SLF's client service were similarly unfavorable: 57.9% of respondents disagreed that employees were helpful, indicating a generally poor client-oriented approach. Moreover, 67.4% stated that SLF did not offer suitable land for their needs, underscoring a major mismatch between available plots and farmers' expectations. According to result of the Friedman



test, there were significant differences in evaluations of these statements with a p-value <0.001. The rate of disagreement was similar in “Obtaining the land was fast” and “They had a suitable land for me”. And significantly better was the evaluation of bureaucracy and the helpfulness of employees.

Table 7

What are the biggest obstacles to acquiring agricultural land from the SLF? (in %)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Obtaining the land was fast	83.3	2.1	8.3	2.1	4.2
It wasn't associated with bureaucracy	59.4	5.2	12.5	2.1	20.8
The fund's employees were helpful	41.1	16.8	27.4	8.4	6.3
They had suitable land for me	57.9	9.5	16.8	4.2	11.6

Source: Survey results, authors' calculations.

5.2.3. Access to loans

Young farmers have a significant demand for additional capital to develop their businesses, with 91% of the **survey** respondents indicating a need for extra funding. During the 2014–2022 period, 76% of respondents applied for a loan or credit. As presented in Table 8, 47% did not secure financing from a bank, relying instead on family or acquaintances (40%) or other non-bank entities (7%). Only 29% applied for a loan from a bank, with 12% seeking personal loans and 17% applying for farm-related loans. Meanwhile, 24% of respondents did not seek any loans or credit during this period.

Table 8

Did you apply for a loan or credit for farm development during the period 2014–2022? (in %)

I took a bank loan for the farm and its development	16.5
I took a personal loan to develop the farm	12.2
I obtained financing from an institution other than a bank	7.0
I asked my family or friends for money	40.0
I did not need funds for business development during 2014–2022	24.3

Source: Survey results, authors' calculations.

The main challenges young farmers face when obtaining loans (Table 9), apart from interest rates (21%), include lack in collateral (14%), need to use family property as collateral (20%), banks' reluctance to lend to young farmers (19%), and the lack of specialized financial products tailored for young farmers (16%).

**Table 9**

What are the main challenges in obtaining loans from the perspective of young farmers? (in%)

Interest rates are high	21.4
I have nothing to use as collateral	13.7
Commercial banks are unwilling to provide loans to young farmers	19.1
It is necessary to use family property as collateral	19.5
There are no banking products for young farmers	15.6
I have little information about options for obtaining business financing	6.1
I do not know, I do not need a loan or credit	4.6

Source: Survey results, authors' calculations.

5.2.4 Differences between new entrants and successors

New entrants and successors face broadly similar administrative, land, and financial constraints in Slovakia. Although responses were compared across the two groups, none of the differences was statistically significant at the 5% level (Table 10). This similarity may reflect the historical development of Slovak agriculture. Before 1989, agriculture was dominated by large state farms and cooperatives. Following the transition to a market economy, these entities were transformed into large corporate farms, while new family farms also emerged. Consequently, many young farmers today either manage newly established small farms or enter farming through succession, but both groups typically have relatively short histories as farm operators and face similar constraints related to land access, finance, administration, and farm development.

CAP support to young farmers

Successors evaluated the adequacy of project financial limits more favorably than new entrants, with mean scores of 2.54 and 2.09, respectively. Successors also gave a higher mean score to the statement that eligibility conditions were well designed (2.56 versus 2.07). Conversely, new entrants gave a slightly higher score to the statement that application bureaucracy was low (1.95 versus 1.69 among successors). As all mean scores were below the neutral value of 3, both groups generally evaluated the design and administration of CAP project support negatively.

Access to land

New entrants assigned greater importance to accessing suitable land to buy or rent than successors, with mean scores of 4.39 and 3.93, respectively (Table 10). A desire to obtain additional agricultural land was reported by 92.9% of new entrants and 86.7% of successors. Land already being leased by other farmers was identified as an obstacle by 80.0% of both groups. Successors



more frequently identified fragmented plots with multiple owners as an obstacle than new entrants (76.7% versus 60.0%).

Access to loans

The need for additional capital was reported by 90.6% of new entrants and 90.0% of successors, indicating virtually no difference between the groups (Table 10). The perceived importance of obtaining a business loan was also similar, with mean scores of 3.04 among new entrants and 3.00 among successors. Commercial banks' reluctance to lend to young farmers was identified as an obstacle by 48.2% of new entrants, compared with 32.1% of successors—a difference of 16.1 percentage points.

The largest observed differences concerned the importance of accessing suitable land, fragmented land ownership and banks' reluctance to lend.

Table 10

Comparison of selected constraints and perceptions of support between new entrants and successors

Domain and indicator	Measure	New entrants	Successors	Test	p-value
CAP support to young farmers					
Project financial limits were adequate	Mean, 1–5	2.09	2.54	Mann–Whitney U	0.191
Eligibility conditions were well designed	Mean, 1–5	2.07	2.56	Mann–Whitney U	0.134
Application bureaucracy was low	Mean, 1–5	1.95	1.69	Mann–Whitney U	0.494
Access to land					
Accessing suitable land to buy or rent	Mean, 1–5	4.39	3.93	Mann–Whitney U	0.063
Desire to obtain additional agricultural land	Share	92.9%	86.7%	Fisher's exact	0.451
Land already leased by other farmers	Share	80.0%	80.0%	Fisher's exact	1.000
Fragmented plots with multiple owners	Share	60.0%	76.7%	Fisher's exact	0.123
Access to loans					
Need for additional capital	Share	90.6%	90.0%	Fisher's exact	1.000
Importance of obtaining a business loan	Mean, 1–5	3.04	3.00	Mann–Whitney U	0.940
Banks unwilling to lend to young farmers	Share	48.2%	32.1%	Fisher's exact	0.187

Source: Survey results, authors' calculations.

6. Discussion

The study fills a notable gap in the literature by focusing on the interplay between CAP start-up grants, land access, credit market constraints, and administrative burdens as institutional barriers in shaping the career trajectories of young farmers in Slovakia. Based on the farm-level



counterfactual results and findings from surveys, it draws out implications for CAP support to young farmers in settings with binding land, credit and administrative constraints.

The counterfactual estimates suggest that start-up grants can improve labor productivity. The outcomes for the other performance indicators are statistically insignificant; survey evidence with young farmers helps explain why.

Generational renewal remains a policy priority in Slovakia and across the EU, but the Slovak case illustrates how entry conditions can limit the translation of financial support into sustained growth (Zagata et al., 2019; Coopmans et al., 2021; Sheridan et al., 2021; Sutherland, 2023; Bertolozzi-Caredio, 2024; Bertolozzi-Caredio et al., 2026).

The farm-level counterfactual analysis indicates positive effects on labor productivity and, in the broader comparison, directionally positive but statistically insignificant differences for other indicators. Overall, however, the results suggest limited and heterogeneous impacts. This is consistent with the research hypothesis that a one-off start-up grant relaxes short-run liquidity constraints but does not, by itself, resolve structural barriers that shape farm size, investment capacity and profitability.

The survey with young farmers clearly confirmed that among key barriers to entry and farm sustainability is access to land. Fragmented ownership and high transaction costs, combined with limited availability of suitable plots and slow, bureaucratic procedures (including through the SLF), restrict entry and expansion and can offset the advantages created by installation aid (Jepsen et al., 2015; Borda et al., 2023; Sudzina, 2025).

In addition, access to finance and collateral with reported credit constraints – insufficient collateral, banks' risk perceptions, and a lack of suitable products for young/small farms – limit beneficiaries' ability to co-finance investment and smooth cash flow. Structural barriers such as insufficient collateral, small farm sizes, and high-risk perceptions among commercial banks restrict young Slovak farmers' ability to secure traditional loans, leading to rejection of bank loans or providing loans under unfavorable terms. In this context, grants may improve some outcomes but remain small relative to capital needs, especially for modernization (European Court of Auditors, 2017; Fi-Compass, 2020).

The survey responses highlight implementation and administrative burden caused by irregular calls, long processing times, and high compliance costs. These frictions can reduce take-up, delay



investment, and lower the effective value of support, which helps explain why estimated impacts are often modest even when grants are valued by recipients.

The study provides evidence-based policy recommendations. It suggests a shift from stand-alone start-up grants toward integrated entry support packages – combining financial aid with market- and institution-focused measures such as business training and advisory services – to enhance farm viability and generational renewal in agriculture in the era of digital rurality and navigating technology needs (European Court of Auditors, 2017; European Commission, 2022, 2025; Rush et al., 2025; He and Leszczynski, 2026).

Non-economic barriers (e.g., rural infrastructure and rural services and perceptions of farming) can further shape entry and retention (Jepsen et al., 2015; Granado-Díaz et al., 2024), but in this study the most consistently reported binding constraints relate to land access, financial constraints, and institutional administrative burden.

To sum up, Slovakia's generational renewal dilemma stems from a complex interplay of long-standing structural roots, financial, social, and administrative barriers. CAP and national instruments provide essential support, but their impact remains limited without strategic coordination, targeted incentives, and robust monitoring and evaluation. Policy innovation should prioritize integrated support packages, supply-side experiments (e.g., land access, finances), and evidence generation to support resilient transition pathways for young farmers (Chiswell, 2025). Addressing these barriers requires coordinated policy innovation informed by rigorous, context-specific evidence.

Among the study limitations, the counterfactual results are constrained by sample size and outcome variability. The study highlights the need for stronger evidence to design integrated interventions for generational renewal in Slovak agriculture. Future research should prioritize longitudinal data tracking entry and succession (survival, income trajectories, diversification and career choices) to assess policy impacts over time (European Court of Auditors, 2017). It should also evaluate land-access innovations – such as land banks, leasing incentives and consolidation strategies – to test whether they improve entry conditions. Finally, research should assess integrated support packages that combine tailored finance (e.g., guarantees, blended finance, microcredit), advisory/training and rural services, complemented by qualitative work on social and lifestyle drivers and analysis of territorial and sectoral heterogeneity to better target policy responses



(Jepsen et al., 2015; Fi-Compass, 2020; Izakovičová et al., 2022; European Commission, 2022, 2025; Calafat-Marzal et al., 2026).

7. Conclusion

The study addresses a literature gap on young-farmer support in post-socialist EU member states by combining a counterfactual evaluation of CAP start-up grants with survey evidence on land, finance, and administrative constraints that shape generational renewal in agriculture and policy effectiveness in practice. It identifies and rigorously analyses the multifaceted challenges facing young farmers in Slovakia. The study employs quantitative counterfactual analysis using national farm-level microdata and a primary collected unique in-depth survey evidence. These complementary techniques provide a robust and nuanced understanding of the effectiveness of CAP start-up support measures for young farmers.

The analysis was structured around four research questions (RQ), which yield the following key findings: Start-up grants were delivered through a small number of calls with slow and uneven administrative processing, implying substantial delays between application, approval, and payment (RQ1).

The counterfactual analysis, based on propensity score matching using farm-level microdata, indicates that receiving a start-up grant is associated with statistically significant positive improvements in labor productivity among supported young farmers compared with the overall farm population. For other performance indicators, the estimated effects are small and statistically insignificant, indicating no measurable impact (RQ2). This evidence is consistent with findings from some other EU countries, suggesting that financial incentives alone are insufficient to drive generational renewal.

Estimated impacts remain directionally similar across alternative matching specifications and control pools, but inference is limited by relatively small samples for young-farmer-only comparisons and high outcome variability (RQ3).

The unique, in-depth comprehensive survey evidence suggests that binding constraints – limited access to land, limited access to finance/collateral, and high administrative burden – reduce take-up, delay investment, and can offset the benefits of a one-off grant, helping explain why measured impacts are often modest (RQ4).



The findings imply that CAP start-up grants alone are unlikely to deliver strong generational renewal where factor markets and implementation capacity are weak. More effective packages would pair financial support with faster and simpler administration and complementary measures that improve access to land and finance for new entrants.

While most of young farmers consider subsidies to be essential for their operations, the experience with start-up grants during the 2014–2022 programming period was predominantly negative. Respondents in surveys highlighted several issues, including poor timing and irregularity of calls for applications, inadequately designed eligibility criteria, and a high level of complexity and bureaucracy in both preparing and submitting applications. First, the management and administration of start-up grants was very inefficient and long-lasting because of the inexperience of the managing authority and the paying agency with the new measure adopted in Slovakia. Second, the size of start-up grants was small relative to the time span of the project. Lastly, the survey findings underscore that administrative inefficiencies, land market barriers, and credit market constraints significantly limit the effectiveness of start-up grants and broader generational renewal policies in Slovak agriculture. To address the ageing of the farming population, EU member states should tackle the persistent problems young farmers face, particularly in accessing land and credit, as well as dealing with excessive red tape.

The distinction between new entrants and successors provides additional insight into the constraints affecting generational renewal. Although none of the differences between the groups was statistically significant, new entrants tended to assign greater importance to accessing suitable land and more frequently identified banks' reluctance to provide credit as a constraint. Successors, by contrast, more frequently identified fragmented land ownership as an obstacle. Both groups reported a similarly high need for additional land and capital and evaluated the design and administration of CAP project support negatively. These findings indicate that the principal land, financial and administrative constraints are shared by both new entrants and successors. Policies promoting generational renewal in Slovakia should therefore address these structural barriers for both groups.

By combining counterfactual econometric analysis with survey evidence, this study shows that CAP start-up grants primarily function as short-term liquidity support, improving labor productivity among supported young farmers relative to the overall farm population, but they do not address deeper structural barriers that constrain broader improvements in farm performance.



The mixed-methods approach reveals why measured impacts on profits and employment remain limited despite positive labor productivity effects: persistent land, credit, and administrative constraints shape how policy benefits materialize for young farmers.

While our study provides valuable insights into the impact of start-up grant support for young farmers in Slovakia, several limitations must be acknowledged. The analysis is based on farm-level observational data rather than a randomized experimental design, meaning that participation in support schemes is not random but influenced by both observable and unobservable factors. To mitigate potential biases arising from non-random assignments, we applied PSM, which adjusts for differences in observed covariates between supported and non-supported young farmers. However, PSM cannot account for unobserved confounders – variables that were not measured or included in the model – which may still influence the results and introduce bias. Consequently, while our approach enhances the credibility of the estimated treatment effects, caution is warranted when interpreting the results, and future research employing alternative methodologies or additional data sources may be necessary to further validate these findings. This was the reason that our econometric analysis was complemented with the survey evidence. However, the survey was based on voluntary participation through the ASYF network and did not employ probability sampling. It may therefore be affected by coverage and self-selection bias. Furthermore, the survey excluded prospective entrants who were interested in farming but ultimately did not enter the sector. The farm-size distribution of respondents did not differ significantly from that of the 2023 CIS-YF beneficiaries, which enhances the credibility of our findings and supports the generalizability of our conclusions for Slovakia as a case study.

Looking ahead, several research avenues emerge from these findings. There is a need to investigate innovative policy solutions for land access, such as the effectiveness of land banks, long-term leasing programs, and land consolidation strategies, as well as the impact of legal reforms and digital land registries on reducing fragmentation and transaction costs. Research should also evaluate the potential of state-backed loan guarantees, blended finance models, and microcredit tailored to young farmers, alongside the effectiveness of integrating financial support with business training and advisory services. Administrative simplification and digitalization are important areas to explore, particularly in terms of reducing red tape and expediting application and evaluation processes for subsidies and land allocation, as well as learning from best practices in other EU countries.



Socio-economic and non-economic barriers also warrant further analysis, including the influence of rural infrastructure, social services, and the cultural image of farming on youth engagement and retention in agriculture, as well as the role of entrepreneurship education and non-farm rural opportunities in attracting young people to the sector. Longitudinal studies are needed to track the business survival, income progression, and career trajectories of young farmers, distinguishing between new entrants and successors, and to assess the impact of succession planning and intergenerational knowledge transfer on farm viability. Comparative policy analysis across EU member states could help identify best practices and context-specific solutions, while studies on the outcomes of integrated support packages that combine financial aid, training, and advisory services – especially land-access instruments, tailored finance/guarantees, and administrative simplification in the context of digital rurality and evolving technology needs – to test which combinations best support entry, viability, and succession. This would provide valuable insights for policymakers.

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Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this manuscript, the authors used Microsoft 365 Copilot (based on a GPT-style large language model) to assist with language editing, improving clarity and coherence of the text. The tool was not used to generate original research content, data, results, or interpretations. After using this tool, the authors reviewed, edited, and validated all content and take full responsibility for the accuracy and integrity of the published article.



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Appendix

Table A1

Matching supported young farmers and non-supported young farmers.

Standardized Mean Differences (Treated - Control)						
Variable	Observations	Mean	Standard	Standardized	Percent	Variance
		Difference	Deviation	Difference	Reduction	Ratio
Logit Prop Score	All	28.2	113	0.24951		0.0016
	Matched	4.0		0.03536	85.83	28.5775
Assets	All	870390.9	2256874	0.38566		4301.816
	Matched	852202.3		0.37760	2.9	2092.931
Liabilities	All	471208.1	1373085	0.34317		5116.252
	Matched	464267.9		0.33812	1.47	1795.851
Revenues	All	260429.8	493033	0.52822		304.2064
	Matched	249639.3		0.50633	4.14	276.2389
Supports	All	39678.1	55736	0.71189		37.1264
	Matched	35199.7		0.63154	11.29	23.0103
Profit	All	-968.6	18939	-0.05114		4.99
	Matched	-1999.5		-0.10558	0.00	6.74
Number of employees	All	2.6	8	0.33788		33.6253
	Matched	2.8		0.36980	0.00	217.7287
Land	All	166.8	168	0.99218		80.7263
	Matched	139.6		0.83047	16.30	46.6854
Number of cattle	All	23.8	61	0.39045		11.08
	Matched	23.8		0.39049	0.00	23.6080
Number of pigs	All	-2.2	23	-0.09575		0.3043
	Matched	2.6		0.11211	0.00	41.3468
Number of sheep	All	45.3	208	0.21713		52.5929
	Matched	31.2		0.14966	31.7	16.3076
Number of poultry	All	-50.4	248	-0.20352		0.0000
	Matched	0.0		0.00000	100.00	
Labor Productivity	All	61139.2	128289	0.47658		47.8663
	Matched	51260.1		0.39957	16.16	36.5006

Source: Authors' calculations



Table A2

Matching supported young farmers and all farmers.

Standardized Mean Differences (Supported - Not supported)						
Variable		Mean Difference	Standard Deviation	Standardized Difference	Percent Reduction	Variance Ratio
Logit Prop Score	All	43	46	0.92922		0.0005
	Region	7		0.14378	84.53	0.0625
	Matched	0		0.00650	99.30	1.1820
Assets	All	-1824480	2953251	-0.61779		0.0001
	Matched	-8064		-0.00273	99.56	0.7153
Liabilities	All	-846490	1688129	-0.50144		0.0001
	Matched	-8004		-0.00474	99.05	0.1662
Revenues	All	-1124903	1905553	-0.59033		0.0002
	Matched	-5063		-0.00266	99.55	0.4648
Supports	All	-175446	190725	-0.91989		0.0022
	Matched	-697		-0.00366	99.60	0.7673
Profit	All	-27092	158785	-0.17062		0.0024
	Matched	-301		-0.00190	98.89	1.0378
Employees	All	-12	17	-0.73867		0.0060
	Matched	0		0.00893	98.79	4.42
Land	All	-572	558	-1.02457		0.0011
	Matched	-5		-0.00875	99.15	0.6408
Cattle	All	-128	225	-0.56929		0.0058
	Matched	-8		-0.03571	93.73	0.0290
Pigs	All	-166	2045	-0.08101		0.0001
	Matched	2		0.00116	98.56	2.02
Sheep	All	-76	193	-0.39193		0.0223
	Matched	-7		-0.03731	90.48	0.6036
Labor Productivity	All	-84149	169259	-0.49716		0.0119
	Matched	-4365		-0.02579	94.81	0.2266

Source: Authors' calculations

Impact of the adoption of chemical inputs on crop yield downside risk

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Abstract: The study aims to analyse the impact of application of chemical inputs like fertilisers or crop protection products on farm crop yield productivity in Estonian and Slovenian agriculture. We combined the propensity score matching (PSM) method with an inverse probability weighted regression (IPWRA) model to derive treatment effects of the adoption of these critical inputs using Farm Accountancy Data Network data. Results exhibit consistency across estimation techniques. Estimates of both IPWRA and PSM models showed that adoption of at least one of the chemical inputs decreases volatility of crop yield output and downside risk. The results are more robust for Estonian than for Slovenian farms suggesting on possible impacts of other exogenous factors such as climate change on mitigating the crop yield downside risk.

Keywords: chemical input adoption; Estonia; fertilisers; food security; household crop yield; crop protection products; productivity; Slovenia

Unexpectedly lower crop yield outcomes or downside risks challenge farmers' use of external inputs that can enhance crop productivity (Möhring et al. 2020). Agriculture crop farm income risk is determined by various factors particularly crop yield instability, price volatility and cost risk (El Benni and Finger 2014). The bibliometric analysis regarding risk in agriculture has revealed that literature has focused on the impacts of climate and food security, and the insurance schemes in agriculture (Novický 2019). Most recently the farm sector has been affected by a changing set of risk sources including more unusual and extremely adverse weather patterns. This induces the need for assessments and adjustments in risk management tools.

Our focus is on crop yield downside risks, which can be caused by various factors related to input uses, agricultural natural factor endowments, climate change and risk management in crop production and agriculture. The conditions for crop production are negatively determined by a high level of risk in agriculture, particularly in crop production, due to climate change and the resulting extreme weather conditions. They increase the likelihood of natural disasters, which is reflected in the quantity and quality of crop production. The ability of early detection and effective management of the risks at the farm level is important for crop market trends in monitoring and decision-making of the price risk, production or income risk with the diversification as the farm's risk management strategy (Jankelova et al. 2017).

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This article aims to investigate the impacts of chemical input adoption on crop yield downside risk by applying propensity score matching (PSM) and inverse probability weighted regression adjustment (IPWRA) estimation procedures. Estonia and Slovenia are selected as the case studies, both being members of the Common Agricultural Policy (CAP) of the European Union. Both countries aim to prevent the impacts of climate change by reducing crop yields' sensitivity to climate change. Slovenian agriculture has suffered the greatest damage from drought, heavy rainfall, floods, hail and windstorms, frost, snow, glaze ice, and weather-related diseases and pests (MAFF 2023). The natural-climatic conditions regarding drought in Estonia as a Northern EU country might be better than in Slovenia as the latter is situated in the Central-Southern EU geographic area in the mixture between Pannonian and Mediterranean and partly Alpine climatic conditions. The cross-country comparison represents a novel contribution to mitigation or reduction measures addressing the crop yield risks and adaptation of crop production to changing conditions. Stabilisation of crop yields can be important for the stability of the income situation of farms.

The CAP considers risk management by promoting and co-financing the implementation of climate change adaptation and mitigation measures through the Rural Development Programme (Ministry of Agriculture, Forestry and Food 2024) or other programmes or projects in the field of agriculture (European Commission 2017). Among the main challenges is the introduction of new, innovative approaches to maintain or increase productivity levels while also successfully adapting to climate change and its vulnerability (Gancheva et al. 2020).

Technology adoption on reducing crop yield risk has been investigated in agricultural economics, most recently particularly with climate change (Santeramo et al. 2024). The econometric modelling of frontier production functions has been an important area of research in agricultural economics (Battese 1992; Battese and Coelli 1992; Čechura et al. 2022). While there are studies on the productivity and efficiency of crop farms (Błażejczyk-Majka et al. 2012; Biagini et al. 2023; Makieła et al. 2025), to our knowledge, there have not been any quantitative farm-level micro-econometric studies that examined whether crop yield output has been impacted with the adoption of agricultural technologies such as fertilisers and/or pesticides in Estonia and Slovenia. From a policy perspective, this is crucial since crop yield output is expected to require improvement in the level of farming practices adoption in agriculture. However, the literature does not provide

straightforward answer both for risk preferences from crop protection products use in agriculture (Bontemps et al. 2021) and the welfare effects of crop biodiversity (Bozzola and Smale 2020).

This paper attempts to fill this gap by assessing the effect of the adoption at least one chemical input (ALOCI) like crop protection products or fertilisers on crop yield productivity using micro-level panel data obtained from Farm Accountancy Data Network (FADN) in two EU countries. Precisely, we use the PSM and the doubly robust IPWRA models to estimate the average treatment effects.

MATERIAL AND METHODS

Estimating the moments of the stochastic production function

The probability distribution of the stochastic production function is evaluated by using a moment-based approach (Antle 1983), allowing for flexible representation of production risks, considered the following specification for y :

$$Y_i = f(X_i, \beta_i) + u_i \quad (1)$$

where: Y_i – eligible crop yield output; X_i – a vector of production inputs (i.e. fertilisers, crop protection products, other intermediate consumption, labour, capital and land); β_i – a vector of parameters, u_i – the identically independently distributed error term; $i = 1, \dots, N$ – individual farms in the sample.

Econometrically, the translog production function is specified as follows:

$$\ln(Y_i) = \beta_0 + \sum_{n=1}^6 \beta_n \ln(X_{in}) + 0.5 \sum_{n=1}^6 \sum_{m=1}^6 \beta_{nm} \ln(X_{in}) \ln(X_{im}) + u_i \quad (2)$$

where: $\ln(Y_i)$ – the natural logarithm of the total crop yield output for farmer i ; $\ln(X_{in})$ – the natural logarithm of n input for farmer i ; $\ln(X_{in})\ln(X_{im})$ – the interaction between inputs n and m , the inputs include other intermediate consumption, total assets, land, labour, fertilisers, and crop protection.

Because some farmers in our sample did not purchase fertilisers and crop protection products in the 2013–2021 years, the two input variables have zero-value observations. Since zero values are unsuitable for modelling in logarithm form [Equation(2)], we follow Villano et al. (2015), Zheng et al. (2021) and Ma et al. (2022)

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by replacing zero values with one to deal with zero values. Because $\ln(1) = 0$, this allows not to omit such values from the analysis. Since prices and crop yields are key factors influencing farmers' decisions, out-of-range values (including negative or extreme outliers) or zeros are unsuitable for modelling (Louhichi 2018). Therefore, in our analysis, we excluded negative crop output values as outliers. Equation (2) is estimated by an ordinary least squares (OLS) regression model to calculate the first three moments, i.e. expected crop yield, its variance and skewness (Huang et al. 2015; Issahaku and Abdulai 2020). Specifically, the expected crop yield is predicted as $E(\ln(Y_i))$.

The second moment represents the variance of crop yield, which is measured by the squared term of the error term, that is, $E(\varepsilon_i)^2$. The third moment represents the downside risk (skewness) of crop yield, which is measured by the third power of the error term, that is, $E(\varepsilon_i)^3$ (Ma et al. 2022).

Estimation strategy

We assume that a risk-neutral and utility-maximising crop farmer i chooses to adopt at least one from critical inputs if the utility derived from using them exceeds that of otherwise (Olagunju et al. 2023). We can express farmer's i adoption decision by a latent variable F_i^* as:

$$F_i^* = \theta_i Z_i + \varepsilon_i \text{ with } F_i = \begin{cases} 1, & \text{if } F_i^* > 0 \\ 0, & \text{otherwise} \end{cases} \quad (3)$$

where: F_i – a binary variable representing adoption status (1 = adopters, 0 = non-adopters); Z_i – a set of farmer characteristics and farm-level factors hypothesised to influence input use decisions; ε_i – the error term assumed to be normally distributed; θ_i – the unknown parameters.

To estimate the impact of ALOCI on the crop yield productivity we explored the propensity score matching (PSM) and inverse probability weighted regression adjustment (IPWRA) to produce unbiased and consistent estimates. The PSM controls for selection bias by controlling for observable confounding factors. However, an important shortcoming of the PSM method is its inability to deal with biases resulting from unobservable characteristics of sampled units. Thus, we employed IPWRA estimator. According to Imbens and Wooldridge (2009), IPWRA contributes to research which isolates the effects of exposure, as the technique adjusts both for the predictors of intervention and for the effects of these predictors.

Propensity score matching (PSM)

The propensity score matching method (PSM) is a quasi-experimental technique often used in observational causal studies (Adjin et al. 2020). We estimate the average treatment effect on the treated (ATT) of critical inputs used on the expected crop yield, crop yield variance and crop yield skewness using the PSM model (package 'MatchIt', Sekhon 2011). Following Sseguya et al. (2020), the ATT can be defined as:

$$ATT = E(\Phi_{1i}|F_i = 1) - E(\Phi_{0i}|F_i = 1) \quad (4)$$

where: $E(\cdot)$ – the expectation operator; Φ_{1i} – the outcome of the household's crop yield that is adopted; Φ_{0i} – the outcome of a household's crop yield that did not adopt.

However, ATT from PSM can still produce biased results in the presence of misspecification in the propensity score model (Robins et al. 2007; Wooldridge, 2010; Wossen et al. 2017). A potential remedy for such misspecification bias is to use IPWRA.

Inverse probability weighted regression (IPWRA) model

IPWRA (using packages 'twang' and 'survey' in R) estimator has the double-robust property that ensures consistent results as it allows the outcome and the treatment model to account for misspecification. ATT in the IPWRA model was estimated in two steps (Imbens and Wooldridge 2009). In the first step, we estimated the propensity scores using multinomial logit regression and in the second step, linear regression was used to estimate the ATT which was computed as follows (Kazal et al. 2020):

$$ATT = \frac{1}{N_A} \sum_{i=1}^n ((\gamma_1 + \eta_1 X_i) - (\gamma_0 + \eta_0 X_i)) \quad (5)$$

where: γ_1, η_1 – estimated inverse probability-weighted parameters for adopters; γ_0, η_0 – estimated inverse probability-weighted parameters for non-adopters; N_A – the total number of adopters.

To evaluate how sensitive the estimated treatment effects are to potential hidden bias, sensitivity analysis was conducted using the 'psens' function from the 'rbounds' package in R to assess the robustness of treatment effects to unobserved confounders. The 'psens' function implements the Rosenbaum bounds approach to evaluate how sensitive the estimated

treatment effects are to potential hidden bias. To test for heterogeneity in treatment effects (*HTE*), we conducted an analysis using interaction terms in our regression models.

Data and descriptive statistics

Data. The analysis is based on the Estonian and Slovenian FADN panel datasets. FADN is a database for a stratified sample of farms across EU countries. This paper focuses on specialist crop farms. The EU Types of crop farms are: (15) specialist cereals, oil-seeds and protein crops (COP); (16) specialist other field crops; (20) specialist horticulture; (36) specialist orchards – fruits; (38) permanent crops combined; (60) mixed crops (European Commission 2022).

We used FADN SE variables codes: SE010 – labour hours used on the farm, measured as total number of hours worked; SE025 – total utilised agricultural area (*UAA*) in hectares (ha); SE030 – leased *UAA* in ha; SE131 – total crop production; SE275 – total intermediate consumption; SE436 – total assets; SE295 – fertiliser expenditures; SE300 – crop protection expenditures; SE410 – gross farm income. For deflation of monetary data in EUR, the agricultural input price index (IA148) and agricultural output price index (IA146) were taken from Statistics Estonia (2021) and the Statistical Office of the Republic of Slovenia (2021); 2015 is a base year.

The crop yield output is calculated as the ratio of total crop production over total *UAA* (SE131/SE025, SE131 is deflated by index IA146 output). Other intermediate consumption (*OIC*) was calculated as the difference between total intermediate consumption and both critical inputs: fertilisers and pesticides ($OIC = SE275 - SE295 - SE300$) and deflated by index IA148 input. Total assets (*TA*), SE436, is deflated by index IA148 input. Land is SE025, total *UAA* in ha. Labour is calculated as the ratio of SE010 over total *UAA*: SE010/SE025. The use of fertilisers is calculated as a ratio SE295 deflated by index (IA148 input) for fertilisers over SE025 (ha). The use of pesticides is calculated as a ratio SE300 deflated by index IA148 input for pesticides over SE025 (ha).

In the FADN database, the farm type and economic size of farm households is determined based on the value of the standard output (*SO*) (Eurostat 2023). In the empirical estimation, economic size classes (that range from 3 to 14) are used as an indicator of farm size. Farms with *SO* EUR 4 000–8 000 belong to size class 3, and farms with *SO* above EUR 3 000 000 belong to size class 14.

We used the age of the farm owner or farm manager if the head of a farm or farm owner was not a manager.

Tenure is calculated as a ratio of difference between total *UAA* (SE025) and leased *UAA* (SE030) to total *UAA* (SE025). Income per ha is calculated as a ratio of gross farm income SE410 over SE025.

The major outcome indicator was crop yield output, which is expressed in natural logarithm.

Descriptive statistics. Table 1 presents the variables' means and compares these for the adopters and non-adopters. The *t*-test values indicating the mean differences between adopters and non-adopters suggest that there are – except for land tenure in both countries and head of farm age and farm income in Slovenia – statistically significant differences between adopters and non-adopters in crop yield output and the used inputs concerning terms of observed characteristics. These notable differences are largely in favour of adopters' farms, which denotes that the adoption would generate a selection bias issue in our estimation.

RESULTS AND DISCUSSION

Following Ma et al. (2022), we utilised the likelihood ratio test (LR) and Akaike Information Criterion (AIC) value to identify the most appropriate functional form. The production functions are estimated by the translog specification [Equation (2)] and Cobb–Douglas specification. The results indicate that the translog specification is preferred (Supplementary Table S1).

Table 2 presents the logit regression model estimates of Equation (3), reporting the determinants of critical inputs used. Labour resources and assets increase the likelihood of ALOCI for Estonian and Slovenian farmers. Whereas the head of farm age decreases the likelihood of ALOCI for Estonian farmers.

Following (Ma et al. 2022), we estimate the treatment effects of the critical inputs using on expected crop yield, crop yield variance and crop yield skewness using the PSM and IPWRA models. Since the PSM methods are sensitive to the exact specification and matching method (Imbens 2004; Caliendo and Kopeinig 2008), we use three different matching techniques: nearest neighbour matching (NNM), optimal matching (OM) and radius matching (RM) as a robustness check. Supplementary Tables S2 and S3 present the matching quality test results, confirming the superior performance of OM for Estonia, and RM for Slovenia.

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Table 1. The descriptive statistics of variables used: adopters vs. non-adopters and statistical *t*-test for Estonia and Slovenia

Variables	Estonia			Slovenia		
	adopters	non-adopters	mean difference	adopters	non-adopters	mean difference
Crop yield output	207.590	13.780	193.800***	37.156	15.3197	21.840***
<i>OIC</i>	1 219.800	397.450	822.350***	230.980	69.5600	161.420***
Total assets (<i>TA</i>)	6 813.260	2 436.930	4 376.330***	3157.170	1 722.5300	1 434.650***
Land (<i>UAA</i> in ha)	324.000	109.630	214.370***	14.390	7.2100	7.180***
Labour	0.270	0.060	0.210***	0.190	0.1600	0.030*
Head of farm age	52.050	53.310	–1.260*	53.980	52.0700	1.910
Land tenure	0.410	0.410	0.000	0.730	0.7700	–0.040
Farm income	83.15	7.640	75.510***	29.160	19.6500	9.500
Farm size (<i>SO</i>)	7.060	5.360	1.700***	5.610	4.6300	0.980***
Fertilisers (expenditures)	4.030	0.000	4.030***	2.120	0.0000	2.121***
Crop protection products (expenditures)	0.760	0.000	0.760***	2.220	0.0000	2.220***
Expected value	0.539	0.436	0.103*	0.519	0.4800	–0.039
Variance	0.313	1.075	–0.763***	–0.054	0.4660	–0.520***
Skewness	–0.467	–2.716	2.249***	5.763	3.3050	2.458***
<i>n</i>	2 106	537	–	1324	60	–

*** and *significance at 0.01 and 0.1 levels, respectively; *OIC* – other immediate consumption; *SO* – standard output; *UAA* – utilised agriculture area

Source: Authors' calculations based on FADN data

Table 2. Determinants of the use of the critical inputs: logit regression model estimates

Variables	Estonia		Slovenia	
	coefficients	marginal effects	coefficients	marginal effects
Head of farm age	–0.001* (0.001)	–0.001*** (0.001)	0.001 (0.000)	0.001 (0.000)
Income	–0.000 (0.000)	–0.000*** (0.000)	0.000 (0.000)	0.000 (0.000)
Assets	0.000*** (0.000)	0.000*** (0.000)	0.000** (0.000)	0.000** (0.000)
Labour	0.018** (0.008)	0.018* (0.008)	0.046 (0.033)	0.046 (0.033)
Land tenure	0.009 (0.023)	0.009 (0.023)	–0.015 (0.021)	–0.015 (0.021)
Constant	0.819*** (0.033)	–	0.912*** (0.297)	–
Number of observations	2 643	2 643	1 384	1 384

***, ** and *significance at 0.01, 0.05 and 0.10 levels, respectively; robust SEs are presented in parentheses.

Source: Authors' calculations

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Tables 3 and 4 present the results for the treatment effects of ALOCI on the first three moments of crop yield output of the PSM (second column) and the IPWRA estimator for Estonia and Slovenia respectively. Our estimates show that ALOCI increases expected crop yield in Estonia but decreases that in Slovenia. For Estonia, sensitivity analysis indicates that the effect on variance is robust to hidden confounders, whereas the effect on skewness may be influenced by unobserved factors. The impact on expected crop yield is inconclusive, as PSM suggests no effect, while IPWRA finds a small but significant effect. For Slovenia, sensitivity analysis confirms that the effect on variance is highly robust to unobserved confound-

ers, while the effect on skewness remains strong and reliable even in the presence of hidden bias. The insignificant effect on expected yield is also robust to potential confounders. The results for Slovenia suggest that the ALOCI is not sufficient for risk efficiency. For example, in northeast Germany risk efficiency was established for the relationship of irrigation of cereals with nitrogen fertiliser (Meyer-Aurich et al. 2016). In addition, Santeramo et al. (2024) argue that in Southern EU geographical areas drought risk is more frequent for spring-summer crops which points to the need to reform policies and strategies of crop insurance schemes to increase farms' resilience to weather shocks.

Table 3. PSM and IPWRA model estimates for Estonia

Outcomes	ATT (PSM)	ATT (IPWRA)	Sensitivity analysis	Heterogeneity treatment effect (HTE)
Expected crop yield	0.097 (0.113) (−0.023, 0.222)	0.278** (0.128) (0.026, 0.531)	no effect ($P = 0.999$)	varies by labour and tenure
Crop yield variance	−0.601*** (0.103) (−0.711, −0.494)	−0.545*** (0.098) (−0.740, −0.351)	strong effect ($P = 0.000$)	varies by income and labour
Crop yield skewness	1.868*** (0.347) (1.526, 2.211)	1.823*** (0.302) (1.228, 2.418)	no effect ($P = 1.000$)	varies by assets income and labour

*** and **significance at 0.01 and 0.05 levels, respectively; heteroskedasticity robust standard errors for PSM results and design-based standard errors for IPWRA results are presented in parentheses; the bootstrap 95% confidence intervals are in parentheses ($n = 1\,000$); sensitivity analysis was conducted using $\gamma = 1.5$, which is considered a conservative assumption (γ – the odds of differential treatment assignment due to unobserved confounders); expected crop yield is measured at log-transformed forms; ATT – average treatment effects on the treated; IPWRA – inversed probability weighted regression adjustment; PSM – propensity score matching

Source: Authors' calculations

Table 4. PSM and IPWRA model estimates for Slovenia

Outcomes	ATT (PSM)	ATT (IPWRA)	Sensitivity analysis	Heterogeneity treatment effect (HTE)
Expected crop yield	−0.162 (0.130) (−0.383, 0.065)	−0.030 (0.107) (−0.242, 0.181)	no effect ($P = 0.725$)	varies by assets
Crop yield variance	−0.553*** (0.123) (−0.726, −0.387)	−0.393*** (0.117) (−0.623, −0.163)	no effect ($P = 1.000$)	varies by assets and labour
Crop yield skewness	2.285*** (0.626) (1.477, 3.105)	1.736** (0.629) (0.499, 2.974)	strong effect ($P = 0.000$)	varies by assets and labour

*** and **significance at 0.01 and 0.05 levels, respectively; heteroskedasticity robust SEs for PSM results and design-based standard errors for IPWRA results are presented in parentheses; the bootstrap 95% confidence intervals are in parentheses ($n = 1\,000$); sensitivity analysis was conducted using $\gamma = 1.5$, which is considered a conservative assumption (γ – the odds of differential treatment assignment due to unobserved confounders); expected crop yield is measured in log-transformed forms; ATT – average treatment effects on the treated; IPWRA – inversed probability weighted regression adjustment; PSM – propensity score matching

Source: Authors' calculations

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The negative and statistically significant *ATT* for crop yield variance for Estonia and Slovenia indicates that ALOCI reduces the volatility of crop yield output.

The results for both countries show that the estimated *ATTs* for skewness is positively and statistically significant. Thus, ALOCI reduces downside risk. Overall, the findings of both PSM and IPWRA model estimations (Tables 3 and 4) are like the results of Table 1, verifying that our *ATT* estimates are robust.

Heterogeneity treatment effect regression results (Supplementary Tables S4 and S5) show that the treatment effects vary based on factors like tenure, labour and income (for Estonia), and assets and labour (for Slovenia), suggesting that targeted interventions could be more effective than uniform policies. This finding is supported by the literature, e.g. Nilsson (2017) and Carter et al. (2019) found that the effect of the investment support varied with the size of the support relative to firm/farm income and had a positive impact on productivity. The policy-makers can design more efficient and equitable agricultural programs by focusing resources on specific subgroups, ultimately enhancing the overall impact and contributing to sustainable development goals. To mitigate agricultural yield risks in Slovenia due to exceptional weather conditions such as droughts and floods, a combination of short-term and long-term strategies and policy measures is essential. Among them is water management with implementation of efficient irrigation systems and investment in water reservoirs to store excess rainfall for dry periods. Irrigation plays a relatively limited but increasingly important role for high-value crops such as vegetables, orchards, and vineyards. Many crops traditionally rely on natural precipitation (Mavsar et al. 2025). However, climate changing weather patterns, including prolonged droughts, are making irrigation more crucial, especially in the Pannonian region in north-eastern Slovenia.

It is also important to adjust crop rotation types to climate change over the hot summer period, for ensuring stable yields, food security, and agricultural sustainability. Resilient crops can encourage the use of drought- and flood-resistant crop varieties tailored to local conditions through research and government supports. This can be supported with early warning systems with develop and expand meteorological forecasting tools to provide timely alerts for extreme weather conditions. It is likely to require up-to-date education and training of farmers on climate-smart

agriculture and support research into precision farming and adaptive technologies.

Soil health management promoting integrated and sustainable farming practices with intercropping and crop rotation, including to mitigate the impacts of high temperature in the summer period, reduced tillage, and organic matter enrichment to improve soil structure and water retention can improve crop yields and increase crop production while reducing environmental footprint (Li et al. 2021; Chai et al. 2021).

Proper fertilisation can enhance soil fertility and crop growth, helping plants withstand stress from drought, pests, and diseases. Balanced fertilisation (nitrogen, phosphorus, potassium) can improve yields. However, excessive use of fertiliser can lead to soil degradation, water pollution, and reduced biodiversity. Precision farming and organic fertilisers can optimise benefits while minimising environmental risks (Čechura et al. 2021).

Crop protection (pesticides and fungicides) protect crops from pests, diseases, and weeds, reducing yield losses. While chemical crop protection improves reliability, overuse can cause pesticide resistance, harm pollinators, and contaminate water sources. Integrated Pest Management, which combines biological controls with minimal chemical use, can be a more sustainable approach.

By combining these measures, Slovenia and Estonia can improve efficiency in use of chemical fertilisers and crop protection products that can help mitigate crop yield risks and enhance agricultural resilience, but carefully managed to ensure sustainability and environmental protection, ensuring stable crop production and food security despite changing climate patterns.

CONCLUSION

This paper investigated the inspirations of farmers' decisions to apply ALOCI on downside risk exposure using FADN farm-level data from Estonia and Slovenia. We used a combination of propensity score matching and the doubly robust inverse probability weighted regression models to achieve our objective.

The results indicate that assets and labour sources were some of the important determinants of ALOCI in both countries. The results reveal that ALOCI increases the expected crop yield in Estonia but decreases that in Slovenia. The latter result and finding are surprising but might indicate less efficient use of chemical agricultural inputs in mitigating downside risk exposure in crop farming. It can be also

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linked to changing climatic conditions with adverse weather conditions, particularly frequent severe droughts with prolonged extremely high daily temperatures when efficiency in use of chemical inputs in terms of fertilisers and pesticides might be limited without complementary use of irrigation to cereals to fertiliser.

Whereas the results for crop yield variance and crop yield skewness are the same for both countries: ALOCI reduces the volatility of crop yield output and reduces downside risk. In particular, the average treatment effect on the treated (*ATT*) estimates shows that ALOCI increases expected crop yield in Estonia by 10% and reduces expected crop yield in Slovenia by 16.2%. At the same time, the ALOCI decreases crop yield skewness for Estonia and Slovenia by 19% and 22% respectively.

The results and findings are robust to alternative matching algorithms and to bias. The results point to the need for policies to encourage financial investment in technology adoption reducing crop yield risk, crop rotation and diversification strategies to mitigate the climate change effects and to adopt eco-friendly farming practices. Farmer organisations models supported with the most recent developments and adoption of artificial intelligence, drone, sensor, and robotic technologies can act as agents for more efficient and sustainable adoption of fertilisers and crop protection on crop yield downside risk.

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