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# Knowledge, diversification and productivity in agriculture

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# Knowledge, diversification and productivity in agriculture


## Abstract

In this thesis I examine how Swedish farms adapt to structural, economic, and environmental pressures, and how knowledge shapes the adaptation processes. The thesis consists of four empirical studies where I analyse short-run responses to shocks, longer-term strategies for economic viability, ecological diversification, and investment behaviour. I use rich Swedish register and administrative data linked to geospatial and climatic information, allowing farms and farmers to be followed over time.

Pre-existing off-farm wage work is assessed as a source of income stability during the 2018 drought in the first study. The results show that farmers who already combine farm and wage income maintain total earnings during the shock, consistent with off-farm work functioning as a pre-committed adaptation strategy rather than an immediate coping response. The second study focuses on how functional crop diversity affects productivity and whether such effects spill over to neighbouring farms. The results indicate that functionally diverse crop rotations raise productivity and generate local spillovers, highlighting crop diversification as a knowledge-intensive innovation process. In the third study hybrid farming, the combination of farm self-employment and off-farm wage work, is examined as a long-term strategy for economic viability. Under certain income compositions and asset configurations, hybrid farming can be a durable state rather than a transitional phase. The fourth study addresses how rising land values relate to productivity growth through the collateral channel. The findings demonstrate that a higher price of pasture can increase productivity growth and investment.

With respect to knowledge, the findings of this thesis show that different forms of human capital, in the form of education, experience, networks, diversification know-how and intergenerational transmission, are central to how farms remain viable under structural, economic, and environmental change.



Keywords: knowledge, diversification, productivity, agriculture, farm viability, hybrid farming, drought, collateral, spatial spillovers, Sweden.

# Kunskap, diversifiering och produktivitet i jordbruket


## Abstract

I denna avhandling undersöker jag hur svenska jordbruk anpassar sig till strukturella, ekonomiska och miljömässiga påfrestningar, och hur kunskap formar anpassningsprocesserna. Avhandlingen består av fyra empiriska studier där jag analyserar kortsiktiga reaktioner på chocker, långsiktiga försörjningsstrategier, diversifiering av växtodling och investeringsbeteenden. Analysen bygger på svenska register- och administrativa data som kopplas till geografisk och klimatrelaterad information, vilket gör det möjligt att följa enskilda gårdar och jordbrukare över tid.

I den första studien undersöks om redan etablerat arbete utanför jordbruket stabiliserade jordbrukarnas inkomster under torkan 2018. Resultaten visar att jordbrukare som kombinerade jordbruksinkomst med lönearbete behöll sin totala inkomst under chocken, vilket tyder på att arbete utanför jordbruket fungerar som en förutbestämd strategi snarare än en omedelbar åtgärd. Den andra studien fokuserar på hur funktionell gröddiversitet påverkar produktiviteten och i vilken utsträckning dessa effekter sprids till närliggande gårdar genom lärande. Resultaten tyder på att funktionsmässigt varierade växtföljder ökar produktiviteten och genererar lokala spridningseffekter. I den tredje studien undersöks hybridjordbrukare, det vill säga jordbrukare som kombinerar företagande i jordbruket och lönearbete utanför sektorn, och om detta utgör en långsiktig försörjningsstrategi. Studien visar att under vissa kombinationer av inkomster och tillgångar kan hybridjordbruk vara ett långvarigt tillstånd snarare än en övergångsfas. I den fjärde studien analyseras om stigande markpriser ökar produktiviteten genom att marken kan belånas för investeringar. Resultaten visar att högre priser på betesmark kan öka produktivitetstillväxt och investeringar.

När det gäller kunskap visar resultaten i denna avhandling att kunskap, i form av utbildning, erfarenhet, nätverk, kompetens i att diversifiera grödor och intergenerationell överföring, är central för hur gårdar förblir livskraftiga under strukturella, ekonomiska och miljömässiga förändringar.



Nyckelord: kunskap, diversifiering, produktivitet, jordbruk, hybridjordbruk, torka, rumsliga spridningseffekter, Sverige.

# Preface

This thesis began to take shape in the late summer of 2021. Now, in the midwinter of 2026, it is finally complete. My background in economics had been centred on spatial dynamics, innovation, and growth. I was fortunate to find a project where these interests could be applied to the agricultural sector. Apart from an enduring love for cows, I entered this work as something of an outsider, and much of the research journey became about learning the different ways agriculture can look like in practice. Throughout the process, one question stayed with me. What does it mean to be a successful farmer today? This thesis is, in many ways, an exploration of that question and a record of everything I learned along the way.

Somewhere in the middle of this journey, AI became part of everyday research life. In a rapidly changing environment, it has become a most useful tool that helps me bounce ideas, get quick feedback on grammar and spelling, and write cleaner and more understandable code. Using these tools made me reflect on how research practices are changing, and on the importance of being open about the support we use while thinking carefully about transparency and responsibility in academic writing.

Whether you are about to read this thesis cover to cover or maybe just glance through the popular science summary, I hope it gives you a small glimpse into the complex, fascinating world I've been exploring.

# Dedication

For Börje and Ulla

# Contents

# List of publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I. Johansson, E., Ferguson, S., Hansson, H., and Nilsson, P. Off-farm labour income stabilises farmers' income during severe drought - evidence from Swedish agriculture (manuscript)

II. Johansson, E. Functional Crop Diversity, Farm Productivity, and Local Knowledge Spillovers (submitted)

III. Johansson, E., Nilsson, P., and Hansson, H. (2025). Transition dynamics of hybrid farmers: a survival analysis of exits and entries into full-time farming. European Review of Agricultural Economics, 51 (5), 1384–1409. doi:https://doi.org/10.1093/erae/jbaf003

IV. Johansson, E., Ferguson, S., Hansson, H., and Nilsson, P., Slijper, T. When land becomes leverage: collateral, and productivity in Swedish dairy farming (manuscript)

Paper III is reproduced according to the open access publishing agreement with the publisher.

The contribution of Eleanor Johansson to the papers included in this thesis was as follows:

I. I was responsible for the data preparation, empirical design, econometric analysis, and drafting of the paper. The co-authors contributed to the formulation of research question and to discussions and revisions throughout the process.

II. This paper was written alone, and I was responsible for all parts of the work, including the conceptual development, data management, econometric analysis, and writing.

III. I was responsible for the data preparation, empirical design, econometric analysis, and drafting of the paper. The co-authors contributed to the formulation of research question and to discussions and revisions throughout the process.

IV. I was responsible for the empirical analysis, model estimation, and drafting of the paper. The dataset used in this paper was constructed by Pia Nilsson. The co-authors contributed to the formulation of research question and to discussions and revisions throughout the process.

# List of tables

# Abbreviations

| | |
|---|---|
| AECM | Agri-Environment-Climate Measures |
| AKIS | Agricultural Knowledge and Innovation System |
| CAP | Common Agricultural Policy |
| CDI | Combined Drought Indicator |
| CEM | Coarsened Exact Matching |
| DiD | Difference-in-Differences |
| FTR | Property Tax Register |
| IPCC | Intergovernmental Panel on Climate Change |
| LISA | Longitudinal Integration Database for Health Insurance and Labour Market Studies |
| LPIS | Land Parcel Identification System |
| MONA | Microdata Online Access |
| PPR | Production Place Register |
| SCB | Statistics Sweden |
| SLX | Spatial Lag of X |
| SNI | Swedish Standard Industrial Classification |
| TFP | Total Factor Productivity |

# 1. Introduction

## 1.1 The challenge of farm viability during change

Agriculture faces a set of overlapping structural, economic, and environmental pressures that challenge the foundations of farming systems. Across much of Europe and other high-income countries, the number of farms has steadily declined while the average farm size has been growing (Eurostat, 2022; Sumner, 2014). Mechanization, market integration, and policy reforms have accelerated this process of consolidation (Eastwood et al., 2010). There is also an ageing farming population, which raises questions about generational renewal (Barry and Robison, 2001; Sutherland, 2023). This is important for both transferring skills and knowledge across generations, but also for ensuring that farming remains an attractive profession for new farmers. These structural changes highlight the uncertainties associated with the long-term organization of farming systems.

Farming is also subject to economic pressures that shape the viability of farming. For instance, if a farm owns land it is commonly the largest share of a farm's assets (Nickerson et al., 2012). Therefore, it is not only a factor in production but also a financial asset that potentially can be leveraged to support investment and renewal. If such investment contributes to productive capacity, it can enhance farm economic performance. This example is part of a wider debate on economic performance of farms. Can farms be profitable, efficient, productive? The economic outcomes can be many, and they all relate to how both the individual farm and the agricultural sector as a whole can be economically viable in the long-run.

Structural change has formed large-scale, specialized farming systems where economies of scale have been dominant. This trend has been reinforced by market forces, demand by consumers and retailers, technological advances, and policy incentives that promote monocultures (Bennett et al., 2012). However, economies of scope can offer important benefits, if diversified farms perform as well as, or better than, specialised ones (de Roest et al., 2018; Kim et al., 2012; Sánchez et al., 2022). Thus, the question is not only whether farms can remain economically viable but also how that viability can be achieved, e.g. via strategies that aim for diversification or specialization on farms.

At the same time, climate change adds an additional layer of uncertainty. While farming has always been influenced by fluctuating weather conditions (Lucas and Chhajed, 2004), climate change is expected to make weather patterns increasingly volatile and extreme weather events more common (IPCC, 2023). This amplifies production risks and complicates long-term planning. Moreover, the relationship between agriculture and climate change runs in both directions. Agriculture is both a significant source of greenhouse gas emissions (Crippa et al., 2021) and a potential avenue for mitigation through for example land use, carbon storage, and biodiversity (Alston and Pardey, 2021; Evenson and Pingali, 2007). This dual role makes adaptation not only a matter of managing risk but also of transforming farming practices in response to environmental pressures. Moreover, agriculture is dependent on a stable climate and functioning ecosystems to maintain production.

These structural, economic, and environmental pressures together define the broader context in which farm viability is challenged. In this thesis, I approach questions related to these challenges through three interrelated themes, knowledge, diversification, and productivity. Each theme captures a different aspect of how farms respond to and are shaped by these pressures, and together they provide complementary perspectives on the dynamics of adaptation and economic performance.

The role of knowledge serves as a central connecting thread in this thesis. Farm decisions are not made in isolation but depend on the skills, information, and resources available to farmers (Chavas and Nauges, 2020; Evenson and Pingali, 2007). Knowledge shapes how farmers interpret risks, evaluate opportunities, and act upon them (Barry and Robison, 2001). This can involve seeking off-farm employment, adjusting production, or making investment decisions (Huffman, 2000; Khanal and Mishra, 2014). It also has a collective dimension, as knowledge is transmitted across generations and exchanged within local networks (Barnett-Howell and Mobarak, 2021; Kolady et al., 2021; Rosenzweig and Wolpin, 1985). Knowledge is thus understood in multiple ways, reflecting its varied roles in shaping farming decisions and adaptation.

Another theme in this thesis is diversification, which for a long time has been recognised as a way for farms to cope with risk and uncertainty (Knapp et al., 2021). Diversification is examined here both through off-farm employment as a way to diversify household income, and through crop diversification as a way to link biodiversity with farm productivity. There are many forms of diversification in farming beyond those considered here. In this thesis, the chosen forms of diversification connect economic viability with broader societal expectations of what a farmer should be and their role in preserving the environment. In contexts of structural and environmental change, diversification is therefore considered not only a coping mechanism but also a pathway for farms to remain viable.

The third theme is productivity, which is commonly treated as an important measure of performance in agriculture (Huffman, 2000). Improvements in productivity have historically driven agricultural growth, enabling farms to produce more output with fewer inputs (Alston and Pardey, 2021). Yet productivity is not simply a technical indicator but also reflects the choices farmers make about how to combine resources, adopt technologies, and organize production (Evenson and Pingali, 2007). Thus, productivity provides a benchmark for assessing how different farm adaptations are reflected in economic outcomes.

These dynamics highlight both the vulnerability and adaptability of farming systems. Agriculture sits at the intersection of shifting farming conditions and societal expectations, both of which demand not only adaptation but also active contributions to solving broader challenges. Farms must balance productivity with adaptability, and economic performance with environmental responsibility, managing the trade-offs and potential synergies that arise between them. However, the path forward is far from clear. Can off-farm work mitigate the income risk from climate change and be a long-term pathway to farm viability? Can ecological practices, such as crop diversification, help farms balance short-term performance with long-term sustainability? And what role does land play in shaping farm productivity and investment? These tensions point to the broader issue motivating this thesis, namely the persistent challenges farms face in remaining viable during structural, economic, and environmental change.

## 1.2 Aims

In light of these issues, the overarching aim of this thesis is to examine how Swedish farms adapt to structural, economic, and environmental pressures, specifically through the economic strategies they employ. Knowledge plays a central role in shaping these strategies and, ultimately, their adaptation. One strategy concerns how they allocate their labour on and off the farm, both to sustain their long-term viability as farmers and to manage income fluctuations caused by environmental risks. Another strategy involves diversifying crop production to balance ecological benefits with productivity. Lastly, farms may leverage assets such as land to secure credit and finance investment. To study these strategies, the thesis focuses on three key outcomes: (i) the time farmers stay in agriculture, (ii) the productivity growth of farms, and (iii) the share of off-farm income. These measures are chosen for their ability to capture long-term patterns that are shaping farming and contribute to farm viability.

Sweden provides a particularly relevant context for examining these issues, as its agriculture is capital-intensive yet still dominated by family farms (Joosse and Grubbström, 2017). This combination creates a setting where farms rely heavily on investment and technology while still being shaped by household decisions, making it well suited for exploring the diverse ways farms can be successful and remain viable under changing conditions. Moreover, Sweden's rich long-term register data allow these adaptation processes to be analysed in detail.

While the pressures that farms face, as outlined above, are well documented, the knowledge-related mechanisms that influence how individual farms adapt, who remains in farming and who expands or exits is important for understanding the types of knowledge in farming and how they directly help or hinder it. Understanding these mechanisms is essential for clarifying how farm-level decisions connect to broader patterns of agricultural development. The thesis consists of four manuscripts, each focusing on a specific question that contributes to the overarching research aim. Read in sequence, the studies move from short-term adjustment to long-term survival, with the aim of highlight how knowledge underpins diversification and productivity as pathways to farm viability. Table 1.1 shows the aim and research question of each paper in this thesis and they are described in more detail below.

The first study examines farmers' responses to weather shocks. The 2018 drought in Sweden created abrupt and widespread production losses. The question is whether farmers who engage in off-farm employment have adapted their income towards the off-farm source in response to the drought as a way to balance income losses. Here, income diversity is the central measure for analysing how farmers cope with weather risks. Knowledge is understood as part of the process of how farmers can adapt in the way they interpret the shock, assess available income options, and decide whether to reallocate labour into off-farm activities. Off-farm work is thus not only an additional income source but also a strategy that draws on specific knowledge and experience to manage risk under uncertainty.

Table 1.1 Aims and research question of each paper

| Paper | Aim | Research question |
|---|---|---|
| I | To analyse how off-farm work shapes income stability under climate shocks | Does pre-existing off-farm employment stabilise income during the 2018 drought? |
| II | To evaluate ecological and spatial dimensions of crop diversification | Does functional crop diversity raise TFP and generate local spillovers? |
| III | To examine hybrid farming as a long-term adaptation strategy | How do farmers transition into, remain in, or exit hybrid farming? |
| IV | To identify whether land values affect investment capacity | Do rising land prices increase productivity through the collateral channel? |

The second study focuses on production choices as an adaptation strategy within farming. The aim is to analyse how crop diversification influences productivity growth at the farm. Moreover, if there is specific knowledge associated with this type of diversification there may be spillover effects between neighbouring farms. Crop diversification in this context is understood as a knowledge-intensive practice and contributes to the discussion on how innovation can be understood in agriculture.

The third study addresses the broader role of off-farm work in shaping farmers' trajectories within farming. It explores the transition dynamics in and out of farming and the use of off-farm work as a long-term strategy. Here the combination of on- and off-farm income is developed into a concept of hybrid farming, drawing a parallel to hybrid entrepreneurs (Folta et al., 2010) where off-farm income can be used as a way to enter into full-time farming, exit farming completely or staying in the hybrid state. This suggests that hybrid farmers have some particular knowledge on how to combine these income sources. Here we also include farming and self-employment experience of both the mother and father to highlight the role of knowledge transferred across generations.

The fourth study considers the financial environment in which farms operate. Rising land values can alter credit access through increased collateral value and therefore investment opportunities for landowning farms. Thus, the purpose of this study is to analyse whether rising farmland prices translate into productivity growth by easing collateral constraints. Here, the unit of analysis changes to the agricultural property (lantbruksfastighet), that is, the physical asset consisting of land and farm buildings rather than the farm business entity. This allows us to include variables of ownership transfer from market purchase or inheritance and thus again add a perspective of how knowledge can be transmitted between generations.

The four papers provide complementary perspectives on knowledge, diversification and productivity in agriculture. The studies can be read as a story about how knowledge first appears as tacit, experience-based know-how, helping farmers interpret shocks and adapt under pressure. It then emerges as a basis for innovation, enabling new practices that improve productivity on and beyond the farm. Beyond coping and improvement, knowledge also shapes strategy, as households proactively combine activities to remain economic viable. Finally, knowledge is shown as something transmitted over time, ensuring continuity and adaptation across generations.

The remainder of this chapter provides the background and theoretical framing for the thesis. Section 2 reviews the literature on how knowledge influences farm adaptation through environmental, economic, and structural dimensions. Section 3 then outlines the empirical setting and data sources, followed by Section 4, which summarises the analytical approach and links the four studies to the overarching research questions. Section 5 concludes and offers a discussion on contributions, limitations, policy implications, and avenues for future research.

# 2. What Role Does Knowledge Play in Agriculture?

This thesis is rooted in agricultural economics, drawing on several strands of economic theory to examine how farms adapt to structural, economic, and environmental pressures. It draws on literature related to climate and environmental risk, diversification strategies, and the role of land in knowledge flows and as a financial asset. Across these dimensions, knowledge serves as a unifying theme, shaping how farmers interpret risks, make decisions, and transmit practices across time and space. Each of the following sections highlights one of these dimensions, showing how knowledge operates across the different empirical contexts examined in the thesis. They provide the conceptual foundation for understanding how knowledge underpins the analyses that follow.

## 2.1 Climate and environment

Farming is inherently exposed to weather variability, and climate change amplifies this vulnerability (Schmitt et al., 2022). While there could be some benefit of a warmer climate in some regions, these benefits can be offset by extreme weather events, even if there are long-term improvements in management and technology (Harrison, 2021). Farmers respond through a mix of adjustments such as altering input choices, investing in risk-reducing technologies, and diversifying income sources (Knapp et al., 2021; Wimmer et al., 2024). Farmers may have incentives to conserve soil or water when these resources underpin their own production, but such private incentives are rarely sufficient to internalize the environmental externalities and meet society's broader demand for environmental quality (Lichtenberg, 2002). For example, practices such as crop rotation, conservation tillage, and diverse crop mixes sustain soil health and reduce pests and disease (Kolady et al., 2021), but farms may need extra incentives to find adoption preferable.

These dynamics matter directly for the two papers where climate and environment enter this thesis. Paper I examines a weather shock and Paper II examines the effects of crop diversification, and knowledge shapes how farmers respond in both cases. Education and managerial capability shape how farmers interpret risk and adopt new technologies (Chavas and Nauges, 2020; Koundouri et al., 2006). Experience and social learning condition the effectiveness of these adaptations, as farmers draw lessons from both their own and their neighbours' choices (Chavas and Nauges, 2020). Similarly, the adoption of biodiversity-enhancing practices depends not only on a farmer's own knowledge but also on knowledge networks, extension services, and the diffusion of information across space (Kolady et al., 2021).

## 2.2 Some diversification strategies

There are many ways diversification can take place in agriculture. Broadly defined, it includes both agricultural and non-agricultural activities, and is closely linked to the concept of *pluriactivity*, where households combine farming with other income sources (Eikeland and Lie, 1999). Non-agricultural diversification can occur on the farm through, for example, agritourism, processing, or energy production, but also off the farm, as farmers engage in wage work or self-employment in addition to farming (Finger and El Benni, 2021; Khanal and Mishra, 2014; Knapp et al., 2021).

In this thesis, the concept of off-farm employment is used where farmers take waged employment outside of farming. Education expands the range of off-farm opportunities available (Khanal and Mishra, 2014). Farm households also use off-farm income as part of broader risk-balancing strategies, with small farms in particular relying on household-level adjustments to stabilise income and consumption (De Mey et al., 2016). Spatial context also matters, with off-farm income patterns shaped by farm size, farm type, and proximity to urban labour markets (Van Leeuwen and Dekkers, 2013).

There is also diversification directly related to the farming itself. For example, we can think of mixed farming systems with combined crop and livestock farming or other mixes with different varieties of farming. This thesis specifically looks at crop diversification. Well-designed rotations recycle nutrients, sustain land productivity, and break pest and disease cycles, while also reducing erosion, improving soil fertility, and supporting ecosystem services (Altieri et al., 2015; Davis et al., 2012; Fausti, 2015; Gebremedhin and Schwab, 1998). Education is also important for on-farm diversity as it increases on-farm effectiveness (Weiss, 1999). Managerial capability and accumulated experience shape how effectively farmers adopt and benefit from diversification and are able to benefit from scope economies (Sumner, 2014).

Thus, knowledge enables farmers to identify, implement, and benefit from diversification strategies. Farmers draw on this knowledge when deciding whether and how to diversify, balancing expected returns against risks and long-term goals. There are various reasons farmers adopt these strategies ranging from increasing profitability, smoothing income, and mitigating risk exposure (Knapp et al., 2021). Therefore, these strategies can be important for the long-run viability of farming. To understand farmers' incentives requires examining whether diversification creates complementarities with economic outcomes (Chavas and Di Falco, 2012).

## 2.3 Knowledge flows and spatial context

Economic geography has long emphasised the importance of space for innovation and growth. Knowledge, especially tacit knowledge, is often described as "sticky," with transfer costs increasing over distance, making geographical proximity valuable for learning, collaboration, and the diffusion of ideas (Iammarino and McCann, 2006). These insights underpin theories of co-location and clustering, where firms benefit from shared labour markets, specialised suppliers, and localized spillovers.

Agriculture is different from other industries because it is spatially bound and the ability of a firm to choose location is limited. Relating location, agriculture and knowledge is therefore better described through networks than other notions of space like pure agglomerations or industrial complexes (Gordon and McCann, 2000). Indeed, networks can be a substitute for agglomerations and provide similar benefits even when economic actors are dispersed in space (Johansson and Quigley, 2004). Diffusion of agricultural knowledge and technology is influenced by learning and social interaction, often with a significant spatial dimension, where farmers learn from neighbours' choices (Chavas and Nauges, 2020).

Location is crucial in understanding knowledge flows, since knowledge has been found to be geographically concentrated (Audretsch and Feldman, 2004). In addition, the capacity to absorb flows of new technological knowledge is facilitated by geographical proximity (Baptista, 2000). While proximity facilitates knowledge flows in agriculture as in other sectors, the mechanisms differ since farms cannot cluster like other industries. Instead, it is local networks, biophysical conditions, and natural prerequisites for agriculture, and social interaction that drive diffusion among spatially fixed farms (Chavas and Nauges, 2020).

In farming, location is also about the land itself, its quality, use, and productive potential. Land is the largest asset in farming and the basis of production, with its value shaped by factors such as soil quality, proximity to markets, policy conditions, and natural amenities (Nickerson et al., 2012). In this sense, land connects the spatial dimensions of farming, shaping both production potential and the local conditions through which knowledge and innovation circulate.

## 2.4 Conceptualising knowledge in agriculture

I have repeatedly referred to knowledge in relation to diversification, land, and environmental adaptation, but what is knowledge in these contexts? Knowledge is not a single attribute but a multidimensional resource that shapes decisions, performance, and long-run survival. One dimension is human capital, broadly reflected in education, information gathering, and extension use, which improves farmers' ability to allocate resources efficiently and to access off-farm opportunities (Khanal and Mishra, 2014; Koundouri et al., 2006).

A second is entrepreneurial and managerial capability, which determines how effectively farmers organise production, adopt innovations, and compete for resources (Eastwood et al., 2010). This type of knowledge can increasingly be understood in the same way as in non-farming occupations (Sumner, 2014). Because of this parallel, we draw on the entrepreneurship literature and use the concept of hybrid entrepreneurs to develop the idea of off-farm employment into *hybrid farmers*. The hybrid entrepreneur engages in their entrepreneurial venture while still keeping their original employment to stay financially secure while expanding the new business (Folta et al., 2010). By looking at farmers with similar behaviour, we can follow the entrepreneurial behaviour of these hybrid farmers.

Closely related to entrepreneurial and managerial capability is innovation capacity, or the ability to generate and implement new practices and technologies, which contributes to productivity and income growth in agriculture (Chavas and Nauges, 2020). This understanding of innovation capacity resonates with the literature on farm-specific human capital, where experience and early exposure embed knowledge in the particular land, technologies, and routines of a farm (Laband and Lentz, 1983; Lentz and Laband, 1990). In Lazear's (2009) skill-weights framework, these context-specific combinations of skills function as firm-specific human capital, providing farmers with a competitive edge in managing and innovating within their production systems.

Knowledge also carries a temporal and familial dimension where intergenerational transfer ensures that skills and practices are passed on, shaping the incentives for and possibility of expansion (Weiss, 1999). The economics of intergenerational transmission has long emphasised how parents' investments in their children's human capital generate persistence in economic outcomes across generations (Becker and Tomes, 1986, 1979). More recent extensions of this framework highlight the importance of early and sustained investment in human capital, showing that limited resources can restrict the development and transfer of productive capabilities (Lee and Seshadri, 2019). In farming, these mechanisms operate through both the transfer of assets and the transmission of farm-specific knowledge that links land, skills, and management experience. Empirical evidence suggests that the economic benefits of succession unfold gradually, as younger generations build on the productive and organisational capacities of their predecessors (Dudek and Pawłowska, 2022).

Finally, knowledge is not only individual but also social because spillovers occur as farmers observe and learn from each other, with adoption patterns and productivity often mediated by spatial proximity and peer networks (Chavas and Nauges, 2020; Hill and Burkhardt, 2021; Kolady et al., 2021). Together, these dimensions highlight knowledge as a central thread in this thesis, as a set of tangible mechanisms that condition how farmers respond to structural, economic, and environmental challenges.

There are several ways to operationalise and proxy these knowledge dimensions. Each paper in the thesis approaches it through specific, observable measures. Paper I examines how households reallocate labour in response to drought, using farmers' agricultural experience to dynamically capture adaptive capacity under an external shock. Paper II explores spillovers from crop diversification, treating crop diversification as a knowledge-intensive innovative process. Knowledge flows are operationalised through spatial proximity that captures how farmers learn from their neighbours' diversification and productivity outcomes. Paper III investigates how farmers stay in farming by combining on- and off-farm work, employing education, agricultural education, and work experience in and outside agriculture to reflect human capital and entrepreneurial capacity. It also incorporates agricultural and self-employment experience of both the mother and father. Finally, paper IV focuses on the role of land as collateral for investment. Here, knowledge enters through the intergenerational dimension by following farms across succession events. The analysis captures how skills and incentives are transmitted alongside assets, shaping long-run investment behaviour.

# 3. Methodology

## 3.1 Data

The empirical analyses in this dissertation rely on rich administrative and register-based data from Statistics Sweden (SCB), combined with complementary sources that provide detailed information about farms and farmers. These datasets facilitate analysis of agricultural production, land use, and farmers from multiple perspectives.

A key source is firm-level financial microdata from Statistics Sweden. These records include variables such as net sales, value added, labour input, debt, and capital. The firms are connected to the Swedish Standard Industrial (SNI) Classification codes which allows for detailed description of the type of production a firm conducts. This means we can pinpoint agricultural producers and further categorise into finer levels such as crop and dairy farming.

Also from Statistics Sweden is the Longitudinal Integration Database for Health Insurance and Labour Market Studies (Longitudinell integrationsdatabas för sjukförsäkrings- och arbetsmarknadsstudier, LISA), a population-based register covering all legal residents in Sweden aged 16 and older. From this register, variables such as education level, years of experience, and income sources can be determined. LISA is also connected to the SNI codes and further also to the firm each individual works at. This means there is detailed information about the workers at a company or, conversely, detailed information about the firm for each individual. It is also possible to determine familial relations, allowing parents and spouses, along with their characteristics, to be linked to the individual.

Another central source throughout the papers is the Land Parcel Identification System (LPIS), administered by the Swedish Board of Agriculture. This dataset contains spatially explicit information on nearly all arable land parcels (fields) in Sweden, including the geographic boundaries of fields, the crops cultivated, and participation in agri-environmental schemes. The LPIS has near-complete coverage of the farming population and forms the backbone in this thesis for measuring land use, crop diversity, and farm location.

To capture land ownership and livestock information, the Property Tax Register (Fastighetstaxeringsregistret, FTR) and the Production Place

Register (PPR) are used. The FTR enables the tracking of farm buildings (real estate assets) and land holdings over time, independent of changes in organizational numbers due to inheritance or sales. The PPR provides information on livestock and production places, including the number and type of animals registered at each firm.

Finally, in order to study the drought in 2018 the Combined Drought Indicator (CDI) from the European Drought Observatory is used (Cammalleri et al., 2021). This information is geographically matched to each farm and allows for the assessment of how weather shocks interact with farmers' incomes.

Based on these sources, three datasets have been constructed, each covering multiple, but not all, of the above sources. An overview of the data sources used in each paper is found in Table 3.1. There is one dataset at the individual level used for the first and third paper, one at the firm level for the second paper and one at the farm building level for the last paper in this thesis. While coverage and sample composition differ between studies, a common feature is the ability to merge geospatial, economic, and demographic information at micro levels. This integrated approach enables empirical analysis of agricultural outcomes both from the perspective of production units, and from the perspective of the individuals that operate them.

Table 3.1 Overview of data sources across the four papers

| Paper | Level of analysis | Time period | Key registers and datasets |
|---|---|---|---|
| **I** | Individual | 2012–2021 | LISA, LPIS, PPR, CDI |
| **II** | Farm | 2009–2021 | LPIS, SCB firm-level financial microdata |
| **III** | Individual | 2001–2018 | LISA, LPIS, PPR |
| **IV** | Farm property | 2011–2021 | FTR, PPR, LPIS, SCB firm-level financial microdata, LISA |

This type of register data is suitable for analysing questions about change. There are both many time periods and many units as these registers are population based. This way it is possible to follow many types of outcomes over time to analyse how farms and farmers adapt to various conditions. Moreover, these data allow for several detailed ways to proxy the knowledge concepts discussed in Section 2. While knowledge cannot be measured directly, a limitation discussed further in Section 5, it can be captured through a range of indirect indicators. For instance, years or level of education, including agricultural education, and years of experience within a specific sector serve as proxies for human capital. Fine-scale spatial distance between farms can be used to approximate knowledge flows, while information on parents' occupations and experience provides a way to capture intergenerational knowledge transfers. These variables provide wide empirical coverage and analytical flexibility.

All data processing and analysis were conducted within Statistics Sweden's secure MONA (Microdata Online Access) environment. MONA provides a controlled research infrastructure that enables linkage and analysis of high-dimensional register data while ensuring confidentiality. This setup allows previously separate data sources from administrative registers, spatially explicit farm and field data, and climatic indicators to be combined within a secure framework.

## 3.2 Methods

The studies in this dissertation use a range of econometric and statistical methods to address both exploratory analyses and causal inference. Some methods are central for estimating the main outcomes, while others are employed to construct variables or improve comparability across groups.

Table 3.2 Overview of analytical methods and their purpose

| Paper | Main analytical method(s) | Purpose in the thesis |
|---|---|---|
| **I** | Coarsened Exact Matching (CEM); Difference-in-Differences | Create comparable control groups; identify causal effects of the 2018 drought on farm and off-farm income. |
| **II** | Spatial Lag of X (SLX) model; Production function | Assess how crop diversification affects productivity and whether neighbouring farms generate local spillovers; estimate productivity growth. |
| **III** | Parametric survival model | Analyse the duration of hybrid farming. |
| **IV** | Difference-in-Differences; Production function | Evaluate how land-price shocks affect productivity growth; estimate productivity growth. |

Table 3.2 provides an overview of the main methods used in each paper and their role within the broader thesis. The sections that follow describe these

methods in greater detail and explain how they are implemented in the empirical analyses.

### 3.2.1 Measuring Total Factor Productivity

Farm-level total factor productivity (TFP) is estimated using a production function, which relates farm output to the main inputs of production such as labour, capital, and intermediate goods. To address potential biases in this estimation, a control function approach following Levinsohn and Petrin (2003) is applied. This method addresses the simultaneity problem that arises when farms adjust their input choices in response to unobserved productivity shocks, creating correlation between inputs and productivity (Marschak and Andrews, 1944).

The estimation relies on a log-linear Cobb-Douglas specification with net sales as output and labour, capital, and intermediate inputs as factors of production. The Cobb-Douglas form is widely adopted in both theoretical and empirical work (Comin, 2010; Konings and Vanormelingen, 2015), ensuring comparability with related studies. The key feature of the Levinsohn-Petrin approach is the use of intermediate input demand as a proxy for unobserved productivity, which is particularly suitable in this context since almost all farms report positive intermediate input use, while many report zero investment. This makes it preferable to the investment-based method of Olley and Pakes (1996).

Estimation proceeds in two stages. In the first stage, a control function is estimated using a flexible third-order polynomial. In the second stage, the input elasticities are identified using a generalized method of moments estimator (Wooldridge, 2010). TFP is then recovered as the residual from the estimated production function, representing the share of output not explained by observable inputs. Generating the first difference of TFP then provides measures of farm-level productivity growth which is used as the outcome variable in Paper II and IV.

### 3.2.2 Coarsened exact matching

To address potential selection bias when estimating the effects of the 2018 drought, a Coarsened Exact Matching (CEM) procedure is employed (Iacus et al., 2012, 2011). In simple terms, matching methods aim to make treated and untreated groups as comparable as possible, so that differences in outcomes can be interpreted as effects of the treatment rather than pre-existing differences between farmers. The motivation for matching arises because drought exposure is heterogeneous across regions due to variation in climate, soils, and agronomic practices (Deschênes and Greenstone, 2007). In addition, farmers' adaptive capacity may differ systematically across locations, which complicates direct comparisons between affected and less affected farmers.

CEM creates a control group of less affected farms that closely resembles the set of severely affected farms in terms of pre-drought characteristics. Unlike propensity score matching, which balances covariates ex post, CEM reduces imbalance ex ante by grouping observations into coarsened strata and then discarding units that fall outside common support (Iacus et al., 2012). This procedure has been shown to perform well in large datasets, yielding lower variance in treatment effect estimates compared to propensity score methods (Bertoni et al., 2020).

The matching is implemented at the farm level using data from 2017, i.e. the year before the drought, and focuses on variables expected to influence vulnerability to drought. Farms are matched within counties to account for geophysical similarities such as soil quality and the length of the growing season. County-level land prices are included to capture regional variation in income potential, economic conditions, and market access. Finally, farms are categorized by the production orientations of crop, dairy, livestock, or mixed production, since drought sensitivity varies systematically across systems (Leister et al., 2015).

The resulting matched sample provides a control group of farms not exposed to severe drought but otherwise similar in terms of key covariates. This matching framework follows the potential outcomes approach of Rubin (1974), where unbiased estimates of treatment effects require that treated and control groups are comparable. Balance is assessed using the multivariate imbalance measure proposed by Blackwell et al. (2009), and sensitivity analyses are used to evaluate the robustness of the matching results. Matching does not produce perfectly balanced groups. Therefore, it is not sufficient to rely on simple mean comparisons to estimate the effect of the 2018 drought (Iacus et al., 2012). For this reason, the next step is to use difference-in-differences techniques to obtain credible causal estimates.

### 3.2.3 Difference-in-differences estimations

Two types of difference-in-differences (DiD) estimations are used in this thesis in Paper I and IV. The DiD framework is a standard way to estimate causal effects by comparing how outcomes change over time for a treated group relative to a comparable control group.

Standard two-way fixed effects estimators can be biased when treatment effects are heterogenous or when treatment timing is not staggered (de Chaisemartin and D'Haultfœuille, 2020; Goodman-Bacon, 2021). In the setting of Paper I with a binary treatment and heterogenous treatment effects, we address these concerns by using the estimator proposed by Callaway and Sant'Anna (2021). This approach combines the weights from the CEM procedure with regression adjustment, allowing for further control of covariates related to farmers' adaptation capacity and off-farm work decisions. In this way, the estimator isolates the average treatment effect on treated farmers while accounting for residual imbalance and heterogeneous responses to the drought. The overall strategy follows a similar logic to Nilsson and Wixe (2022), who also combine CEM with a panel estimator in a Swedish farm context, although the specific estimator differs.

A second difference-in-differences specification is applied in Paper IV to study how land-price shocks affect farm productivity through increased collateral value, drawing on the approach of Schmalz et al. (2017). The analysis compares farms that own all their land with farms that consistently rent, using cumulative land-price growth at the county level as a continuous treatment. In this setting, landowners experience an expansion of collateral capacity when land prices rise, whereas renters who face the same local economic and environmental conditions but lack collateralizable assets do not. Differences in productivity responses between these two groups can therefore arguably be attributed to variation in access to collateral.

Identification relies on both spatial and temporal variation in land-price dynamics. Prices increase more in some counties than in others, and these dynamics unfold unevenly over time. To address the concern that owners and renters may differ systematically in ways that also shape productivity responses, the specification includes a rich set of farm-level controls and their interactions with land-price growth. County-year fixed effects absorb regional trends in land prices and investment opportunities. This design isolates the causal channel from collateral to productivity while accounting for potential confounders at the farm and regional levels.

### 3.2.4 Spatial Lag of X Model

To assess whether productivity growth is influenced not only by a farm's own diversification but also by that of neighbouring farms, a Spatial Lag of X (SLX) specification is applied (Halleck Vega and Elhorst, 2015). This type of spatial model tests whether farms located close to each other show related outcomes once their own characteristics are accounted for, capturing potential neighbour effects. The SLX specification allows for the identification of both direct effects of farm-level characteristics and local spillover effects from nearby farms, while accounting for shared regional conditions (Storm and Heckelei, 2018).

A key challenge in estimating spillovers is separating them from unobserved spatially correlated factors, such as soil quality, infrastructure, or market access. Following Vroege et al. (2020), regional averages of farm characteristics are included in the model to capture broader contextual influences, thereby reducing the risk that local spillovers are confounded with regional effects. Nevertheless, as highlighted by Manski (1993), endogenous and contextual effects cannot be fully disentangled, and the estimated spatial lag coefficients should be interpreted as overall local spillover effects (Gibbons and Overman, 2012).

Neighbourhoods are defined using an inverse-distance weighting matrix based on the ten nearest farms, with weights row-standardised to ensure comparability across observations (Halleck Vega and Elhorst, 2015). This approach reflects that closer farms exert stronger influence than those farther away and is consistent with applications in agricultural settings where spillovers are expected to decay with distance (Läpple et al., 2017; Läpple and Kelley, 2015; Mannaf et al., 2023).

The SLX specification is particularly suited for settings where spillovers are expected to operate through observable practices, such as diversification behaviour, rather than directly through productivity outcomes. Unlike models with endogenous spatial lags, the SLX avoids simultaneity bias and complex feedback loops, making estimation and interpretation more transparent (Akbari et al., 2023; Halleck Vega and Elhorst, 2015).

### 3.2.5 Survival Analysis

To analyse the duration of hybrid farming, a parametric survival model is employed. Survival analysis is suitable for modelling the time until an event occurs and, in this case, it captures how long individuals remain in the state of combining farm and off-farm income. A Weibull specification is chosen, as it allows the baseline hazard to be estimated directly and provides efficient estimates when hazard rates follow a monotonic pattern (Crowther and Lambert, 2014).

The model includes the share of off-farm income as the key explanatory variable, along with its squared term, and controls for individual-, family-, farm-, and regional-level characteristics. This structure makes it possible to assess how both economic incentives and background factors influence the likelihood of remaining a hybrid farmer.

To account for unobserved heterogeneity, a shared frailty specification is estimated as a sensitivity check (Gutierrez, 2002). Frailty terms are defined at the family level, reflecting that genetic or environmental factors may jointly shape agricultural and entrepreneurial ability (Lazear, 2004; Lucas, 1978). This extension allows for correlated risks within families, improving the robustness of the survival estimates.

# 4. Paper summaries and key findings

## 4.1 Off-farm labour income stabilises farmers' income during severe drought - evidence from Swedish agriculture

This paper studies whether pre-existing off-farm wage work stabilises farmers' incomes during an extreme weather shock. Linking Swedish registers of individual farmers (2012-2021) to the Combined Drought Indicator (CDI), severe exposure is defined via the CDI "Alert" threshold and effects are estimated using Coarsened Exact Matching combined with a Difference-in-Differences approach. The analysis shows that full-time self-employed farmers experience a short-run income loss in 2018, which largely faded in the following years. In contrast, farmers who already combine farm and wage income maintain stable total earnings. Moreover, they do not increase the off-farm income share following the shock. This pattern is consistent with off-farm work operating as a long-term strategy farmers committed to before the shock, rather than an immediate adjustment to shocks.

The effect of the drought is not the same across all types of farms. Crop farmers experience a temporary income gain, consistent with price effects under supply shortfalls. Livestock farmers on the other hand face declines, and dairy and mixed farms show no clear change. These results highlight that farmers already combining farm and wage work are less exposed to income losses from drought. The pattern suggests that farmers draw on experience that enables them to sustain diversified economic strategies under pressure. In this sense, the paper points to hybrid farmers as a distinct group with particular knowledge, entrepreneurial traits, or strategies. This concept is developed more in depth the third paper.

## 4.2 Functional Crop Diversity, Farm Productivity, and Local Knowledge Spillovers

This paper examines whether functional crop diversification contributes to farm productivity growth and whether such effects spill over to neighbouring farms. It uses panel data on around 30,000 Swedish farms that have crop production from 2009 to 2021. Total factor productivity is estimated and linked to a spatial lag of functional diversity, capturing both own-farm practices and neighbours' practices.

The results show that farms with more functionally diverse rotations achieve higher TFP growth, consistent with ecological complementarity improving efficiency. Importantly, farms also benefit from being located near other diversified farms, suggesting that localised knowledge spillovers occur between farms. Proximity then facilitates observational learning and the diffusion of knowledge-intensive practices. These effects are robust after controlling for county-level conditions, and they appear in both favourable and less favourable production areas, reinforcing that they reflect genuine peer influence rather than shared geography.

The study highlights that functional crop diversification is not only an ecological strategy but also an innovative process, requiring skills and experimentation that can diffuse through local networks. In this paper, innovation is interpreted broadly as the process through which farmers generate and adopt new ecological and management practices that improve efficiency. Functional crop diversification fits this view because it involves experimentation, learning, and adaptation to local conditions. The observed spatial spillovers suggest that these productivity effects are not purely ecological or environmental in origin but reflect the diffusion of knowledge-intensive practices through local networks. If no knowledge or innovation were involved, we would not expect to see neighbouring farms benefit from each other's diversification behaviour. In the wider scope of this thesis, the paper moves from diversification as an income strategy (off-farm work) to crop diversification as a production strategy, showing how knowledge operates both within and across farms.

## 4.3 Transition dynamics of hybrid farmers: a survival analysis of exits and entries into full-time farming

This paper investigates whether hybrid farming, meaning the combination of self-employment in agriculture with wage work outside the sector, is a temporary step or a stable long-term strategy for farmers. Using Swedish matched employer-employee register data (2001–2018) covering over 54,000 hybrid farmers, a parametric survival model is estimated to track transitions out of the hybrid state. The analysis distinguishes between exits into full-time farming and exits out of agriculture altogether, while accounting for individual, family, farm, and regional characteristics. This includes individual and intergenerational human capital and experience related to both agriculture and self-employment.

Results show a non-linear relationship between the share of off-farm wage income and survival in the hybrid state. At low shares, off-farm work increases the likelihood of exit, consistent with hybrids either building up toward full-time farming or preparing to leave agriculture. At higher shares, however, off-farm income stabilises the hybrid position, reducing exit risks in both directions. Agricultural assets (land, buildings) and farm-specific education and work experience lower the risk of exit, while non-agricultural work experience increases it. Interestingly, prior entrepreneurial experience (self-employment) supports staying hybrid, but parental self-employment experience sometimes raises exit risks, suggesting intergenerational dynamics are more complex than simple transmission.

The paper positions hybrid farming as more than a transitional phenomenon. Under certain conditions it represents a durable long-term strategy for economic viability. In the broader thesis, this study develops the idea first raised in the drought analysis that hybrids may be distinct in their ability to withstand shocks, by showing how income composition, assets, and knowledge condition their survival trajectories. It also sets up the next chapter on land and collateral by highlighting the central role of assets in determining whether hybrid farmers can sustain or expand their operations.

## 4.4 When land becomes leverage: collateral and productivity in Swedish dairy farming

This paper examines whether rising farmland prices translate into productivity growth through the collateral channel. Land is not only a productive input, but also the main form of collateral in agriculture, and rising land values can expand borrowing limits for owners. Using Swedish dairy farm data from 2008-2021, farms that own all their land are compared with farms that consistently rent, exploiting regional variation in land-price growth as an exogenous shift in collateral capacity.

The results show that higher prices for pasture increase productivity, while arable land prices do not. Effects are strongest when the renter group is more strictly defined in terms of how much land they rent, confirming the contrast between farms with and without collateral. Among owners, productivity gains are concentrated in farms with at least some debt-free periods, consistent with the idea that collateral matters most when it actually can expand borrowing capacity. These findings suggest that the observed effects operate through the collateral channel rather than simply reflecting wealth or regional demand.

Within the broader thesis, this study further adds to the intergenerational dimension. By using the farm building as the unit of analysis, the paper follows farms across ownership events, distinguishing between family transfers and market acquisitions. This approach shows that land is more than a financial asset. It anchors continuity, enabling the transmission of both collateral and farming knowledge across generations.

# 5. Conclusions

This thesis set out to examine how Swedish farms adapt to structural, economic, and environmental pressures, and how knowledge shapes these processes. Across the four studies, the results point to several conclusions showing that adaptation takes multiple forms.

First, the initial study shows that off-farm work functions as a pre-committed risk-management strategy in response to drought rather than a short-term reaction. This shows that adaptation can be embedded in the income mix structure before a shock occurs.

Second, understanding ecological processes like functional crop diversity as an innovative practice means we can view it both as a production strategy and as a channel for observing learning between farms.

Third, hybrid farmers combine on- and off-farm work in ways that can be deliberate long-term strategies that ensure a viable income for the individual.

Fourth, rising land values can increase productivity for farms that own their land by expanding their collateral capacity. This appears to translate into productive capital investment, not simply land expansion. This suggests that differences in ownership status shape the ability to leverage rising land values for credit, potentially creating productivity gaps between owners and renters.

Fifth, knowledge can be seen in many forms across these papers. Experience, education, income composition, ecological practices, and patterns of interaction with neighbouring farms all shape how farmers interpret conditions, manage risk, and adjust their production and investment choices. Thus, farm viability depends not only on land, capital, or market conditions but also on the practical, accumulated, and transmitted knowledge that farmers draw upon in their decisions. By integrating these empirical perspectives, the thesis provides a broader understanding of how different forms of knowledge support adaptation in the face of ongoing structural and environmental change.

## 5.1 Contributions

This thesis makes several contributions to the study of farm viability under structural, economic, and environmental pressures. Each paper addresses a distinct mechanism of adaptation while together forming a complementary understanding of how knowledge supports farm viability.

First, off-farm income as a pre-committed strategy contrasts with findings from other contexts where farmers typically turn to off-farm work after shocks occur and reveals off-farm employment as a long-term adaptation rather than a short-term coping response (Mishra and Goodwin, 1997; Musungu et al., 2024).

Secondly, the off-farm concept is deepened by viewing it through an entrepreneurial lens as hybrid farming in Paper III. This links the concept of the hybrid entrepreneur from entrepreneurship research (Folta et al., 2010) to the agricultural context and provides a new conceptual bridge between the two literatures.

Third, both these studies (Paper I and III) offer methodological advances by using large-scale Swedish register data to follow thousands of hybrid farmers over time and connect their trajectories to education, family background, and asset holdings. This longitudinal design provides a more detailed and dynamic picture of hybrid farming than has previously been available in agricultural economics.

Fourth, functional crop diversification is examined in Paper II. The findings provide new empirical evidence that ecological practices can also strengthen economic performance that can spill over between farms. This adds to both literature on diversification and economic gains (Fabri et al., 2024; Nilsson et al., 2022; van der Ploeg et al., 2019), as well as spatial knowledge flows in agriculture (Läpple et al., 2017; Vroege et al., 2020). Conceptually, it reframes diversification as both risk management and an innovative process, broadening the understanding of innovation in agriculture beyond technology adoption to include knowledge-intensive ecological practices.

Fifth, financial structure is linked to productivity in the fourth study. The main contribution lies in the methodological and conceptual advances that make this analysis possible. By introducing the farm building as the unit of analysis, the study follows farms across ownership transfers, capturing both family succession and market transactions. This approach provides an opportunity to connect asset-based financing with intergenerational continuity.

Sixth, the transmission of knowledge and assets across generations can be analysed using the type of linked register data used in Paper III and IV.

They incorporate ownership transfers from parents as well as parents' experience in agriculture and self-employment. In doing so, it adds to the literature on land as a productive and financial asset (Nickerson et al., 2012) and to research on intergenerational transfer and farm-specific human capital (Laband and Lentz, 1983; Sutherland, 2023).

## 5.2 Limitations

These contributions also come with limitations. Using register data allows long time horizons and structural analysis but sacrifices some detail. We observe outcomes rather than motivations and cannot directly measure the underlying processes that drive farmers' decisions or the knowledge they draw upon. Nor can we observe farmers' underlying ability, such as managerial skill, learning capacity, or differences in how effectively they can translate knowledge into action. These forms of ability may shape both their strategies and their outcomes. The thesis therefore relies on indirect indicators of knowledge such as education, experience, spatial proximity, and intergenerational links which approximate its tacit or experience dimensions. Other measures are also proxies, for instance, income shares as a stand-in for labour allocation. Identification strategies mitigate but cannot eliminate the issues of unobserved heterogeneity.

A further limitation concerns external validity. The drought analysis is specific to Sweden in 2018. While the income smoothing through off-farm work is likely are relevant in other contexts, the size of the estimated effects may differ in regions with other climatic conditions or exposure to drought. Similarly, the collateral channel is examined within the Swedish dairy sector. The underlying mechanism, in which rising land values relax borrowing constraints and enable productivity-enhancing investments, is not unique to Sweden and should be applicable to dairy farms in other countries. However, the magnitude and timing of such effects are likely to depend on sector-specific production technologies, credit market institutions, and land-price dynamics.

A further limitation relates to identification in the spatial analysis. Spatial models cannot fully separate endogenous spillovers, where one farm's behaviour directly influences another's, from shared local conditions, where neighbouring farms are exposed to similar conditions or characteristics that shape their outcomes independently of any interaction. This makes it challenging to isolate the precise mechanism behind observed spatial dependence.

Finally, the conceptual framing has its own boundaries. While knowledge is treated as a central thread, it remains partly implicit through these proxies rather than observed directly. This means that the thesis does not measure knowledge directly, but instead observes the outcomes that knowledge produces. Other important pathways to farm viability, such as insurance, cooperation, or environmental services, fall outside the scope of the thesis. Recognising these gaps is essential as they determine how far the findings can be generalised, but they also highlight promising directions for future research on the multiple forms of knowledge that underpin adaptation and performance in agriculture.

## 5.3 Policy implications

First, the analysis of hybrid farming suggests that some households combine farming and off-farm work as a stable economic strategy rather than a temporary phase. This has implications for how policies define "full-time farmers" or target support, as hybrids may not fit conventional categories but still contribute to agricultural production and rural economies. Recognising hybrid farming as a deliberate long-term strategy also matters for how structural change is monitored, since trends in "exit" or "full-time farming" can otherwise be misinterpreted if diversification is treated as withdrawal from agriculture.

Second, the results on crop diversification highlight that productivity and innovation can arise from ecological practices with local spillovers. This suggests that extension services, advisory systems, and agri-environmental schemes should take account of the knowledge dimension and the social diffusion of practices, not only farm-level incentives. Within the Common Agricultural Policy (CAP), diversification and ecological practices are supported through the Agri-Environment-Climate Measures (AECMs). The results from this study show that diversification generates productivity benefits through ecological and knowledge-based mechanisms. These are the kinds of mechanisms the AECMs aim to support.

Third, the evidence on off-farm employment shows that labour-market access matters for how farms manage climate shocks. Policies that shape rural employment opportunities, education, or infrastructure therefore influence farm viability indirectly, even when not targeted at agriculture. This is relevant for the CAP's ongoing post-2027 work, where labour conditions in rural areas and the forthcoming climate adaptation plan are recognised as central to farm resilience (European Commission, 2025).

Fourth, the paper about land values and collateral shows how changes in land prices shape farms' investment possibilities. For policy purposes, it is important to recognise that credit and investment policies may need tools that reach farms without substantial land assets, since collateral-based lending could amplify existing differences in investment capacity.

These themes also resonate with current policy developments in Sweden. The National Food Strategy 2.0 places strong emphasis on profitability, resilience, and the capacity of the food sector to invest, innovate and adapt to climate-related and structural challenges (Ministry of Rural Affairs and Infrastructure, 2025). A similar shift is visible in the strengthening of Agricultural Knowledge and Innovation Systems (AKIS) and the establishment of several knowledge hubs (kunskapsnav), where coordinated knowledge provision and closer links between research, advisors, and farmers are expected to support sustainable production (Swedish Board of Agriculture, 2024). The findings in this thesis reinforce the relevance of such knowledge-driven approaches, since many of the mechanisms identified depend on how information circulates and how different forms of farming are recognised within policy frameworks.

## 5.4 Future research

In researching farmers' transition dynamics, an interesting question emerged. What happens after they exit the sector if they do not retire? Understanding the trajectories of former farmers, whether they move into self-employment, wage work, or remain connected through land ownership, would add a valuable dimension to the study of structural change. This line of inquiry could also extend to the household level, recognising that individual and family choices are often intertwined. At the other end of the spectrum, future work could investigate hybrid farmers who appear to use the hybrid state as a pathway into full-time farming. What do they do before farming, and what characteristics set them apart? These questions point toward a broader agenda of tracing farming over long periods to understand how it starts, how it succeeds, and how it ends.

A second avenue concerns the spatial dimension of knowledge. This thesis has shown that local crop diversification can spill over into productivity gains on neighbouring farms, but the underlying networks remain unobserved. Future research could develop ways to identify these networks within register data, for instance by combining geospatial proximity with shared characteristics, cooperative memberships, or family ties. Doing so would strengthen the link between spatial patterns and the social interactions through which knowledge circulates.

Finally, there is scope to improve the identification of causal effects in spatial analysis. While this thesis applies a spatial lag approach, disentangling peer effects from the shared environment remains challenging. Further work could integrate data on advisory services, extension programs, or information-sharing platforms to better understand how institutional actors shape knowledge flows alongside farmer-to-farmer interactions. This would extend the analysis beyond spatial proximity and offer a richer view of the channels through which knowledge diffuses and supports adaptation.

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# Popular science summary

Swedish farms face major challenges today. Climate change brings more unpredictable weather, the farming population is ageing, and many farms struggle with profitability. At the same time, society expects agriculture to deliver healthy food, protect the environment, and stay productive. In this thesis I ask a simple question behind all these pressures. How do farms manage to stay viable? It turns out, an important part of the story is how knowledge is used, shared, and passed on.

In the thesis I bring together four studies, each of which looks at a different aspect of farm adaptation. In the first study, the 2018 drought is investigated, one of the most severe in modern Swedish history. The results show that farmers who already had off-farm wage jobs were able to keep their total income stable during the drought. They did not suddenly take on more off-farm work. Instead, these jobs were part of a long-term strategy that helped them withstand climate shocks.

In the second study I look at farms with crop rotations where the crops have different but complementary ecological roles and how this relates to the productivity growth on the farm. The results indicate that productivity increase with more diverse rotations. These benefits also "spill over" between neighbouring farms, suggesting that farmers learn from each other and adapt based on what they see around them. Crop diversification can therefore not only be good for the environment, it can also be economically beneficial.

The third study looks at hybrid farmers, those who combine farming with wage work outside agriculture. Instead of being only an in-between state on the way into or out of farming, hybrid farming can be a stable, long-term way of making a living. The results show that the ability to balance these two income sources depends on skills, experience and assets.

The fourth study focuses on land, which is both a productive resource and a financial one. When land values rise, farmers who own their land can borrow more against it, making it easier to invest. The study shows that higher land prices can increase productivity. This highlights how access to credit, and the assets that make credit possible, shapes long-term development.

These studies show that there is no single path to a viable farm. Some farmers rely on off-farm work, others innovate through ecological practices, and others invest through their land. What unites them is the role of knowledge. Education, experience, skills, networks, and the intergenerational transfer of know-how are all important. Understanding these knowledge-based mechanisms helps explain how farms adapt to the pressures of climate change, economic uncertainty, and structural change.

# Populärvetenskaplig sammanfattning

Svenska jordbruk står inför stora utmaningar. Klimatförändringar leder till mer oförutsägbart väder, många lantbrukare närmar sig pensionsåldern och lönsamheten kan vara svag. Samtidigt förväntar sig samhället att jordbruket ska bidra till en trygg livsmedelsförsörjning, skydda miljön och fortsätta vara produktivt. I denna avhandling ställer jag en enkel fråga: hur lyckas gårdar förbli livskraftiga? En viktig del av svaret handlar om hur kunskap används, delas och förs vidare.

Avhandlingen består av fyra studier som var och en belyser olika sätt som gårdar anpassar sig på. Den första studien handlar om effekten av torkan 2018, en av de allvarligaste i modern svensk historia. Resultaten visar att lantbrukare som redan hade lönearbete utanför gården kunde hålla sin totala inkomst stabil under torkan. Andelen inkomst som kom från arbete utanför jordbruket ökade inte. Istället hade de dessa jobb som en långsiktig strategi som hjälpte dem att stå emot torkan.

I den andra studien analyserar jag hur produktiviteten påverkas på gårdar med växtföljder där grödorna har olika men komplimenterande ekologiska funktioner. Resultaten visar att mer diversifierade växtföljder ger högre produktivitetstillväxt. Fördelarna sprids också mellan närliggande gårdar genom att lantbrukare observerar och lär sig av varandra. Växtdiversifiering kan därför vara både miljömässigt och ekonomiskt gynnsam.

Den tredje studien handlar om hybridjordbrukare som kombinerar jordbruk med lönearbete utanför sektorn. I stället för att bara vara en övergångsfas visar studien att hybridjordbruk kan vara ett stabilt och långsiktigt sätt att försörja sig. Förmågan att balansera dessa två inkomstkällor beror på färdigheter, erfarenhet och tillgångar.

Den fjärde studien fokuserar på mark, som både är en produktionsresurs och en finansiell tillgång. När markpriserna stiger kan markägande lantbrukare belåna marken mer och därmed lättare investera. Studien visar att högre betesmarkspriser kan öka produktiviteten. Detta tydliggör hur tillgång till kredit, och de tillgångar som möjliggör kredit, påverkar långsiktig utveckling.

Tillsammans visar studierna att det inte finns en enda väg till en livskraftig gård. Vissa lantbrukare förlitar sig på inkomster utanför jordbruket, andra utvecklar ekologiska metoder och ytterligare andra investerar med hjälp av sin mark. Det gemensamma är betydelsen av kunskap. Erfarenhet, färdigheter, nätverk och kunskap som förs vidare mellan generationer. Att förstå dessa kunskapsbaserade mekanismer hjälper oss att se hur gårdar anpassar sig till klimatförändringar, ekonomisk osäkerhet och strukturell omvandling.

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III

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# Transition dynamics of hybrid farmers: a survival analysis of exits and entries into full-time farming

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## Abstract

Using Swedish-matched employer–employee data from 2001 to 2018 and parametric survival analysis, we examine how the share of off-farm wage income affects survival time in the state of hybrid farming. We find a non-linear relationship between the share of off-farm wage income and the risk of exit; at lower levels, the share of off-farm wage income increases the risk of exiting agriculture completely and exiting from hybrid farming into full-time farming, while at higher levels it decreases the risk of exiting the hybrid state. This indicates that at higher levels of off-farm income, hybrid farming can be a stable state.

**Keywords:** hybrid farmers, off-farm wage income, farm survival, individual heterogeneity, Sweden

**JEL classification:** Q12, J43, J62

## 1. Introduction

Developing the agricultural sector in Europe to ensure sufficient and stable food supply is a cornerstone of the Common Agricultural Policy (CAP) in the European Union (EU) (European Commission, 2023). Yet, over the last decades, European agriculture has witnessed structural change, leading to fewer but larger farms (Eurostat, 2022). This has spurred a discussion in EU Member States about what the future of agriculture will look like and who will be the farmers (Sutherland, 2023). In this paper, we contribute to this discussion by investigating the role of farmers' hybrid behaviours by focusing on

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how they combine farming and off-farm wage work. It has long been debated whether off-farm wage work is a transitional state in or out of full-time farming or whether it can be a stable situation for farmers (Kimhi, 2000; Findeis, Hallberg and Lass, 1987). In particular, we test whether off-farm wage work functions as a substitute or a complement to the farming practice. Our premise is that understanding how farmers divide their time between agriculture and off-farm wage work as a means both to secure sufficient incomes and to be fully employed throughout the year is one of the keys to better understand the future development of the sector. In this paper, we focus on the transitional dynamics of farmers who are active in agriculture either as the sole operator at a farm, or principal or secondary operators at jointly operated farms. Our aim is to provide new insights about the hybrid behaviours of those who are active as part-time self-employed farmers, and how that affects their decisions to exit agriculture, enter into full-time farming or continue to combine activities.

It has become a common feature of agricultural labour markets in many countries to have a large proportion of farmers engaged in non-agricultural income-generating activities (Cavazzani and Fuller, 1982; Biørn and Bjørnsen, 2015; Mittenzwei and Mann, 2017; Nordin and Höjgård, 2019). In Sweden, from which we bring the empirical data for this study, 63 per cent of self-employed farmers had another occupation outside of farming in 2020 (The Swedish Board of Agriculture, 2022). This calls for further analysis of how structural differences in returns to labour in the farm sector vs. the non-farm sector contribute to a continued outflow of labour from agriculture, that is whether it puts the long-term survival of the sector at risk (Finger and El Benni, 2021). This trend might also exacerbate social inequalities by reducing the number of small farms (Mishra *et al*., 2002; Neuenfeldt *et al*., 2019).

The relationship between farm survival and the existence of off-farm income as a means of supporting farm incomes has been extensively studied in the agricultural economics literature (Gasson, 1986; Weiss, 1999; Breustedt and Glauben, 2007; Pfeiffer, López-Feldman and Taylor, 2009; Khanal and Mishra, 2014). The literature highlights that engaging in off-farm activities is important for farm survival and growth for several reasons. It can provide farmers with a more stable and reliable income stream compared to income solely derived from farming activities (Mishra and Goodwin, 1997; Vrolijk and Poppe, 2020). It can also supplement low agricultural incomes and provide farmers with additional financial resources, which can be invested in their farming operations (Evans and Ngau, 1991; El Benni and Schmid, 2022). This could be due to the inability of farm business to generate sufficient revenue or simply because some farming practices naturally occur part-year (e.g. a seasonal crop farm). However, off-farm wage work might also provide an incremental way out of farming, as indicated by Kimhi and Bollman (1999), for the case of Israeli family farms. Notwithstanding the contribution of previous research, there is still limited evidence on transitions from this type of farming to eventual exit or transition into full-time farming for the individual farmers. Investigating the mechanisms of these transitional behaviours is highly relevant to understanding the type of practices that farmers use and the type of employment policies that should be supported in the agricultural sector.

Therefore, in this paper, we take an individual-level approach and focus on the heterogeneity of farmers engaged in dual-income generating activities through 'hybrid entrepreneurship' or 'hybrid farming'. We build on the definition of hybrid entrepreneurship that was introduced by Folta, Delmar and Wennberg (2010) where hybrid entrepreneurs are defined as those individuals who engage in self-employment and at the same time have wage employment.[1] We modify this definition by focusing on those who are self-employed in agriculture while having either a main or a secondary job in non-agricultural wage work.[2] Our focus is motivated by the long-standing discussion whether hybrid farming is a way in or a way out of farming or whether it can be a stable situation for farmers (Kimhi, 2000; Findeis, Hallberg and Lass, 1987) and adds valuable knowledge to better understand how agriculture is likely to develop. Specifically, we use matched employer–employee data from Statistics Sweden (2001–2018) and parametric survival analysis to investigate how the share of off-farm wage income affects the probability that a farmer will stay in the state of hybrid farming or leave farming altogether. To understand how hybrid farmers transition in and out of farming, we separate the analysis into (i) farmers who exit farming completely after being hybrids and (ii) farmers who become full-time farmers after exiting as hybrids.[3]

Our data are detailed and allow us to observe individuals' occupational status and industrial belonging over time to separate out self-employed farmers and their main and secondary sources of income. We can also observe key characteristics of the individual farmers including education, labour market experiences, social status and family background. This allows us to account for intergenerational perspectives, such as the transfer of entrepreneurial and farm-specific human capital from parents to their children (Laband and Lentz, 1983; Dunn and Holtz-Eakin, 2000; Lazear, 2009). Our analysis takes into account factors that are specific to individuals and their farm operations, family background and external conditions, all of which affect heterogeneity in income opportunities due to, e.g., heterogeneous endowments with agricultural production factors, abilities and skills (Finger and El Benni, 2021).

Our results show a non-linear relationship between off-farm wage income and the risk of exit. For smaller shares of off-farm wage income, the risk of exiting increases for both those who exit hybrid farming to become full-time farmers and those who exit farming completely. At higher levels of off-farm wage income, the risk instead decreases for both those hybrid farmers who become full-time farmers and those who exit farming completely.

1 A phenomenon that has received increasing attention in the entrepreneurship literature (c.f. Luc *et al.*, 2018; Demir *et al.*, 2020; Gänser-Stickler, Schulz and Schwens, 2022).

2 This is common in Sweden and elsewhere (Nordin and Höjgård, 2019).

3 In this study, a farmer may be both the operator of the farm and a co-farmer. The distinguishing feature is that a farmer must be self-employed, and thus a spouse or children to the main farm operator can be part of the sample. We use the term farmer for all these individuals for the sake of brevity and completeness, as they are all self-employed farmers although not always the main operator at a specific farm.

This suggests that hybrid farming can act as a transitional state at low shares of off-farm wage income and be a stable situation for farmers with larger shares. Moreover, we find that higher individual income increases the risk of exiting the hybrid state and that family income (including the income of the spouse) increases the risk only for hybrids that exit farming completely. We perform several sensitivity analyses to confirm our results, including estimations that account for unobserved heterogeneity at the individual and family levels, which largely supports the main results. A direct implication of our findings is that encouraging hybrid farming can help farmers to remain in agriculture, thereby supporting the continuity and development of agricultural production and food supply.

## 2. Background and previous studies

Off-farm wage employment has been recognised as a global phenomenon for several decades, particularly in industrialised countries where structural changes in agriculture have led to a decline in full-time farming (Zimmermann and Heckelei, 2012). Since the 1950s, the total number of farmers has decreased globally, while the number of part-time farmers has increased significantly (Nordin and Höjgård, 2019; Giller *et al*., 2021; Zorn and Zimmert, 2022). Simultaneously, there has been an intensification in the amount of time spent to earn off-farm income (Cavazzani and Fuller, 1982; Lien *et al*., 2006), which has largely stabilised over the past decade (Shahzad and Fischer, 2022). These trends highlight the growing importance of recognising off-farm activities and understanding their role in farmers' income strategies. In this study, we focus on individual off-farm wage employment as they represent a particular way of diversifying individual income risk compared to on-farm diversification or running non-farm enterprises along the farm business. Using individual panel data, we contribute new empirical evidence to this growing area of research that is critical to understand how farmers adapt to changing economic conditions.

Farmers can diversify their income through both on-farm and off-farm activities, which provide multiple streams of income that can strengthen the economic viability and hedge individual and/or family income against economic fluctuations (Khanal and Mishra, 2014). Off-farm activities, also referred to as 'pluriactivity', involve the generation of income from non-farm economic activities. These can be further categorised into two main types: wage employment and self-employment, where individuals run enterprises in addition to farming (Eikeland and Lie, 1999). This separation is particularly relevant for understanding off-farm income diversification strategies because wage work and self-employment present fundamentally different economic behaviours, risks and time commitments. Wage employment offers a more predictable and stable source of income, often linked to external labour market conditions, which may be attractive for farmers seeking to smooth income in times of low agricultural profitability (Mishra and Sandretto, 2002). In contrast, self-employment in non-farm enterprises may involve greater entrepreneurial risk and time investments, making it a less predictable but potentially more lucrative form of income (Meert *et al*., 2005). Because of this, it is more likely that choosing waged off-farm work is related to the survival of the farm business compared with the choice of having self-employed off-farm income. This, combined with the fact that farmers with off-farm wage employment represent the vast majority of hybrid farmers in our sample, leads us to focus the analysis on farmers with paid-off-farm employment.[4]

The decision to enter off-farm wage employment and become a hybrid farmer is often motivated by economic and risk management considerations. Furthermore, increased agricultural productivity, coupled with the finite nature of land, makes it possible for farmers to maintain output while dedicating less time to farming, thus freeing up labour for off-farm wage work (Corsi and Salvioni, 2017). Engaging in off-farm wage work can therefore be seen as an efficient use of labour resources. For many farmers, this is not only a way to improve household income but also a strategy for farm survival and growth, allowing them to invest in new technologies, expand landholdings or adopt more efficient farming practices (Meert *et al*., 2005; Key, 2020). However, the decision to engage in off-farm wage work may not always be voluntary or driven purely by economic optimisation (Bessant, 2006). For some farmers, off-farm employment may be a necessity rather than a choice, driven by the need to secure more stable or higher income to manage farm risks, especially when farm income is highly volatile. This may reflect a response to external constraints, such as financial pressure or insufficient farm revenue, rather than a proactive strategy. The involvement of other household members, such as a spouse choosing to work off the farm, can also shape the extent to which hybrid farming strategies are pursued (Bharadwaj, Findeis and Chintawar, 2013). Thus, the hybrid state may represent both a deliberate opportunity to diversify income and a constraint imposed by external economic conditions.

While balancing time and labour between farming and off-farm work can generate income stability, it may limit the capacity to make timely farming decisions during labour-intensive periods, such as sowing or harvesting. Off-farm wage income also serves as a risk management tool, helping farmers to stabilise household income in the face of farm output variability (Mishra and Sandretto, 2002; Darnhofer, 2010). Studies such as those by Mishra and Goodwin (1997) and Kwon, Orazem and Otto (2006) have found that off-farm wage income tends to increase with higher farm income variability, reinforcing the role of the hybrid state in reducing risk. These factors make the hybrid status especially appealing to young or beginning farmers, who face higher barriers to entry and more income uncertainty than established farmers (Bubela, 2016).

Once a farmer has entered the hybrid state, the decision to remain in this state is often driven by the ongoing balance between the benefits of off-farm wage work and the demands of the farm. Off-farm wage employment may

4 In our sample, 8.9 per cent of hybrid farmers are also self-employed outside of farming, which is not part of the analysis.

become a persistent state for farmers who find that it provides stable supplemental income without significantly affecting farm output (Corsi and Salvioni, 2017). In this context, the hybrid state can become an integral part of the individual farmer's long-term income strategy, allowing the farmer to hedge against farm income variability and invest in improvements to the farm. The hybrid state may also enable farmers to gradually accumulate capital for larger investments, such as agricultural land or expensive machinery, which could further improve farm efficiency (Meert *et al*., 2005; Key, 2020). For some farmers, the stability and predictability of off-farm wage incomes become crucial components of household financial planning, reducing the need to rely solely on fluctuating agricultural returns (Finger and El Benni, 2021). However, remaining in the hybrid state is also contingent on external factors, such as the availability of local off-farm jobs and broader market conditions (Reidsma *et al*., 2010, 2018).

The decision to exit the hybrid state can go in two directions: either into full-time farming or an exit from farming altogether. For some farmers, the hybrid state is a temporary state, used as a transitional step out of agriculture. This follows the traditional view that farmers leave farming due to increasing opportunity costs and higher wages outside of agriculture (Weiss, 1999; Zimmermann, Heckelei and Domínguez, 2009). As Cavazzani and Fuller (1982) suggest, if local labour markets do not offer sufficient opportunities for off-farm wage work, the hybrid state becomes unsustainable, potentially pushing farmers out of the agricultural sector entirely. On the other hand, some farmers can use the hybrid state as a pathway into full-time farming. In such cases, off-farm income serves as a financial buffer, while farmers make the investments needed to establish a profitable farm. This strategy mirrors hybrid entrepreneurship, where individuals maintain their wage work while gradually transitioning into full-time self-employment (Folta, Delmar and Wennberg, 2010; Demir *et al*., 2020). For farmers, off-farm wage work can be the primary source of income until the farm becomes profitable enough to support the household on its own (Thorgren *et al*., 2016). The decision to exit the hybrid state, therefore, depends on both internal factors (such as farm profitability and individual preferences) and external conditions (such as market trends and local employment opportunities).

The empirical evidence on the role of off-farm wage employment in farm survival is mixed, motivating further analysis. Several studies indicate that off-farm wage employment reduces farm exit rates, as it stabilises household income and supports continued farming (Kimhi and Bollman, 1999; Glauben, Tietje and Weiss, 2006; Breustedt and Glauben, 2007; Ferjani, Zimmermann and Roesch, 2015). However, others find that off-farm wage employment can also increase the likelihood of farm exit, particularly in regions experiencing overall declines in the farming population (Weiss, 1999; Goetz and Debertin, 2001). These mixed findings suggest that the impact of hybrid status on farm survival is context-dependent and may vary based on regional and individual factors.

Agricultural income can be viewed from two perspectives: production-side income and household-level income. On the production side, income is generated by the use of agricultural production factors such as labour, land and capital, leading to value-added through farming activities (Hill and Hirsch, 2019). At the household level, income determines the consumption possibilities for the family, which includes both agricultural and non-agricultural income components. Differences in farm household income arise due to heterogeneous endowments, including production factors, abilities and skills, as well as differences in the economic and biophysical environment and regional policies (Finger and El Benni, 2021). Thus, these factors are important to control for in an analysis focusing on the role of income. Moreover, there is an important difference in using aggregated regional data which can obscure individual farm dynamics and individual-level data. The latter is essential for capturing the full range of income diversification strategies. For example, Goetz and Debertin (2001) found that off-farm wage employment can either stabilise farm income or accelerate farm exit depending on the regional context, further underscoring the importance of incorporating both micro-level and regional analyses in studies of hybrid status. By using individual-level data on farmers and their incomes, as opposed to regional averages, this paper aims to uncover the dynamics behind farmers' decisions to remain in the hybrid state, either into full-time farming or out of farming completely.

## 3. Data and summary statistics

We use population-based register data from Statistics Sweden to distinguish hybrid farmers between 2001 and 2018. The data are detailed and contain demographic and financial information on all legal residents in Sweden over the age of 16 years from 1990 onwards, collected from a number of sources including individual tax statements, birthplace registries, financial records and school records. We use data on occupational status and industrial belonging to separate out self-employed farmers and measure their characteristics in several key dimensions including age, education, experience, income, social status and type of income-generating occupations. We merge data from additional sources to control for characteristics of their farm operation and factors external to the farm. This includes data from the Land Parcel Identification System (LPIS) and the Property Price Register (Fastighetsprisregistret) to obtain information about farm size (in hectares), land ownership in terms of the value of both farm buildings and agricultural land (at the individual level), as well as agricultural land prices measured at the county level.[5] We also utilise the multigeneration registry to link individuals with their parents to create variables that account for parents' self-employment experience, further described in Section 3.2.[6]

5 This is the most disaggregated data on agricultural land prices in Sweden.

6 This register includes all individuals born from 1932 onwards who have been Swedish registered at any time since 1961.

### 3.1. Definition of hybrid farmers and off-farm income

Our definition of hybrid farmers is contingent on two classifications. Firstly, we use Swedish Standard Industrial (SNI) Classification codes to distinguish individuals who derive any labour and/or business income from agricultural activities, across sub-industry sectors. The data allow us to determine whether these activities are primary or secondary sources of income[7] for the individual, i.e. the largest and second-largest incomes, respectively. This means we can determine what part of an individual's income comes from farming and what comes from off-farm wage work, i.e. the size of the income is not important for the definition, but rather the possibility to separate the income sources. Secondly, information on individuals' self-employment status allows us to ascertain that the farming income comes from self-employment. As mentioned earlier, our definition of hybrids is based on Folta, Delmar and Wennberg (2010), i.e. we define hybrid farmers as those who engage in farming as self-employed while having a primary or secondary job in non-agricultural wage work. Our approach of using SNI Classification codes to distinguish the industry belonging to the occupations allows us to study farmers who work on their own farm, but also a co-farmer such as a spouse or child can be included in the sample as long as they are self-employed. The hybrid state can be volatile, and farmers can change their occupation over time, for instance by letting the farm rest for a year. This can cause problems with multiple entries and exits. We explain how this is handled in the model in Section 4.2.

Based on this definition of hybrid farmers, the central variable in the analysis measures wage income outside the farm. This is defined as the share of income earned from off-farm wage work relative to the total income, which can range between zero and one. We measure this using information on gross salary and/or business income from off-farm wage work and agriculture, which allows us to examine how the relative dependence on off-farm wage employment may be important for surviving in the hybrid state. Because income differs across professions for the same number of hours worked, it would be better to measure main and secondary occupations based on hours worked. However, these data are not available, and thus we use the taxable labour income as the basis for the definition, which is closely related to hours worked since it includes salary from employment and business, social insurance benefits and pension payments. Since engaging in off-farm wage work can be a transition in or out of farming or potentially a stable state, we considered both a linear and a non-linear effect and found the latter to provide a better fit. Thus, the model is estimated with the share of off-farm income as well as its squared covariate.

7 A secondary source of income can be up to 50 per cent of the total income, i.e. it is determined on income and not hours worked.

### 3.2. Control variables

Other important income variables are total declared income and family income.[8] Total declared income is included to control for the size of income and not only the relative importance of the two incomes. Several studies highlight the importance of the spouse in the off-farm labour decision (Benjamin and Kimhi, 2006). We therefore include family income to account for the income of other family members that can serve as a way to support farming practices. Family income is constructed based on family identities available in the data. Since the dataset tracks individuals over time, this variable evolves as individuals change their family belonging, such as when they move out of their parents' household or alter their social status through marriage or cohabitation. Incomes of the spouse are thereby included and alleviate concerns that our results may be biased with regard to the spouse (Blumberg and Pfann, 2016). Additionally, we also run the regressions with standard errors clustered at the family level to further account for within-family correlation.

It is well established that human capital is highly important for the individual's decision to become and remain self-employed (Dunn and Holtz-Eakin, 2000; Unger *et al*., 2011). Human capital can be acquired by individuals from on-the-job training and from formal education, but it can also be informally transferred in the family (Becker and Tomes, 1986; Laband and Lentz, 1983; Dunn and Holtz-Eakin, 2000). Intergenerational knowledge transfer is especially important to control for in the context of agriculture, which is largely an inherited occupation.[9] We consider several time-varying covariates to account for human capital, including individuals' labour market experience and formal education, such as employment experience within and outside the agricultural industry and years of schooling (Müller and Arum, 2004). We use an indicator variable measuring if the individual has any type of agriculture-specific education either at upper secondary school or at the university level. Previous literature has measured informal knowledge transfer from parents by indicators of parents' self-employment experience (c.f. Blumberg and Pfann, 2016; Lindquist, Sol and Van Praag, 2015; Markussen and Røed, 2017). We follow such approaches and include variables to measure both the fathers' and the mothers' self-employment experience and experience in agriculture to proxy the intergenerational transfer of entrepreneurial human capital and farm-specific human capital. Including both parents extends the literature as previous studies on agriculture have relied solely on information on fathers to proxy intergenerational knowledge transmission (c.f. Laband and Lentz, 1983; Lentz and Laband, 1990; Colombier and Masclet, 2008).

8 All income variables have been discounted by the consumer price index as reported for Sweden by Statistics Sweden.

9 Swedish agriculture is governed by family farms and the greater part of all individuals who are self-employed in agriculture have carried over the ownership of their family farm (Joosse and Grubbström, 2017).

We merge data from additional registers to control for characteristics of the farm operation in terms of farm size (in hectares) and the estimated market value of land and buildings in ownership of the individual.[10] Considering the dominance of family farms in Sweden and the fact that agricultural assets (such as land and farm holdings) tend to be passed over within the family (Joosse and Grubbström, 2017), these variables might also serve as proxies for inherited farm assets and capture the scope for transmission of farm-specific human capital. We include other common individual controls like gender, and marital status (married or cohabitated). Additionally, we include age and its squared covariate to control for non-linear effects and adjust for the length of expected remaining life, which is important for the farmer making costly changes with anticipation of future benefits (Goetz and Debertin, 2001). Many farmers continue their practice after the retirement age of 65 years. Thus, the main regression includes all farmers, but to account for exits that may be due to retirement we also run the regression on a subsample where all farmers who turn 65 years during the period are removed. The number of children under the age of 18 years in the household is included as an ordinal variable that varies over time and status as married and/or in cohabitation is included as a dichotomous variable (Blundell, Pistaferri and Saporta-Eksten, 2016). We also include an indicator for previous self-employment as such experience can increase the chance of engaging in self-employment in the future (Frederiksen, Wennberg and Balachandran, 2016).

Lastly, we follow Schaak *et al*. (2023) and include a set of factors external to the individual, including land prices at the county level and indicators for changes in the European CAP via dummy variables for the periods 2007–2013 and 2014–2018, where 2001–2006 is the reference period. Additionally, the model includes year controls for 2004, 2014 and 2018 when there were major droughts in Sweden and a control for population density at the municipality level to account for varying market-related conditions to operate a farm. Detailed variable definitions can be found in Supplementary Table S1.

### 3.3. Summary statistics

Table 1 displays summary statistics for the variables described earlier in terms of means for all observations over the period of investigation. Detailed summary statistics and a correlation matrix can be found in Supplementary Tables S2 and S3. In Table 1, column 1 shows the hybrid farmers who remain in the hybrid state after 2018, column 2 shows those who enter into full-time farming after exiting the hybrid state and column 3 shows the individuals who after exit leave farming completely. This distinction is used to examine transitional dynamics and address some of the discrepancies in the literature in this regard (Kimhi, 2000). The sample is based on the population of all hybrid farmers from 2001 to 2018. However, if there are missing values in key variables for some years, this will cause the individual to be removed from the sample.

10 The LPIS and the Swedish Property Tax registry (see Supplementary Table S1 for detailed variable definitions).

This leads to a sample that contains around 300 thousand observations representing 54,107 individual hybrid farmers. The average time in the hybrid state is 5.5 years, and of the hybrids that exit, almost 50 per cent of the individuals left farming completely during our period of investigation and about 40 per cent transitioned into full-time farming. The 10 per cent of hybrid farmers that remained in the hybrid state beyond 2018 represent about a third of all observations in the sample.

Summary statistics show that the share of the off-farm income is relatively high for all groups in the sample and the highest for those hybrid farmers who later exit farming altogether. These individuals also have the highest declared income. The farmers who remain in the hybrid state have higher family income, indicating that hybrid farming is not only an individual decision but also depends on the family. The hybrids who remain also have a higher value of their agricultural fixed assets in terms of land and agricultural buildings. The value of land and buildings is the lowest for those hybrids who exit farming completely, perhaps indicating that they sell off their land before eventually exiting completely. Alternatively, this could represent farmers who did not acquire enough agricultural assets through, e.g., inheritance and thus decided not to continue. The proportion of women is relatively low in all groups, the highest among those who leave agriculture entirely (35 per cent) and the lowest among those who enter full-time agriculture (17 per cent).[11]

Hybrid farmers who exit farming completely less often have agricultural-specific education, at the upper secondary school or university level. They also have less agriculture-specific work experience. The agricultural-specific experience is the highest among the farmers who remain in the hybrid state and slightly lower among those who exit into full-time farming. This could indicate that some farmers become hybrids to gain experience and then enter into full-time farming. As expected, we also see that the farmers who remain in the hybrid state have a higher prevalence of parents (both mother and father) with experience as self-employed and with agricultural experience. The hybrid farmers who exit farming completely more often have self-employed farming as their secondary income source, i.e. the income is less than 50 per cent of the total income. This could be an indication that there is a 'shadow of death' effect for their farms with a decline in farm performance because of, e.g., reduced investments and market pressures before an eventual exit from the market (Griliches and Regev, 1995). For these farmers, this process could involve gradually decreasing their time dedicated to their farm, which in turn leads to a decline in their farm income. This share is smaller for hybrid farmers who exit into full-time farming and the smallest for farmers who remain hybrids.

Looking at the types of farming in the sample, we see that mixed farming is the most common followed by crop farming for all groups. Cattle or

11 We also performed the analysis with the sample split between males and females, which rendered similar results. However, analysing through the lens of gendered differences in agriculture is beyond the scope of the present analysis.

**Table 1.** Summary statistics and mean values over the period of investigation

| | (1) Hybrids who remain in the hybrid state | (2) Hybrids who exit into full-time farming | (3) Hybrids who exit farming completely |
|---|---|---|---|
| Share off-farm income | 0.52 | 0.49* | 0.77* |
| Declared income (100s SEK) | 1,167.9 | 938.1* | 1,666.9* |
| Family income (100s SEK) | 3,801.1 | 3,289.9* | 3,565.8* |
| Female (=1) | 0.25 | 0.17* | 0.35* |
| Age | 50.6 | 52.5* | 51.1* |
| Years of education | 12.0 | 11.7* | 12.1* |
| Agricultural education (0/1) | 0.36 | 0.39* | 0.17* |
| Work experience (years) | 21.7 | 18.2* | 18.5* |
| Agricultural work experience (years) | 12.7 | 11.3* | 6.65* |
| Married or cohabited (0/1) | 0.64 | 0.65 | 0.64 |
| Number of children | 0.36 | 0.13* | 0.14* |
| Family member engaged in farming (0/1) | 0.61 | 0.61* | 0.45* |
| Self-employment prior to becoming hybrid (0/1) | 0.75 | 0.79* | 0.56* |
| Self-employed mother (0/1) | 0.16 | 0.093* | 0.098* |
| Self-employed father (0/1) | 0.23 | 0.14* | 0.14* |
| Agricultural experience mother (0/1) | 0.089 | 0.053* | 0.037* |
| Agricultural experience father (0/1) | 0.15 | 0.091* | 0.064* |
| Value of land and buildings (100s SEK) | 4479.6 | 3373.4* | 2179.0* |
| Farm size (Ha) | 77.5 | 84.5* | 43.4* |
| Land price (1,000s SEK/Ha) | 479.3 | 353.2* | 359.0* |
| Population density municipality | 93.8 | 79.6* | 115.1* |
| Self-employed farming as secondary income (0/1) | 0.24 | 0.34* | 0.36* |
| Self-employed farming as primary income (0/1) | 0.31 | 0.38* | 0.094* |
| Crop farming (0/1) | 0.19 | 0.23* | 0.20* |
| Livestock farming (0/1) | 0.15 | 0.15* | 0.12* |
| Poultry farming (0/1) | 0.01 | 0.01* | 0.006* |
| Dairy farming (0/1) | 0.16 | 0.13* | 0.13* |
| Mixed farming (0/1) | 0.49 | 0.48* | 0.54* |
| Observations | 94 049 | 82 507 | 122 959 |

**t*-test for difference in means compared to column 1 at 1 per cent significance.

dairy farming follows, and lastly, only a few engage in poultry farming. Different types of farming could be important in the decision to engage in off-farm work.[12] Certain farming activities, particularly those that are less labour-intensive or have shorter growing seasons, may naturally lend themselves to part-time work. For instance, crop farming often follows seasonal patterns where peak labour demands are concentrated in specific periods, allowing farmers to pursue off-farm employment during slower periods. In contrast, livestock farming, especially dairy, requires year-round attention, which may limit opportunities for consistent off-farm employment. This suggests that for some farmers, hybrid farming is not merely a transitional state but a long-term strategy. Farmers who operate in less time-intensive types of farming may be better positioned to sustain hybrid employment in the long run without experiencing a decline in either their farm or off-farm income. It is interesting that such a large share engages in mixed farming as this is another type of diversification strategy and may indicate that certain farmers have a strong preference for diversification of any type.

## 4. Empirical model

We use a parametric survival model to estimate how different risk factors influence the survival time, or duration, in the state of being a hybrid farmer. Parametric survival analysis is an alternative to the traditional semi-parametric Cox model and can directly estimate the baseline hazard function without restrictive assumptions and thereby obtain more efficient estimates (Crowther and Lambert, 2014). We estimate a Weibull parametric survival model characterised by the following hazard function $h_i(t)$[13]:

$$h_i(t) = exp(x_{it}\beta)\rho t^{\rho-1} \tag{1}$$

where $h_i(t)$ denotes the hazard function at time $t$ for individual $i$ with covariate vector $x_{it}$ and coefficient vector $\beta$, and the shape parameter $\rho$, estimated from the data, provides the slope of the function to represent the hazard's trend over time. Specifically, if $\rho > 1$, the risk of exit increases over time, if $\rho < 1$, it decreases and if $\rho = 1$, the risk of exit is constant, and the Weibull model reduces to an exponential model $h_i(t) = \lambda$. The hazard function can be interpreted as the instantaneous rate of failure given survival up until time $t$ such that $h_i(t) = \frac{f(t)}{S(t)}$, where $S(t)$ denotes the survival function. This follows common survival analysis notation $S(t) = P(T > t) = 1 - F(t)$, where $T$ denotes random time-to-failure with cumulative distribution function $F(t) = P(T \leq t)$. Moreover, $f(t)$ denotes the probability density function of the time-to-failure and $T$ denotes a random variable representing the likelihood of failure occurring at time $t$. We also note that $f(t)$ is the derivative of the cumulative

12 We run the regressions for each type of farming. The results are found in Supplementary Table S7 in the appendix.

13 This is suitable with data that exhibit monotone hazard rates that increase or decrease with time, which is the case for our data (Figure 1) (Crowther and Lambert, 2014).

distribution function $F(t)$, which can also be expressed as $f(t) = -\frac{d}{dt}S(t)$ (Kleinbaum and Klein, 1996).

Following the model in Equation (1), our estimated model is specified as follows:

$$h_i(t) = exp\left(\beta_0 + \beta_1 OFFINC_{it} + \beta_2 OFFINC_{it}{}^2 + \beta_3 IND_{it} + \beta_4 FAM_{it} + \beta_5 FARM_{it} + \beta_6 REGION_{it}\right)\rho t^{\rho-1} \quad (2)$$

where $\beta_1$ and $\beta_2$ denote the estimated coefficients for the variables of interest. Specifically, *OFFINC* measures the share of off-farm income relative to the total income for individual $i$ at time $t$, ranging between zero and one, and $OFFINC^2$ denotes its squared covariate. Moreover, $\beta_0$ denotes the intercept term and $\beta_3 - \beta_6$ denote vectors of regression coefficients for the individual-, family-, farm- and regional-specific controls included in the model (defined and summarised earlier). The baseline hazard specified parametrically is provided by $exp(\beta_0)\rho t^{\rho-1}$. In estimating Equation (2), we obtain information on how the survival time in the state of hybrid farming is influenced by the covariates or the 'risk factors'.

### 4.1. Unobserved heterogeneity at the individual and family levels

Although the model in Equation (2) is specified to account for a range of individual characteristics and family background factors, there is a possibility that unobserved factors are left unaccounted. This might, for example, include a risk component and innate managerial skills such as 'entrepreneurial ability' or unobserved factors at the level of the family (Lucas, 1978; Lazear, 2004). Our approach to account for within-group variation is to conduct sensitivity analyses and estimate a survival model incorporating shared frailty (Gutierrez, 2002).[14] A frailty model accounts for the presence of a latent multiplicative effect on the hazard, represented by $\alpha$, which is assumed to have mean one and variance $\theta$. In the shared frailty model, this unobserved frailty is shared among groups of individuals. In our analysis, individuals are grouped based on their family belonging. We would preferably use the childhood family, but this limits the sample size and is instead incorporated into the baseline regression as a robustness test. By grouping on family belonging, the model accounts for heterogeneity that arises due to genetic or environmental factors that affect an individual's entrepreneurial or agricultural ability.

Individuals with $\alpha > 1$ have a higher frailty and thus an increased probability of exiting compared with those of average frailty, while those with $\alpha < 1$ have a decreased probability of exiting compared with the population average (Kleinbaum and Klein, 1996). The model used in the sensitivity analyses is identical to Equation (2) with the difference that it includes a frailty term $\alpha_j$ for each family $j$. We note that in the regression output, alpha refers to the estimated variance of the frailty term across families, not the family-specific

14 See Gutierrez (2002) for a detailed representation of the survival time frailty model.

parameter $\alpha_j$. The estimated model is specified as follows:

$$h_{ij}(t) = \alpha_j exp\left(\beta_0 + \beta_1 OFFINC_{it} + \beta_2 OFFINC_{it}{}^2 + \beta_3 IND_{it} + \beta_4 FAM_{ijt} + \beta_5 FARM_{it} + \beta_6 REGION_{it}\right)\rho t^{\rho-1} \quad (3)$$

where $h_{ij}(t)$ denotes the hazard at time $t$ for individual $i$ belonging to family $j$ and where the remaining variables are defined in accordance with Equation (2).

### 4.2. Survival time

The survival is measured in years from the first time we code an individual as a hybrid farmer to the last year we observe them as any type of hybrid in the data. We use this more general hybrid definition to determine the exit because many farmers have their farms resting while they for instance acquire an education. This would mean that they appear to exist in the data when in fact they are not. By allowing for this wider definition after entry, we avoid getting false exits and multiple exits per individual. Regarding entries, we have delayed entries in the data since not all farmers became hybrid farmers in 2001, and the data are left-censored since some hybrids could have been in this state before 2001. The data are also right-censored since not all individuals have exited as hybrids in 2018. Both left- and right-censoring can affect the likelihood estimates and bias the results (Klein and Moeschberger, 2006). To account for both these types of censoring, we have made the appropriate adjustment in the regression analysis.

The Kaplan–Meier survival estimate is depicted in Figure 1 and illustrates the probability of survival as a function of time. It is split between the hybrid farmers who exit into full-time farming and those who exit farming completely. This graphical representation shows the time-to-event distribution, allowing us to observe the proportion of individuals surviving at different time intervals, while also managing censored observations to provide a comprehensive view of survival trends across the studied period. The probability of surviving as a hybrid past a certain number of years is indicated to decrease for both groups, but initially faster for the hybrid farmers than those that exit farming completely.

## 5. Results and discussion

The regression results are displayed in Table 2. Columns 1 and 2 show the results of estimating Equation (2) for the whole sample split on the hybrids who exit into full-time farming and those who exit farming completely. Columns 3 and 4 are the same categories for the shared frailty model equation (3) accounting for within-family heterogeneity. Including frailty in the survival model allows us to account for unobserved heterogeneity across farmers, which could influence their likelihood of engaging in off-farm work. The estimated alpha parameters, which capture the variance of the frailty term, suggest that there is notable heterogeneity among farmers in terms of their likelihood to engage

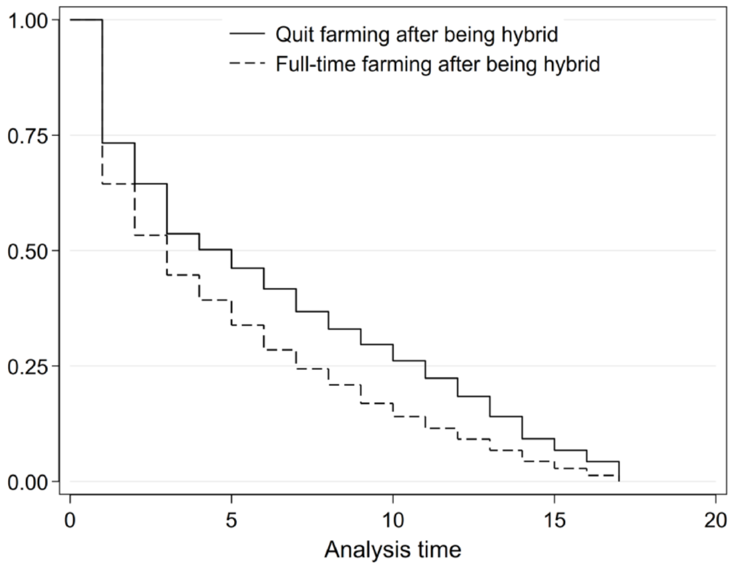


**Figure 1.** Kaplan–Meier survival estimate for hybrid farmers who exit into full-time farming and hybrid farmers who exit farming completely.

in off-farm work. The fact that these alpha terms are negative and significant indicates that some farming households are less likely to exit hybrid farming, for reasons not explained by the observable characteristics. Such family-level effects could include shared resources, farming traditions or other unobserved family-specific factors. As described earlier, these unobserved factors create clustering in the data—as farmers within the same family can share resources and are presumably more alike in several key dimensions—which is accounted for by the frailty term. Using this approach, we can analyse the individual characteristics that are important without disregarding the role of the family.

## 5.1. Income

Results indicate that the share of off-farm income at low levels increases the risk of exiting and, at some point, changes and decreases the risk. This holds for both the hybrids who exit into full-time farming and those who exit farming completely, but the magnitude of the coefficients is larger for the latter. We calculate the turning point around 0.3 for those who become farmers after exiting the hybrid state and slightly above 0.5 for those who exit farming completely.[15] Thus, those who exit farming completely are dependent on a larger share of off-farm income to sustain the hybrid state, but as the off-farm income falls below 0.5 the increase in the likelihood of exit is stronger compared to the turning point for those who exit into full-time farming. This shows that

15 The exact values for the share of off-farm income where the term changes from positive to negative are for models 1–4, respectively, 0.32, 0.53, 0.29 and 0.54.

**Table 2.** Results from survival analysis

| | Standard survival regression | | Regression with shared frailty | |
|---|---|---|---|---|
| | (1) Exit hybrid farming into full-time farming | (2) Exit farming completely | (3) Exit hybrid farming into full-time farming | (4) Exit farming completely |
| Share off-farm income | 1.105*** | 3.215*** | 1.058*** | 4.241*** |
| | (0.098) | (0.108) | (0.118) | (0.146) |
| Share off-farm income squared | −1.707*** | −3.057*** | −1.817*** | −3.951*** |
| | (0.087) | (0.086) | (0.104) | (0.112) |
| Declared income (ln) | 0.052*** | 0.059*** | 0.067*** | 0.070*** |
| | (0.005) | (0.006) | (0.007) | (0.008) |
| Family income (ln) | 0.014 | 0.143*** | 0.012 | 0.197*** |
| | (0.013) | (0.013) | (0.016) | (0.016) |
| Female (=1) | 0.005 | −0.070*** | 0.003 | −0.147*** |
| | (0.022) | (0.015) | (0.027) | (0.022) |
| Age | −0.060*** | −0.090*** | −0.093*** | −0.157*** |
| | (0.007) | (0.006) | (0.009) | (0.009) |
| Age squared | 0.001*** | 0.001*** | 0.001*** | 0.002*** |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Years of education | −0.042*** | −0.026*** | −0.060*** | −0.034*** |
| | (0.004) | (0.003) | (0.006) | (0.005) |
| Agricultural education (0/1) | −0.041** | 0.033 | −0.063** | 0.093*** |
| | (0.020) | (0.021) | (0.026) | (0.033) |
| Work experience (years) | 0.025*** | 0.066*** | 0.036*** | 0.108*** |
| | (0.005) | (0.005) | (0.006) | (0.007) |
| Agricultural work experience (years, ln) | −0.528*** | −0.422*** | −0.685*** | −0.821*** |
| | (0.018) | (0.014) | (0.020) | (0.021) |
| Married or cohabited (0/1) | −0.094*** | −0.123*** | −0.097*** | −0.146*** |
| | (0.019) | (0.016) | (0.024) | (0.022) |
| Number of children | 0.031** | −0.034*** | 0.017 | −0.020 |
| | (0.014) | (0.012) | (0.019) | (0.018) |
| Family member engaged in farming (0/1) | −0.096*** | −0.092*** | −0.121*** | −0.091*** |
| | (0.019) | (0.016) | (0.024) | (0.023) |
| Self-employment prior to becoming hybrid (0/1) | −0.130*** | −0.170*** | −0.183*** | −0.256*** |
| | (0.023) | (0.017) | (0.029) | (0.025) |
| Self-employed mother (0/1) | 0.128*** | 0.050* | 0.188*** | 0.067* |
| | (0.039) | (0.027) | (0.048) | (0.040) |
| Self-employed father (0/1) | 0.019 | 0.102*** | 0.005 | 0.134*** |
| | (0.037) | (0.025) | (0.045) | (0.036) |
| Agricultural experience mother (0/1) | −0.011 | −0.064 | −0.052 | −0.079 |
| | (0.051) | (0.044) | (0.066) | (0.065) |

(continued)

**Table 2.** (Continued)

| | Standard survival regression | | Regression with shared frailty | |
|---|---|---|---|---|
| | (1) Exit hybrid farming into full-time farming | (2) Exit farming completely | (3) Exit hybrid farming into full-time farming | (4) Exit farming completely |
| Agricultural experience father (0/1) | 0.033 (0.044) | 0.016 (0.035) | 0.050 (0.057) | 0.016 (0.052) |
| Value of land and buildings (ln) | −0.134*** (0.009) | −0.154*** (0.008) | −0.193*** (0.012) | −0.285*** (0.012) |
| Farm size (Ha, ln) | 0.053*** (0.004) | 0.045*** (0.003) | 0.068*** (0.005) | 0.077*** (0.005) |
| Land price (1,000s SEK/Ha) | 0.002*** (0.000) | 0.002*** (0.000) | 0.001*** (0.000) | 0.001*** (0.000) |
| Population density municipality | 0.001 (0.018) | −0.045*** (0.012) | −0.010 (0.025) | −0.063*** (0.020) |
| Constant | 0.765*** (0.196) | −1.149*** (0.174) | 2.162*** (0.241) | 0.842*** (0.232) |
| ln *p* | 0.204*** (0.007) | 0.258*** (0.006) | 0.433*** (0.013) | 0.650*** (0.016) |
| ln alpha | | | −0.723*** (0.069) | −0.110* (0.060) |
| Observations | 176,556 | 217,008 | 176,556 | 217,008 |

Standard errors are in parentheses.
*$p < 0.10$.
**$p < 0.05$.
***$p < 0.01$.
Stata reports $p$ which corresponds to $\rho$ in the hazard equation. Alpha is the estimated variance of the frailty term across families.

hybrid farming can be a stable situation for farmers in cases where the off-farm income contributes to a sufficiently large share of the total income (Mishra and Goodwin, 1997; Vrolijk and Poppe, 2020). Therefore, hybrid farming may not only be a transitional state in or out of farming. These main results are illustrated in Figure 2, which shows the predicted hazard ratios for different levels of off-farm income across the four models. The hazard is generally lower in the models with frailty, and there is a stronger non-linear relationship for hybrid farmers that exit farming completely.

Having a larger total income on the other hand appears to increase the risk of exiting in all four models. For the hybrids who exit into full-time farming, this could reflect that for some farmers the hybrid state is a necessity where they cannot survive solely on the farm income (Zimmermann, Heckelei and Domínguez, 2009), and for others, who are successful in their farming operations, they can transition into full-time farming. These results are in line with previous findings in the literature on hybrid entrepreneurs in a non-agricultural

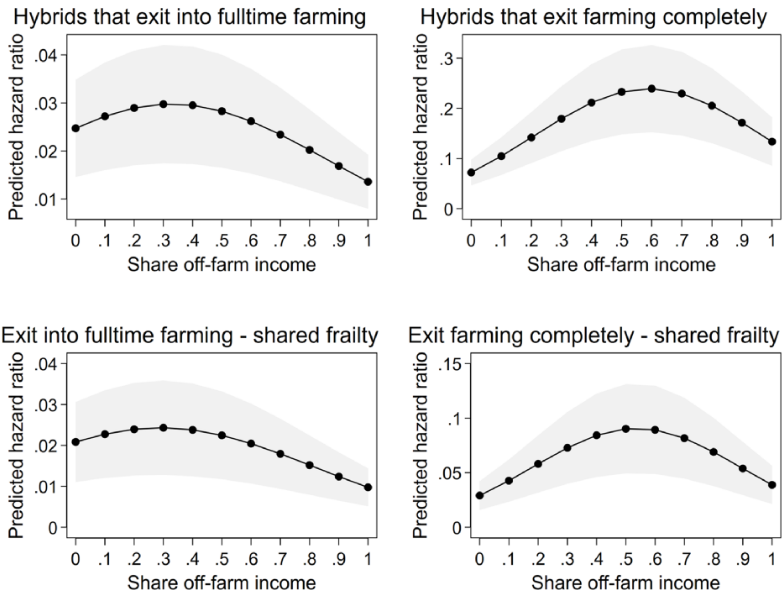


**Figure 2.** Predicted hazard ratios for different levels of off-farm income.

context (Thorgren *et al*., 2016). Regarding family income, results show that it increases the likelihood of exiting as a hybrid for the hybrids who exit farming completely, which suggests that family income does not support the survival of the farming business. This could be because hybrid farmers already have support from their off-farm income, and thus the family income is less important. Results also show a positive relation between the value of land and farm holdings in ownership of individuals, indicating that such resources are important for maintaining production, regardless of whether the individual runs the farm as a hybrid or full time.

### 5.2. Knowledge and experience

Years of education appear to reduce the risk of exiting as a hybrid for both groups, and so does having an agricultural-specific education for those who become full-time farmers. Non-agricultural work experience increases the likelihood of exiting in most models, indicating that such experience makes it more attractive (or lucrative) to work outside of farming. Agricultural work experience, on the other hand, reduces the likelihood of exiting across all four models, which shows the importance of industry-specific experience (Laband and Lentz, 1983; Lazear, 2009). Results also confirm the important role played by entrepreneurial experience (previous self-employment) in reducing the likelihood of exit (Toft-Kehler, Wennberg and Kim, 2014). Contrary to expectations, we find that the parents' self-employment experience increases the likelihood of exiting, when significant, and that their agricultural experience is never significant. This is likely to reflect that the variables specified at the individual level (agricultural experience and education) effectively capture family background characteristics. This is a plausible interpretation given that individuals who attend an upper secondary school or university with specialisation in agriculture often have a background in a family farm (Joosse and Grubbström, 2017). We do find, however, that having a family member engaged in farming reduces the likelihood of exiting across all models, confirming the importance of the family. While the other parent-related variables reflect their experience that could be transferred to children, this additional family variable accounts for the immediate support provided by actively engaged family members, such as a spouse, children or siblings, on the same farm in the same year.

### 5.3. Additional findings

In addition to these main results, we also comment on the age variable for which we also predict a non-linear relationship. For all models, we can confirm a non-linear relationship, i.e. that age initially decreases the risk of exit and then increases it. Results show that for hybrid farmers who exit into full-time farming, age starts to increase the risk around 43 years. For those who exit farming completely, age starts to increase the risk of exit around 50 years.[16] Thus, hybrid farmers transitioning to full-time farming potentially use hybrid methods early in their careers while establishing their farms. As a result, their turning point happens earlier than those who completely leave farming. Although our study does not focus specifically on the role of gender, we note that while gender appears insignificant in explaining exits into full-time farming, it seems like women are associated with a lower likelihood of exiting farming completely compared to men. This could indicate that the hybrid state offers flexibility, which is relatively more important among women. In line with expectations, we can confirm the role of marital status (being married or in cohabitation) in decreasing the risk of exits for all models, indicating the role played by a spouse on farms (e.g. via shared responsibilities).

Farm size increases the risk of exit across all models. This could be because large farms are difficult to maintain in the hybrid state. There is a small positive increase in the chance of exit from the land price, indicating the opportunity cost of owning the land compared to selling it. Lastly, population density has a small negative effect on the risk of exit for hybrid farmers who exit completely. This could indicate that in more densely populated areas there are more abundant labour market opportunities outside of farming that make a complete exit easier.

### 5.4. Sensitivity analyses

In addition to the main analysis, we perform a series of sensitivity analyses to determine the robustness of the results. Firstly, we run the baseline and shared frailty regression on a smaller sample of hybrids who remain hybrids

16 We also attempted to use age classes, which did not reveal a more complex relationship.

continuously until they exit or the period of analysis ends. This is a stricter definition of hybrid farmers which implies we do not have to consider repeated exits. Secondly, we perform the baseline regression on a sample where all individuals past the age of 65 years are removed. Farmers are getting older in Sweden, and elsewhere, and many continue farming well past the Swedish legal retirement age of 65 years. However, if these farmers exit due to retirement, it could distort the results, particularly among those who exit farming completely. Lastly, we run a regression where we cluster on childhood family belonging to capture the unobserved heterogeneity at the family level in a different way. Specifically, we use the family belonging when an individual is 16 years old. This implies that the oldest farmers in this sub-sample are 45 years old (those who were 16 years old in 1990). Lastly, we also run the regression for different types of production orientations: crops, cattle, dairy, poultry and mixed production (crop-livestock). The results are shown in Supplementary Tables S4–S7, respectively. Overall, the results are very similar across all three sub-samples with only a few variables changing significance level. The main income variable, share of off-farm income, has the same direction as in the baseline model in all cases except in the continuous hybrid sample for hybrids who exit into full-time farming. Additionally, when dividing the sample by farming type, the non-linear relationship for off-farm income does not appear for dairy and poultry farmers, which makes sense as these represent production orientations that are generally more difficult to pursue on a part-time basis (Lien *et al.*, 2006).

## 6. Conclusion

This study highlights the dynamics of hybrid farming, particularly focusing on its potential as either a transitional phase or a stable, long-term state for farmers. By using individual-level data from both farmers and co-farmers engaged in hybrid farming in Sweden from 2001 to 2018 and employing parametric survival analysis, we provide novel insights into the factors influencing farmers' decisions to remain in or exit hybrid farming.

We find that the relationship between off-farm income and the risk of exiting hybrid farming is non-linear. While a lower share of off-farm income increases the likelihood of exit, particularly for those transitioning to full-time farming, a larger share of off-farm income increases the likelihood to remain in a hybrid state. However, those who exit farming completely are dependent on a higher threshold of off-farm income, which suggests that hybrid farming may provide a sustainable financial structure under certain conditions. This indicates that hybrid farming is not always a transitional phase but can be a stable state where off-farm income plays a critical role in maintaining the long-term financial viability of the farm.

We also find that higher family income tends to increase the likelihood of exiting farming altogether. This might reflect situations where non-farm income sustains the household while farm income remains insufficient, eventually leading to a full exit. Agricultural assets, such as land and buildings, serve as a protective factor, reducing the risk of exit from the hybrid state for both groups. Educational background and prior agricultural work experience are critical in reducing the risk of exiting hybrid farming. Non-agricultural work experience, on the other hand, increases the attractiveness of other work, increasing the risk of exit. Interestingly, while individual self-employment experience lowers the risk of exit, parental self-employment experience seems to have the opposite effect, indicating intergenerational dynamics.

The results are highly relevant for policy discussions about how future agriculture is likely to develop and how individual farmers respond to changing economic conditions in finding stable financial conditions, employment and income year-round. These results also underscore the need to consider hybrid farming as a potential long-term state rather than merely a temporary phase. Supporting hybrid farmers with policies that encourage the balance between on-farm and off-farm income could promote the continuity of agricultural production. This could for instance be through tax incentives for dual employment or rural employment programmes to expand off-farm employment opportunities.

Our study naturally leads to additional questions for further research on what happens to hybrid farmers who exit farming completely after maintaining a hybrid state but do not retire. Understanding their transition to other sectors or occupations could provide important further insights into how hybrid farming serves as either a stepping stone or a permanent exit from agriculture. Comparative studies between full-time farmers and hybrid farmers could further illuminate the specific factors that drive the decision to either fully commit to farming or exit entirely.

## Supplementary data

Supplementary data are available at *ERAE* online.

## Conflict of interest

We are not aware of any conflicts of interest associated with this manuscript and the funding indicated for this research is without any influence on the outcome. Helpful comments by the anonymous reviewers are gratefully acknowledged.

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This thesis examines how Swedish farms adapt to structural, economic, and environmental pressures, and how knowledge shapes these processes. Using detailed register and geospatial data, four studies analyse income stability during drought, productivity and spillovers from functional crop diversity, the long-term role of hybrid farming, and how land values influence investment and productivity. Across these dimensions, the findings highlight the central importance of human capital, experience, networks, and knowledge transmission for sustaining a viable farm business.

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