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STRUCTURAL CHANGES IN AGRICULTURE:
A Critical Analysis of Common Agricultural Policy Reforms

Andrius Kažukauskas

This thesis is submitted to Trinity College Dublin for
the degree of PhD

April, 2011

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Summary

This thesis focuses on the impact of European Union (EU) Common Agricultural Policy (CAP) reforms on structural change in the EU agricultural sector. The CAP is still the most integrated of all EU policies and consequently makes up a large share of the EU budget. The main aim of this thesis is to provide an empirical assessment of structural changes in the EU agricultural sector due to the recent agricultural policy reforms. The objective is to gain a deeper understanding of the adjustment processes that take place in agriculture. This requires an identification of causal relationships between exogenous factors, political intervention and farmers' decision making. The strong focus of the thesis is on the development of adequate and innovative quantitative methods and models to support the analysis of structural change due to agricultural policy reforms.

This thesis considers three important facets of structural change: farm exits, productivity and environmental behaviour. Chapters 2 and 3 analyse the impact of subsidy decoupling - a recent agricultural policy reform in the EU - on the productivity of farms. These two chapters contribute to both the policy debate on the impact of CAP reform on the agricultural sector and to the literature on productivity estimation in the following ways: first, few studies to date have analysed the *ex-post* effect of CAP reform on total factor productivity of the agricultural sector, particularly from a cross-country perspective; second, this is the first study which tries to identify switching behaviour and specialisation as a productivity improving mechanism by explicitly incorporating this mechanism into the analysis of farm productivity; third, the modified semi-parametric productivity measurement methodologies are introduced for the estimation of productivity in agriculture for the first time; fourth, it presents a feasible alternative for estimating productivity using the semi-parametric productivity estimation approaches where actual market exit data are not available. Both chapters of the thesis find evidence to support the fact that the decoupling policy has had positive and significant effects on productivity, particularly in Ireland.

Chapter 4 provides an *ex-post* cross-country farm level empirical analysis of farmers' market exit behaviour in response to the reforms of the CAP subsidy decoupling policy. Using a panel dataset for the EU15 countries for the period 2001-2005, quasi-experimental empirical methods and innovative methodological approaches are applied to identify the causal relationship between the decoupling policy and farm market exit. The analysis shows that, contrary to *a priori* expectations, the probability of farm exit decreased due to the policy change, particularly for farms where payments are only partially decoupled. It is also found, however, that the reform facilitated exit for farms that had already made the decision to leave the sector.

After the recent reforms of the CAP EU farmers are subject to cross-compliance measures requiring them to meet a set of environmental conditions to be eligible for public support. To date, the overall effect of environmental cross-compliance on environmental outcomes is not clear. Chapter 5 of the thesis is the first attempt to empirically evaluate the impact of the newly reorganised European agricultural policy on farmers' environmental performance. Quasi-experimental methods (difference-in-differences) are applied to measure the causal relationship between cross-compliance and farm environmental performance. The main finding is that cross-compliance policy has a positive effect on EU farmers' environmental outcomes in terms of fertiliser and pesticide reduction. This result also holds for farmers who participate in other voluntary agro-environmental schemes. However, the results do not support the proposition that farmers who rely on larger shares of public payments have a stronger motivation to improve their environmental performance.

Acknowledgements

My greatest thanks go to my PhD thesis supervisor, Dr Carol Newman, for her excellent guidance through the maze of PhD research. Some of the material presented in Chapters 2, 3 and 4 draws on our joint papers.

To my other co-authors, namely Johannes Sauer, Fiona Thorne and Daragh Clancy, for their significant contribution.

To the Irish Department of Agriculture, Fisheries and Food for providing financial support through the Research Stimulus Fund.

To all my friends I have met at Trinity College Department and Dublin. Especially, I would like to thank my office mates, namely Karol and Baggy, for not only their assistance, stimulating discussions (not only about economics!) and creation of the *craic* in the office but also for grand office football matches and penalty shootouts!

To the administration team of the Department of Economics for all their help.

To my both brothers and my parents for their support.

To Jurate who simply completes me on the path to become not only an economist but also a person, a man, a friend, a swimmer, a cyclist, a skier etc. *Ačiū, kad esi ir kad būsi.*

Andrius
25 March, 2011, Umeå

Contents

CHAPTER 1

1. Introduction

"Some people change when they see the light, others when they feel the heat"

Caroline Schoeder

1.1. Opening note

The agricultural sectors in developed and developing countries have experienced significant structural changes and challenges in recent times which are driven by a range of factors, such as technology changes, in particular, developments in biotechnology, changes in food consumer preferences and aggregate food/energy demand volumes, globalisation and international trade agreements, and agricultural policy reforms. Although structural change is a traditional topic in agricultural economics and a wide range of literature already exists, research on the impact of policy reforms on farm structural change is less developed. Empirical research on the impact of policy is essential to manage structural change in rural areas in terms of economic, environmental and social objectives.

A robust methodological approach is a key element in assessing the impact of agricultural policy changes. There are many methodological challenges in attempting to identify the impact of policy reforms. There is a range of issues to be addressed, such as the behavioural foundations of farmers' decision making, the challenges of econometric analysis based on historical observations, the range of endogeneity issues related to these econometric approaches, etc. Thus, one of the main challenges to research on structural change in agriculture is the development of robust methods for the empirical identification of the impact of policy changes. This objective is at the heart of this thesis.

There are many different ways to define structural change. In the literature the definition of *structural change* varies depending on the underlying definition of the *agricultural structure*. Zimmermann (2006) provides two orientations: one relating to productivity changes (e.g. Oehmke and Schimmelpfennig 2004; Kim et al. 2005) and another relating to the structure of the industry, such as farm exit or farm size changes. For the purpose of this thesis, structural change is understood in a broad sense and is best defined as the movement of farms between certain farm types. The thesis considers three important facets of structural change: farm exits, productivity and environmental behaviour.

Farm exit is traditionally the key indicator of structural change in agriculture (e.g. Weiss 1999; Hennessy and Rehman 2006). Farm exits drive resource reallocations among surviving farms, and so it is important to understand the impact of farm exits on productivity, but also to view farm exits as an indicator of structural change.

Total factor productivity change is another important part of structural change in agriculture. As sustained productivity growth is important for the welfare of farmers and also for the prosperity of the wider society, it is at the centre of attention for policy makers. Understanding the determinants of productivity growth and, in particular, how policy change impacts on productivity is a crucial empirical research question.

The third facet of structural change considered in the thesis is environmental behaviour. The protection of water and soil resources and the preservation of biodiversity are central considerations as environmental awareness and concern about pollution are increasingly recognised by agricultural policy makers and society in general. The impact of intensive farming on water eutrophication and wildlife habitat loss is evident across all EU countries. The underlying assumption of this thesis is that policy reform, which affects farm production behaviour, might also bring related environmental implications. These implications might be anticipated, or not, by policy makers. Thus, environmental aspects of structural change in agriculture are also recognised as critical issues in this thesis.

The thesis focuses on the impact of the reform of the CAP on structural change in agriculture. The CAP dates back to the early days of European integration, when Member States made a commitment to restructure and increase food production, which had been damaged as a result of the Second World War. The 1999 and 2003 reforms were pivotal policy changes in the development of the CAP which attempted to meet the new requirements of farmers, consumers and environment. This thesis addresses two specific policy changes, namely, the subsidy decoupling from farm production decisions and the introduction of environmental cross-compliance requirements for farms getting direct payments. Reforms notwithstanding, the CAP is still the most integrated of all EU policies and consequently takes a large share (40 percent) of the EU budget.

The main aim of this thesis is to empirically assess structural changes in the EU agricultural sector due to the recent agricultural policy reforms. The objective is to gain a deeper understanding of the adjustment processes that take place in agriculture. This requires the identification of the causal relationship between exogenous factors, political intervention and farmers' decision making. A strong focus of the thesis is on the quantitative methods that support the analysis of structural change due to policy reforms. This thesis is comprised of four chapters, each of which are stand alone empirical research papers. The remainder of this introduction outlines the motivation and key contribution of each paper. It should be noted that there is no overall conclusion to this thesis as each paper contains its own set of conclusions and policy recommendations.

1.2. Policy evaluation framework and thesis structure

Chapter 2 analyses the impact of subsidy decoupling on the productivity of Irish dairy farms. The decoupling of direct payments from production is expected to make production decisions more market-oriented as farmers move from mainly subsidy revenue maximisation objectives toward demand-oriented profit maximising behaviour. Economic theory suggests that the decoupling of subsidies should lead to a reduction in the efficiency losses associated with coupled subsidy policies (Chambers 1995; Serra et al. 2006).

However, empirical studies to date have struggled to find a significant relationship between the decoupling policy and productivity/efficiency in the dairy sector. In this paper we put forward four reasons as to why this may be the case. First, the introduction of the decoupling policy coincided with increased uncertainty due to greater price volatility in international dairy product markets. Faced with such uncertainty farmers may react differently to decoupling than would otherwise be the case. Second, the decrease in dairy product market support (such as the market intervention price) and the increase in milk quotas that have been introduced alongside the decoupling of payments make it difficult to disentangle the effects of the different policy changes. Third, lucrative capital grants given to farmers post-decoupling may have encouraged unprofitable farmers to make bad capital investment decisions made possible by the buffer of the decoupled payments to subsidise production activities. Fourth, most empirical investigations relying on the Stochastic Frontier Approach (SFA) fail to explicitly control for simultaneity and selection biases in estimating production function parameters and resultant productivity or efficiency estimates.

This paper contributes to the literature in the following ways. First, we estimate agricultural sector production functions using a modified Olley and Pakes (1996) methodology (OP) which, to our knowledge, has not been used in the field of agricultural economics. Second, the paper compares productivity trends estimated using the SFA and modified OP techniques, and discusses possible reasons for differences in these trends. Third, the paper introduces SFA efficiency estimates as a proxy for the probability of survival in the OP estimation procedure and evaluates the influence of possible selection bias. Finally, it investigates the effect of decoupling on Irish dairy farmers' productivity using the modified OP productivity estimation results.

By separating the effect of decoupling from other policy changes, we find a positive impact of decoupling on productivity of Irish dairy farms. Our findings also suggest that generous capital investment grants led to overinvestment in the sector and had a negative effect on productivity. Moreover, uncertainty about the introduction of decoupling in 2005 and increased milk price volatility had a negative effect on productivity. Once both of these factors are controlled for, the expected positive effect of decoupling on productivity is observed.

Chapter 3 explores the effect of decoupling on productivity in the Irish, Dutch and Danish agricultural sectors. In particular, it focuses on enterprise switching and specialisation as productivity improvement mechanisms. The three case studies of Ireland, Denmark and the Netherlands present an interesting setting for studying the dynamics of the process of adjustment of farms to a changing agricultural policy environment, in particular, in relation to productivity changes, given that the decoupling policy was implemented in different ways in each country. Ireland introduced a fully decoupled payment policy in 2005 based on subsidy payments made in the reference years 2000 to 2002. Denmark also switched to decoupling in 2005, but the decoupled payments are based on a flat-rate per hectare on top of an additional amount based on the historical entitlements, also with 2000-2002 as the reference period. In the Netherlands, the single farm payments are based on historical entitlements from 2006.

In this paper, we propose that, apart from the reasons mentioned above, another possible reason why empirical studies have failed to uncover a significant relationship between decoupling and productivity is that the policy change is too recent for farmers to react and so loss-making farms persist in the sector (Breen et al. 2006). It is also possible, however, that more subtle changes are taking place in the sector that aggregate productivity analyses do not reveal. This paper explores one possible dimension, namely to what extent farm switching behaviour in terms of product adding, dropping, swapping and/or specialisation of farm activities has contributed to productivity growth in the sector.

The paper contributes to both the policy debate on the impact of CAP reform on the agricultural sector and to the literature on productivity estimation in the following ways: first, few studies to date have analysed the *ex-post* effect of CAP reform on total factor productivity of the agricultural sector, particularly from a cross-country perspective; second, this is the first study which tries to identify switching behaviour and specialisation as a productivity improving mechanism by explicitly incorporating this mechanism into the analysis of farm productivity; third, the paper applies the modified semi-parametric productivity measurement methodologies introduced by Olley and Pakes (1996) for the estimation of productivity in agriculture; fourth, it presents a feasible alternative for estimating productivity using the semi-parametric productivity estimation approaches where actual market exit data are not available.

The study finds evidence to support the fact that the decoupling policy has had positive and significant effects on productivity, particularly in Ireland. The paper does not find product switching behaviour associated with decoupling to be an important source of productivity improvements. The study does find evidence, however, that increased specialisation in more productive farming activities is an important productivity transmission mechanism post-CAP reform. A possible explanation for the inertia of farmers in product switching behaviour is that farmers may have started their behavioural adjustment to the introduction of the decoupling policy in less significant and less expensive ways, such as, simply increasing their production in more profitable and productive products before implementing more drastic measures such as changing production system or the farm's product mix.

Chapter 4 analyses the impact of the introduction of decoupling on one component of the dynamics of the sector, namely farm exit behaviour, using quasi-experimental methods.

The study exploits the variation across countries in the timing of the implementation of the policy to identify the causal relationship between the decoupling of direct payments and farmers' decisions to exit farming.

Andersson (2004) and Happe et al (2008) highlight the fact that understanding the impact of decoupling on structural change and productivity of the EU agricultural sector have largely been neglected. The scarcity of cross-country *ex-pos*t research on the impact of the decoupling policy and, in particular, its impact on structural change, such as farm exit, in the EU agricultural sector, indicates a clear need for *ex-post* studies of the kind presented in this paper. The paper provides an empirical cross-country analysis of farmers' market exit behaviour after the recent CAP reform. It uses an extensive farm level panel dataset for the EU15 countries for the period 2001-2005 and exploits the variation in the timing of the implementation of the policy to employ a difference-in-differences (DinD) approach that allows a causal relationship between the policy change and farm exit to be identified. Using a difference-in-differences approach allows us to separate out the effect of the policy change from other country and farm specific factors that may have impacted on farmers' production decisions. Other contributions to the empirical agricultural economics literature are made by constructing new farm exit proxies that allow us to define *gradual* farm exit and a decoupling rate variable that controls for the fact that farms in different countries and farming systems may rely on subsidy payments to varying degrees. The model is extended to take account of the fact that the extent to which farms depend on subsidies may also have an impact on how they are affected by the policy change. This allows us to understand better the mechanism through which decoupling impacts on farm exit to a greater extent than in the basic model. In addition, a new innovative control for unobserved farm heterogeneity is included which allows us to control for productivity changes in identifying the policy effect.

We find evidence that the decoupling policy had a positive effect on farm survival probability. This result is robust for almost all model specifications explored. The results suggest that the reason may be associated with the fact that payments remain linked with production given that only partially decoupled payments have a negative effect on farm exit.

We also find some evidence that land reduction and disinvestment intensity increased for those exiting farms that were 'policy-treated'. This may be explained by the increased certainty in the farm business environment leading farms contemplating exit prior to the policy change to make the decision to exit once the policy is in place.

Chapter 5 explores a different aspect of CAP reform namely the introduction of cross-compliance measures, requiring farmers to meet a set of environmental conditions to be eligible for public support. Environmental cross-compliance obligations reinforce incentives for farmers to change their behaviour towards the environment. Quasi-experimental methods (difference-in-differences) are applied to measure the causal relationship between cross-compliance policy implementation and the environmental performance of farms.

The effectiveness of any cross-compliance programme depends on numerous factors. Winter and May (2001) discuss some of these factors. In principal, regulated farms comply with a given regulation when they conclude that the benefits of compliance (here, received subsidies), exceed the costs of compliance (here, costs of improving environmental conditions). A second motivation for compliance comes from regulated farmers' combined sense of moral duty and agreement with the importance of a given regulation. Awareness of what a given regulation is requiring is also a prerequisite for compliance. Nevertheless, Juntti (2006) argues that the likelihood of achieving significant environmental improvements in Europe with cross-compliance is low. The reason for this is an apparent mismatch between the aspirations set out by the 2003 CAP reform to simultaneously liberalise the agricultural sector, secure high international competitiveness and at the same time to enhance environmental standards. According to Juntti (2006), these multiple aims limit the capacity of cross-compliance to properly secure environmental objectives.

To date, the overall effect of the CAP reform and newly introduced EU-wide environmental cross-compliance on environmental outcomes is not clear. To the best of my knowledge, this paper is the first attempt to empirically evaluate the impact of the newly reorganised European agricultural policy on farmers' environmental performance.

One of the main cross-compliance environmental issues is water pollution, soil quality and the protection of biodiversity. Thus, in this paper the focus is on specific quantitatively measurable and available environmental indicators related to the above primary cross-compliance environmental issues. The farm's usage of artificial fertilisers and pesticides are considered as the environmental indicators (proxies) for cross-compliance effectiveness.

The effect of the cross-compliance policy on farm environmental performance is identified using a differences-in-differences method, where the differential response of farms subject to cross-compliance relative to the environmental performance of farms that were not subject to cross-compliance measures earlier than 2005 is investigated. The main hypothesis is that the cross-compliance measures should improve environmental performance in the form of fertiliser and pesticide reduction. To sharpen the identification, farms' dependency on overall subsidies and also participation in other agro-environmental schemes are taken into account. Observed and unobserved farm-level heterogeneity is accounted for by controlling for farm productivity changes and other farm and/or time specific characteristics.

The paper finds evidence that farmers subject to the cross-compliance policy improved their environmental performance by significantly reducing their fertiliser and pesticide use. However, the study finds no significant policy effect differences between policy-treated and policy-untreated farms when farm direct payment dependency levels are taken into account. This might reflect a low probability of being checked and punished under this regulation and a relatively low non-compliance fine. When farms that participate in other agro-environmental programmes are taken into account the study finds evidence that the cross-compliance policy effect is mostly negative and significant for fertiliser use allowing us to conclude that the cross-compliance reinforces other policies directed to reduce the impact of farming activities on the environment.

1.3. Future research possibilities

The newly introduced CAP instruments, manifested by the introduction of subsidy decoupling reform, have by no means supplanted other types of agricultural supports, such as a wide range of grants for farmers and rural communities. The overlap of different policy tools and their different objectives make them difficult for farmers to understand and for society in general to realise their potential impact. This is particularly the case when EU-wide policies interact with national level policy tools and objectives. As a result of a strong lobbying by farm groups the implicit motivation of policy makers is often that changes should not be too severe. One of the recent examples of the lack of determination in implementing more liberal policies is the reinstated EU dairy export subsidy program after the dairy price collapse in 2009. In addition, in some cases the objectives of agricultural policy programs might even be contradictory, such as policies aimed at promoting farm competitiveness on the one hand and improving environmental standards on the other. The interaction between different types of agricultural policies and policy objectives deserves more attention by the academic community and policy makers alike. This is an area for future research which is touched on briefly in this thesis.

1.4. Note on co-author contributions

Chapters 2, 3 and 4 of the thesis have been submitted for publication in international peer review publications and are currently either under review or are already published. Chapter five has not yet been submitted for publication. While the thesis is entirely my own work, co-authors have been included on all papers due to their significant contribution. My PhD thesis supervisor Carol Newman is included as the co-author in chapters 2, 3 and 4 because of her significant support and guidance during the thesis organisation, theoretical and statistical discussions. Fiona Thorne is also acknowledged as co-author for chapter 2 as she has contributed by helping with the Irish farm data issues and provided constructive comments. Johannes Sauer is included as co-author in chapters 3 and 4 for his intimate knowledge of the topics and insightful comments. Daragh Clancy is also acknowledged as a co-author in chapter 4 for his contribution to the agricultural policy background section.

CHAPTER 2

2. Analysing the effect of decoupling on agricultural production: Evidence from Irish dairy farms using Olley and Pakes approach[1]

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Abstract

Recent reform of the Common Agricultural Policy has led to the decoupling of direct payments to farmers from production. This policy change is expected to make farmers' production decisions more market oriented as their subsidy revenue maximisation objectives become profit maximizing objectives. In this paper we explore the impact of decoupling on the productivity of Irish dairy farms using a modified version of Olley and Pakes methodology for productivity estimation. We isolate the effect of decoupling on productivity by controlling for other policy changes that have occurred alongside decoupling. We also explore the effect that uncertainties associated with increased price volatility may have had on farmers' decisions in the post-decoupled period.

Keywords: Ireland, productivity, semi-parametric estimation, dairy farming, decoupling

JEL classifications: D24, Q12, Q18

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[1] Our thanks to Alan Matthews, Johannes Sauer for valuable comments.

2.1. *Introduction*

In January 2005 a new financial support mechanism for farmers was introduced in the European Union (EU). The Single Farm Payment (SFP) was a significant reform of the Common Agricultural Policy (CAP) in that it decoupled the level of subsidies for each farm from production levels. One of the aims of the decoupling of direct payments was to re-orientate farmers toward market outcomes with the expectation that farmers will change their primarily subsidy revenue maximisation objectives to profit maximizing behaviour. This change is expected to induce efficient/productive farms to exit unprofitable businesses or reshuffle resources to other sectors leading to aggregate productivity gains for the sector as a whole. In this paper we explore the impact of decoupling on the productivity of Irish dairy farms. We use a modified version of Olley and Pakes (1996) methodology for productivity estimation and compare our findings to results obtained using the more commonly applied Stochastic Frontier Approach. Using the former allows us to explain, in part, why previous studies may have failed to find a significant effect of decoupling on productivity.

The literature analysing the effect of decoupling has so far failed to identify significant productivity improvements that can be linked to this policy change (Carroll et al. 2008; Howley et al. 2009). Howley et al. (2009) use a partial equilibrium model to project the impact of decoupled payments on Irish agricultural production. By comparing actual observed market data with projections from the model between 2005 and 2008, they find that decoupled payments continue to have a strong effect on agricultural production in many sectors, although this effect is less than if the subsidy payments were still fully coupled. Carroll et al. (2008) conducted an ex-post analysis of decoupling on Irish farm efficiency and found some evidence that in the cattle rearing, cattle finishing and sheep sectors decoupling led to improvements in efficiency. However, no such evidence was found for dairy farming.

There are a number of possible reasons why empirical studies to date have struggled to find a significant relationship between the decoupling policy and productivity/efficiency in the dairy sector. First, the introduction of the decoupling policy coincided with increased uncertainty due to greater price volatility in international dairy product markets. Hennessy (1998) shows that support policies that are decoupled affect the decisions of risk-averse producers when there is uncertainty (ex-ante analysis). Faced with such uncertainty farmers may react differently to decoupling than would otherwise be the case. Second, the decrease in dairy product market support (such as the market intervention price) and the increase in milk quotas that have been introduced alongside the decoupling of payments make it difficult to disentangle the effects of the different policy changes. Third, lucrative capital grants given to farmers post-decoupling may have encouraged unprofitable farmers to make bad capital investment decisions made possible by the buffer of the SFP to subsidise production activities.[2] Fourth, most empirical investigations relying on the Stochastic Frontier Approach fail to explicitly control for simultaneity and selection biases in estimating production function parameters and resultant productivity or efficiency estimates (Matthews et al. 2006; Newman and Matthews 2006; Abdulai and Tietje 2007; Matthews et al. 2007; Newman and Matthews 2007; Carroll et al. 2008; Hassine and Kandil 2009; Carroll et al. 2011).

This paper contributes to the literature in the following ways. First, we estimate agricultural sector production functions using a modified OP methodology. Second, we compare productivity trends estimated by SFA and modified OP techniques, and discuss possible reasons for differences in these trends. Third, we introduce SFA efficiency estimates as a proxy for the probability of survival in the OP estimation procedure and evaluate the influence of possible selection bias. Finally, we investigate the effect of decoupling on Irish dairy farmers' productivity using the modified OP productivity estimation results. One of the goals of this paper is to disentangle the effect of the various exogenous and endogenous changes that have occurred simultaneous to the introduction of the SFP. In doing so we control for other policy changes that have occurred alongside decoupling (relating to intervention prices and milk quotas) and explore the effect that uncertainties associated with increased price volatility may have had on farmers' decisions. We also pay particular attention to farmer's decisions in relation to capital investments in the post-decoupling period.

This paper is structured as follows. Section 2.2 provides the methodologies used for estimating productivity. Section 2.3 presents data related issues and the descriptive

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[2] The principal objective of the new capital investment scheme is to assist farmers in meeting new requirements under the European Communities. The new scheme provides grant-aid for facilities for the collection and storage of animal excreta, soiled water and other farmyard manures and related facilities, together with new equipment for the application of same to farmland. The standard grant rate can be up to 70% of the initial investment.

statistics for inputs and output. Section 2.4 discusses the main results and Section 2.5 concludes.

2.2. Empirical approach

In order to obtain estimates of farm level productivity changes we employ two methods which differ in the way in which they deal with simultaneity and selection bias. The simultaneity problem affects the coefficients on the inputs in the production function. Productivity is unobservable to the econometrician but is known by the farmer and so will affect his choices in relation to input usage. This correlation between unobserved productivity and inputs causes simultaneity bias when we use simple econometric techniques for estimating the production function parameters. Selection bias arises due to the correlation between farm exit decisions and productivity. The estimates of productivity depend on the estimates of the input coefficients. Therefore, consistent estimation of the input coefficients is crucial for consistent productivity estimates. Both potential biases must therefore be carefully addressed.

We start by assuming a Cobb Douglas production function:

$$\ln y_i = \beta_0 + \sum_{k=1}^{K} \beta_k \ln x_{ki} + e_i \tag{2.1}$$

where y_i is the farm's output level, x_{ki} is a vector of k production inputs (capital, labour etc) and e_i might represent management quality differences between farms, measurement errors, or sources of shocks caused by weather, machine breakdowns, etc. Ordinary Least Squares estimation of this equation is problematic due to simultaneity bias. Inputs are generally chosen by the farmer according to its productivity level. If the farmer has prior knowledge of its productivity which is embedded in e_i when making these input choices, the choices will be correlated with e_i.

There is a second endogeneity problem present when using OLS to estimate the parameters of Equation (2.1). If farms have knowledge of their productivity level (e_i) prior to exiting the sector, farms that continue to produce will be a selected group that will be partially determined by fixed inputs such as capital. The farms with a higher capital stock are expected to have a smaller probability of exiting the sector. This endogeneity problem can cause a downward bias in the coefficients on fixed inputs such as capital (Ackerberg et al. 2007).[3]

The Stochastic Frontier Approach, originally proposed by Aigner et al. (1977) and Meeusen and van den Broeck (1977), deals with the simultaneity problem by imposing a structure on the distribution of the part of the error term that captures technical efficiency. To demonstrate we use the Pitt and Lee (PL) (1981) and the Battese and Coelli (BC) (1992) models. Using this approach, Equation (2.1) is simply extended to a general panel data specification by adding the subscript t to output, inputs and the error term. We first assume a time-invariant inefficiency term (Pitt and Lee 1981):

$$\ln y_{it} = \beta_0 + \sum_{k=1}^{K} \beta_k \ln x_{kit} + v_{it} - u_i \tag{2.2}$$

The error term, e_{it}, is assumed to be a composite made up of a statistical noise component (v_{it}) and a non-negative technical inefficiency component (u_i). The assumption of time invariant inefficiency may hold in short panels but becomes less plausible when the number of time periods increases. Battese and Coelli (1992) relax this assumption by parameterising the inefficiency effect:

$$u_{it} = u_i \times \exp\left[-\eta(t-T)\right] \tag{2.3}$$

where $t=1,2,....,T$ is time and η is a parameter to be estimated. In the Stochastic Frontier Approach simultaneity bias is eliminated by assuming that the inefficiency term is independent and identically distributed. This assumption may be wrong for a number of reasons. For example, it could be that the inefficiency term is a function of farm specific variables (such as farm size in terms of capital, land, etc) or/and the last period farm productivity or efficiency level. Furthermore, selection bias is ignored. However, using such an approach, or any of its many extensions, to measure the productivity of agricultural

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[3] It should be noted that if farms with small amounts of capital have a lower probability of exiting, then self-selection will be associated with a positive bias in the farm size coefficient.

enterprises is attractive given the homogeneity of the technology employed and, at least within EU countries, the artificial incentives to remain in production even if unprofitable, thus reducing the possibility of selection bias. However, as the sector moves in a more market-oriented direction, the need to explicitly control for simultaneity and selection bias becomes necessary. Previous studies which have used this approach may not be appropriate for linking policy changes to TFP in the future.

To address these issues we consider the semiparametric approach to estimating productivity proposed by Olley and Pakes (1996). The outline of the OP procedure presented here closely follows the expositions by Van Biesebroeck (2003), Pavcnik (2002) and Rizov and Walsh (2008). The production function to be estimated is given by:

$$\ln y_{it} = \beta_0 + \beta_l \ln l_{it} + \beta_d \ln d_{it} + \beta_h \ln h_{it} + \beta_k \ln k_{it} + \beta_a \ln a_{it} + w_{it} + v_{it} \tag{2.4}$$

where y_{it} is the farm's output level, l_{it}, d_{it} and h_{it} are labour, direct costs and herd inputs respectively, which are adjustable over one time period; k_{it} and a_{it} are capital and land variables which are quasi-fixed and which can be adjusted over two time periods; w_{it} is the productivity term which is observable by farmers but not by the econometrician; and v_{it} is a white noise term. Simultaneity exists between the choice of inputs and productivity since productive farms are more likely to make capital investments to increase the future value of the farm. There is also a selection bias since farms only stay in business if the liquidation value is smaller than the anticipated future value of profits. Farms with a higher stock of capital and more capital intensive farms are less likely to exit as they face higher sunk costs. Thus, larger farms with more capital stay in business for longer regardless of their productivity levels. Smaller farms with less capital tend to exit sooner when their productivity levels are below an average productivity level for the sector. Thus, the expectation of productivity is not equal to zero given the farm's survival probability, but is a decreasing function of capital, therefore yielding a downward bias on the capital coefficient.

The farm's problem can be described by the maximisation of its expected value of current and future profits:

$$V(k_{it},a_{it},l_{it},h_{it},d_{it},w_{it}) = \max\{L_{it},\Pi(k_{it},a_{it},l_{it},h_{it},d_{it},w_{it}) - c(i_{it}) + \rho E[V_{it+1}(.)|\Omega_{it}]\}$$

(2.5)

where L_{it} is a liquidation value if the farmer decides to sell the farm, $\Pi_{it}(.) - c(i_{it})$ is a profit function, $c(i_{it})$ represents the cost associated with capital adjustment, ρ is a discount factor and Ω_{it} is available information at time t. The farm has to make two decisions. The first is the exit decision. Second, if the farm decides to continue its activity in the next period it must decide how much capital to invest. The optimal exit rule can be described as:

$$X_{it} = \begin{cases} 1, \textit{if } w_{it} \geq \varpi_{it}(k_{it},a_{it}) \\ 0, \quad \textit{otherwise} \end{cases}$$

(2.6)

The outcome $X_{it} = 1$ denotes that the farm stays in farming activity if its unobserved productivity w_{it} exceeds some threshold value ϖ_{it}. The threshold value depends on the stock of capital and land. If the farm has more capital, this means higher sunk costs and higher exit costs which decrease the exit threshold for the farm.

If the farm stays in business we assume that investment takes place. Conditional on the farm investing, the investment function can be described as $i_{it} = i_{it}(k_{it},a_{it},w_{it},z_{it})$. Under some weak conditions, the investment equation is a monotonically increasing function of productivity (w_{it}). Investment decisions also depend on capital stock and farm specific-characteristics (z_{it}). Decisions on investment and market exit are explicitly related to farm specific characteristics. In our model we assume that soil quality, having an off-farm job or having children can affect investment decisions.

The productivity/investment relationship can be inverted by expressing productivity as an unknown function of investment, capital, land and farm specific characteristics, $w_{it} = i_{it}^{-1}(k_{it},i_{it},a_{it},z_{it})$, relying on the assumption that there is only one unobserved farm specific variable (w_{it}) and that investment is increasing in w_{it}. Substituting this expression into the production function given in Equation (2.4) gives the estimating equation for the first step.

$$\ln y_{it} = \beta_0 + \beta_l \ln l_{it} + \beta_d \ln d_{it} + \beta_h \ln h_{it} + \phi_t(k_{it}, a_{it}, i_{it}, z_{it}) + v_{it} \tag{2.7}$$

where $\phi_{it}(.) = \beta_k \ln k_{it} + \beta_a \ln a_{it} + i_{it}^{-1}(k_{it}, i_{it}, a_{it}, z_{it})$. The unknown function $\phi_{it}(.)$ is approximated by a fourth order polynomial. This model can be estimated using OLS to uncover the coefficients on the variable inputs in the production function and the joint effect of all state variables on output. The variable inputs are not affected by simultaneity bias as $\phi_{it}(.)$ fully controls for the unobservable w_{it}; v_{it} does not affect the input coefficients as by assumption it is not observable by the farm before the investment decision is made.

The next task is to separate the effect of capital on output from its effect on the investment decision (i.e. the source of endogeneity). We assume that the productivity term follows an exogenous first order Markov process, i.e. productivity terms are serially correlated, and so current farm productivity carries information about the future productivity of the farm. Thus, current productivity is a function of past productivity:

$$\begin{aligned} w_{it} &= E\left[w_{it} \mid \Omega_{it-1}\right] + \xi_{it} \\ w_{it} &= E\left[w_{it} \mid w_{it-1}\right] + \xi_{it} \\ w_{it} &= g\left(w_{it-1}\right) + \xi_{it} \end{aligned} \tag{2.8}$$

ξ_{it} is not correlated with the state variables at time *t* as these variables are only functions of the information available at time *t-1*. Substituting Equation (2.8) into Equation (2.4) yields:

$$\ln y_{it} = \beta_0 + \beta_l \ln l_{it} + \beta_d \ln d_{it} + \beta_h \ln h_{it} + \beta_k \ln k_{it} + \beta_a \ln a_{it} + g(w_{it-1}) + \xi_{it} + v_{it} \tag{2.9}$$

We can rearrange this equation with $w_{it-1} = i_{it-1}^{-1}(.)$ and $\kappa_{it} = \xi_{it} + v_{it}$ to get:

$$\ln y_{it} - \hat{\beta}_0 - \hat{\beta}_l \ln l_{it} - \hat{\beta}_d \ln d_{it} - \hat{\beta}_h \ln h_{it} = \beta_k \ln k_{it} + \beta_a \ln a_{it} + g(i_{it-1}^{-1}(.)) + \kappa_{it} \tag{2.10}$$

where $i_{it-1}^{-1}(.) = \hat{\phi}_{it-1}(.) - \beta_k \ln k_{it-1} - \beta_a \ln a_{it-1}$ and $\hat{\phi}_{it-1}(.)$, $\hat{\beta}_0$, $\hat{\beta}_l$, $\hat{\beta}_d$ and $\hat{\beta}_h$ are estimated in the first stage. If no farms exit the sector, we can estimate consistent coefficients on capital and land in this production function using the non-linear least squares (NLLS) estimation technique.

Where we have exiting farms we also have to correct for the selection bias that this introduces. In this case, the current productivity level depends on the previous productivity level *and* on the farm's decision to stay in business ($\gamma(w_{t-1}, \overline{w})$):

$$\begin{aligned} w_{it} &= E\left[w_{it} \mid \Omega_{it-1}, X_{it} = 1\right] + \xi_{it} \\ w_{it} &= E\left[w_{it} \mid w_{it-1}, X_{it} = 1\right] + \xi_{it} \\ w_{it} &= \gamma\left(w_{it-1}, \varpi_{it}\right) + \xi_{it} \end{aligned} \tag{2.11}$$

This leads us to the following production function in place of Equation (2.10):

$$\ln y_{it} - \hat{\beta}_0 - \hat{\beta}_l \ln l_{it} - \hat{\beta}_d \ln d_{it} - \hat{\beta}_h \ln h_{it} = \beta_k \ln k_{it} + \beta_a \ln a_{it} + \gamma(i_{it-1}^{-1}(.), \varpi_{it}) + \kappa_{it} \tag{2.12}$$

Since ϖ_{it} is not observable, OP uses actual market exit data to control for this term and models the probability of farm survival as a function of capital, land, investment and farm specific variables. Our contribution to the OP methodology is to extend this approach by estimating the probability of survival, P_{it}, using the efficiency level, e_{it}, estimated using SFA, and exploiting other farm-specific characteristics. This is necessary since actual market exit data are not available.

It is widely assumed in the market exit literature that efficient firms are more likely to survive. Tsionas and Papadogonas (2006) explicitly link stochastic measures of technical efficiency to the likelihood of market exit. Dimara (2008) find that high levels of technical efficiency increase median survival times and lower the hazard rate of exit in general. We assume that the probability of staying in business is not only a function of ϖ_{it} but also of farm specific characteristics z_{it}. We predict the probability of survival using a tobit model[4]:

$$e_{it} = \sum \theta_z z_{it} + \overline{w}_{it} + \varsigma_{it}$$
$$e_{it} = \sum \theta_z z_{it} + \Gamma_{it}(k_{it}, a_{it}, i_{it}) + \varsigma_{it} \tag{2.13}$$

where $\Gamma_{it}(k_{it}, a_{it}, i_{it})$ is a fourth order polynomial and e_{it} is individual technical efficiency estimated using the SFA method with values ranging from 0 to 1. The predicted values $\hat{e}_{it} = \hat{P}_{it}$ are used to proxy the probability of survival.

Using estimated values for $\hat{w}_{it-1}$, $\hat{P}_{it-1}$ and the variable input elasticities, the production function can be written as:

$$\begin{aligned}\ln y_{it} - \hat{\beta}_l \ln l_{it} - \hat{\beta}_d \ln d_{it} - \hat{\beta}_h \ln h_{it} &= \\ \beta_k \ln k_{it} + \beta_a \ln a_{it} + \gamma(\hat{\phi}_{t-1} - \beta_k \ln k_{it-1} - \beta_a \ln a_{it-1}, \hat{P}_{it-1}) + v_{it}\end{aligned} \tag{2.14}$$

The capital and land coefficients can be estimated in the last step using NLLS. Similar to the first stage, γ (.) is approximated nonparametrically by a fourth order polynomial.[5] The estimated coefficients are used to calculate the productivity term:

$$tfp_{it} = \exp(\ln y_{it} - \hat{\beta}_l \ln l_{it} - \hat{\beta}_d \ln d_{it} - \hat{\beta}_h \ln h_{it} - \hat{\beta}_k \ln k_{it} - \hat{\beta}_a \ln a_{it}) \tag{2.15}$$

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[4] As OP uses the actual binary market exit data, the probit model is employed in their paper. We employ the tobit model for the estimation of the probability of market exit because the obtained technical efficiency measures from SFA are continuous but are bound by 0 and 1.

[5] It should be noted that farm specific differences in productivity are accounted for using this fourth order polynomial function of capital, land, investment and other farm-specific variables.

2.3. *Data*

The data used for estimating the productivity of Irish dairy farms are taken from the National Farm Survey (NFS). The NFS is conducted annually by Teagasc, the Irish Agricultural and Food Authority. The sample is based on a stratified random sample, representing farm size and system of production. In this paper, we focus on the production function for the main output of dairy farms, i.e. milk production. Inputs, which are not directly assigned to milk production, are allocated proportionally to a share of milk output in total farm output. A balanced panel dataset comprising 101 farms and a full unbalanced sample with 507 farms are used (see Table 2.1 for two sample descriptive statistics). The balanced sample is used as a robustness check.

Output is measured using total milk sales deflated according to the Irish Central Statistics Office (CSO) milk price index. A value figure is chosen over quantity due to the fact that milk differs in quality across farms. The deflated value takes into account quality differences (Carroll et al. 2011).

Table 2.1 Descriptive statistics for farms in the NFS representative sample 2001-2007[6]

Variables	Balanced		Full	
	Obs.	Mean	Obs.	Mean
Output, EUR	707	107010	1959	89995
Capital, EUR	707	78887	1959	65696
Land, acres	707	83.94	1959	74.95
Labour, units	707	1.37	1959	1.28
Herd size, cow No.	707	67.05	1959	58.20
Direct costs, EUR	707	35392	1959	30725
Soil type 1, D	707	0.56	1959	0.56
Soil type 2, D	707	0.38	1959	0.37
Soil type 3, D	707	0.06	1959	0.07
Children, D	707	0.56	1959	0.54
Off-farm job, D	707	0.09	1959	0.10

Note: D stands for a dummy variable. Soil type 1 represents the best quality land.

Labour, capital, herd size, direct costs and land are used as the production inputs. Allocated values of family, casual and hired labour to dairy farming are used as the labour input. The value input was chosen over a labour unit variable for similar reasons to the output

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[6] The 2001-2007 period is selected since we are interested in exploring the most recent developments in the dairy sector and we want to compare farm productivity dynamics in the post-1999 CAP reform era with the productivity dynamics in the decoupled payment environment after 2005.

variable. The quality of casual and hired labour is quite different across farms. These labour quality differences are reflected in different wage rates. The herd input is calculated as average herd size (cow numbers). The direct cost input includes expenses on concentrates, feeds, fuels, electricity, vet services/medicines and other miscellaneous direct costs. The capital input includes the estimated value (by farmer) of machines and buildings. Acres devoted for the feed area are used as the land input. When inputs are not explicitly assigned to dairy farm activity in the data, they are allocated according to the proportion of dairy gross output in total gross output. This allocation approach was also used by Thorne and Fingleton (2005) and by Carroll et al. (2011) for NFS data. All variables are deflated using price indices which are available from EUROSTAT except for the labour input variable which is deflated by the agricultural average wage rate (AAWR). Table 2.1 presents descriptive statistics of all variables used in our analysis.

Table 2.2 Possible selection bias: capital intensity and how often farms appeared in the NFS representative sample, 2001-2007

	>=6		<6		>=3		<3	
Variable	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean
Output, EUR	1073	103233	886	73963	1695	93234	264	69203
Capital in 10000 EUR	1073	7.56	886	5.37	1695	6.81	264	5.06
Labour, units	1073	13209	886	11032	1695	12491	264	10511
Herd, cow No.	1073	64	886	51	1695	60	264	48
Direct costs, EUR	1073	34920	886	25644	1695	31757	264	24096
Land, acres	1073	81	886	67	1695	76	264	66
SOIL1, D	1073	0.59	886	0.52	1695	0.57	264	0.52
SOIL3, D	1073	0.06	886	0.07	1695	0.07	264	0.06
CHILD, D	1073	0.57	886	0.51	1695	0.54	264	0.54
OFFFARM, D	1073	0.1	886	0.11	1695	0.1	264	0.11
Capital/labour	5.47		4.62		5.2		4.49	

Note: D stands for a dummy variable. Soil type 1 represents the best quality land.

Table 2.2 provides an indication of the possible importance of accounting for selection bias in the representative NFS sample. To demonstrate the importance of farm exit, we divide the 2001-2007 NFS dairy farm sample into four subsamples according to how many times the farms appeared in the NFS.[7] First, we divide the sample into two subsamples: one subsample consisting of farms which appeared in the NFS six or more times and the other

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[7] It is worth noting that farm entry is not an issue in this analysis as in our sample no farmer started a dairy business in the 2001-2007 period.

less than six times. On average, the former subsample consists of farms which are 40 percent bigger in terms of capital. These farms are also more capital intensive. When we compare the two NFS subsamples that contain farms which appear three or more times and less than three times in the survey, respectively, the average size difference is similar. The farms which are in the sample for more time periods are more than 34 percent bigger in terms of capital and tend to be more capital intensive in their milk production.

2.4. Results

2.4.1. Production function results

Table 2.3 presents the estimates of the input coefficients (elasticities) from the production function estimations as described in Section 2.2.[8] The production function elasticities are estimated using the full unbalanced panel data sample.

Table 2.3 Input elasticities

Coefficients	OLS_CD	SFA_PL	SFA_BC	OP no correction for selection bias	OP with correction for selection bias
Direct costs	0.3762***	0.3089***	0.3089***	0.3441***	0.3441***
	0.0135	0.0079	0.0079	0.0135	0.0135
Herd	0.6826***	0.6827***	0.6827***	0.6633***	0.6633***
	0.0201	0.0136	0.0137	0.0205	0.0205
Labour	0.0421***	0.0487***	0.0487***	0.0639***	0.0639***
	0.0101	0.0048	0.0048	0.0105	0.0105
Capital	0.0593***	0.0487***	0.0486***	0.0254	0.2155
	0.0067	0.0041	0.0041	0.0405	1.0405
Land	-0.0505***	0.0075	0.0075	0.0731**	-0.1567
	0.0161	0.0147	0.0148	0.0371	1.0957
RTS	1.1098	1.0965	1.0965	1.1445	1.0714

Note: The negative land elasticity result may be caused by the large quantity of under-resourced land in Irish agriculture.[9] The bootstrapped standard errors are presented for the capital and labour elasticities in the modified OP models. Standard errors in parentheses (*** $p<0.01$, ** $p<0.05$, * $p<0.1$).

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[8] See Table A2.1 for the full set of production function estimates.

[9] See Carrol (2008) for more discussion.

There are two reasons why we should worry about coefficients estimated using OLS. First, there is a simultaneity problem associated with input choices. The positive correlation between the productivity term and the variable inputs could lead to an upward bias in the OLS estimates. In our OP model we assume that herd, labour and direct costs are the variable inputs which can be adjusted in the same period that productivity is realised. Herd size can be adjusted to some extent in one year by transferring heifers, buying cows or selling them. Labour inputs are also assumed to be adjustable in one year since farmers usually hire casual workers for seasonal jobs, i.e. farmers can hire and lay off casual workers without high contractual costs. The direct costs such as concentrates, feed and fuel can be even more easily and faster adjusted to changing farm needs. The more severe the upward bias the easier it is to adjust the input to current realisations of productivity (Olley and Pakes 1996). Comparing OLS and OP elasticity estimates of the variable inputs, it is clear that the direct cost coefficient is reduced by OP estimation. It seems that the labour and herd inputs are not very easily adjusted as their coefficients are similar to the OLS estimates. The labour, herd and direct cost coefficients estimated using SFA are somewhat smaller or similar to the OLS estimates. The direct cost coefficient drops by roughly 20 percent – much more than the coefficients on the other variable inputs. These results could suggest that SFA goes some way to addressing the simultaneity problem. Since simultaneity bias and omitted variable bias are very similar problems (endogeneity bias), they have the same solution. The simultaneity problem can be constructed as an omitted variable problem. The inefficiency term in SFA could be seen as the omitted variable which could capture the causes of the simultaneity problem in the production function. The coefficients on capital and land are also affected by simultaneity. After correcting for selection bias the modified OP produces a much higher capital coefficient, although the coefficient is insignificant. The insignificant capital and land coefficients can be explained by the economic environment during the 2001-2007 period where higher asset values on farms meant that the sale of assets and farms was common. Thus, the more land and capital (buildings) farmers had the bigger incentives they had to sell their assets for property development regardless of productivity levels.

2.4.2. Probability of exit

Next we introduce the possibility of selection bias. OP controls for selection bias using actual data on observed exit. Unfortunately, our sample has no such data. However, since we suspect possible selection bias in our sample[10], we proxy the actual exit variable using an efficiency term which we estimate using SFA for the full sample. The empirical literature suggests that technical efficiency is a good predictor for market exit (Tsionas and Papadogonas 2006; Dimara et al. 2008).

Table 2.4 Tobit models of farm survival

Coefficients	Tobit_BC	Tobit_PL	Coefficients	Tobit_BC	Tobit_PL
lnCapital	0.0470***	0.0233***	lnCapex^2	-0.0022	-0.0009
	0.0072	0.0048		0.0021	0.0014
lnLand	-0.0109	-0.0071	lnCapex^3	-0.0001	0.0001
	0.0100	0.0067		0.0008	0.0005
lnCapex	-0.0039	-0.0016	lnCapex^4	0.0001	0.0001
	0.0036	0.0024		0.0001	0.0001
SOIL1	0.0379***	0.0239***	lnCapital*lnLand	-0.0126	-0.0074
	0.0046	0.0030		0.0132	0.0088
SOIL3	-0.0239	-0.0179***	lnCapital*lnLand^2	-0.0025	0.0054
	0.0089	0.0059		0.0115	0.0077
CHILD	0.0139***	0.0100***	lnCapital*lnLand^3	-0.0015	-0.0033
	0.0043	0.0029		0.0031	0.0021
OFFFARM	-0.0080	-0.0028	lnCapita*lnCapex	-0.0027	-0.0012
	0.0070	0.0047		0.0042	0.0028
lnCapital^2	0.0228***	0.0101**	lnCapita*lnCapex^2	-0.0003	-0.0003
	0.0077	0.0051		0.0009	0.0006
lnCapital^3	-0.0071**	-0.0041**	lnCapita*lnCapex^3	0.0000	0.0000
	0.0030	0.0020		0.0001	0.0000
lnCapital^4	-0.002294*	-0.0009	lnLand*lnCapex	0.0062	0.0030
	0.0013	0.0009		0.0059	0.0039
lnLand^2	-0.0979***	-0.0678***	lnLand*lnCapex^2	-0.0010	-0.0007
	0.0200	0.0133		0.0029	0.0019
lnLand^3	-0.0251**	-0.0142*	lnLand*lnCapex^3	0.0000	0.0001
	0.0109	0.0073		0.0007	0.0004
lnLand^4	0.0356***	0.0238***	Constant	0.8142***	0.7820***
	0.0109	0.0073		0.0055	0.0036

Note: The tobit_BC model uses a technical efficiency term estimated by BC model as the dependant variable and the tobit_PL uses a PL efficiency term as the dependant variable. Standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

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[10] The threat of selection bias arises, not due to a biased sample selection process, but due to the fact that we only observe farms which have survived in our randomly drawn sample.

The probability of exit is obtained by estimating the tobit model given in Equation (2.10), where $\Gamma_{it}(.)$ is a forth order polynomial in k_{it}, a_{it} and i_{it}. The farm specific characteristics included are soil quality, the presence of children and whether the farmer has an off-farm job. Soil quality can have a significant effect on grass yields. Larger grass mass might reduce the need to buy feed from other farms. Thus, higher quality soil can reduce direct costs and increase the farm's productivity. Having children can have a positive effect on the survival decision as having children can increase a farmer's motivation to stay in business and keep the farm business for future generations. Having an off-farm job can reduce the time the farmer can dedicate to farming activity. The less attention devoted exclusively to farming, the greater the potential for lower productivity levels and a higher probability of exit. The results of the tobit models are presented in Table 2.4.

The tobit model results are consistent with expectations. Higher quality soil has a significant positive effect while lower quality soil has the expected negative significant effect on the probability of survival. As expected, off-farm jobs lead to less efficient farms and a higher probability of exit, however the coefficient on the off-farm job dummy is insignificant. Having children increases the motivation of farmers to stay in farming activity.

The second problem with the estimation of the production function is that there may be a bias in the fixed variables. The estimated probability of farm survival can help us deal with the selection bias problem which can be an issue in OLS and SFA estimation. In our paper, we treat capital and land as quasi-fixed production factors. Since farms with a larger capital stock have a higher probability of staying in the dairy business, even with lower productivity levels, it is expected that this relationship can lead to a downward bias in the capital coefficient. After adjusting the OP capital coefficient estimates for this selection bias by using our estimated predicted probability of survival, we get a higher capital coefficient as expected (see Table 2.3). The capital coefficient increases to 0.21 while the OLS estimate is 0.06 and the SFA estimate is 0.05. The fact that SFA capital elasticities are even smaller than the OLS elasticities casts doubt on the robustness of SFA in estimating capital elasticities where selection bias may be an issue.[11]

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[11] Other probability of survival estimates, such as estimates from the tobit model using PL efficiency terms, produce similar results for the capital coefficient.

2.4.3 Comparison of SFA and OP productivity estimates

OP and SFA production function elasticity estimates are used to calculate farm productivity levels. Individual farm level productivity and a productivity index are constructed using Equation (2.11). An aggregated Irish dairy farming productivity measure is calculated annually using the NFS weights so the results are representative of the whole Irish dairy farming population.

Figure 2.1 Productivity indices: OP vs. SFA using the balanced panel

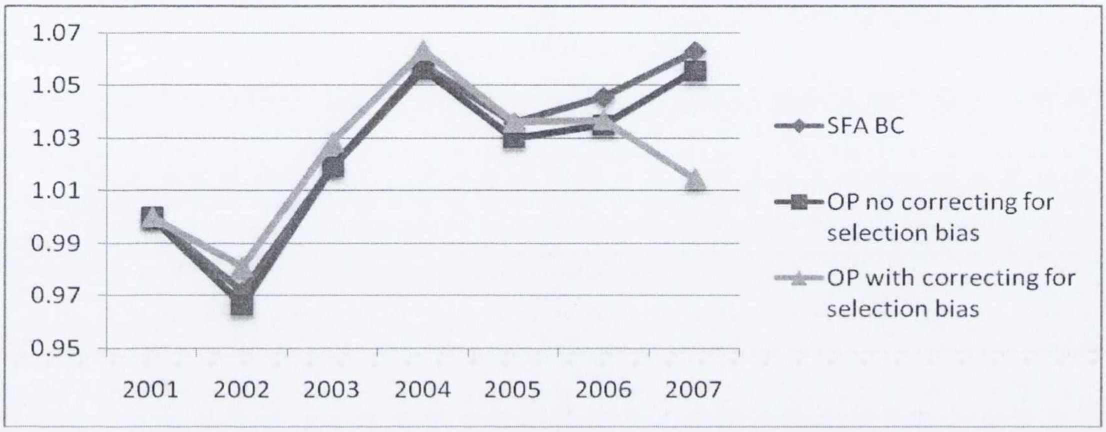
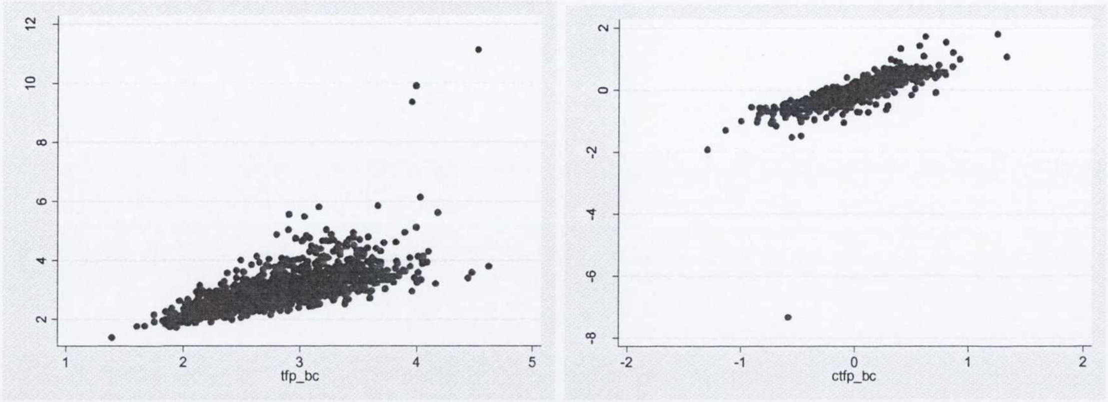


Figure 2.1 presents the estimated cumulative productivity indices using SFA and OP productivity estimation techniques, with a Cobb-Douglas (CD) production function specification. Both productivity estimation techniques, SFA and OP, produce quite similar TFP trends. Battese and Coelli's (1992) time variant inefficiency model with a Cobb-Douglas specification shows the highest overall increase in dairy farm productivity from 2001 to 2007, i.e. 6.3 percent or a compound annual growth rate (CAGR) of 1.02 percent. Productivity, as estimated using OP before correcting for selection bias, increases by 5.6 percent (0.91 CAGR). After adjusting for selection bias there is just a 1.5 percent (0.24 CAGR) increase in productivity levels over the 2001-2007 period. The dairy sector productivity growth results using SFA and OP before correcting for selection bias are in line with the findings of Newman and Matthews (2006) and Carroll (2008). Both papers use SFA for estimating the Irish dairy sector productivity growth. Newman and Matthews (2006) estimated 1.2 percent growth per annum over the 1984-2000 period while Carroll (2008) estimated 1.4 percent growth over the 1996-2006 period.

Figure 2.2 OP after correcting for selection bias vs. Battese and Coelli's time variant inefficiency SFA model with a Cobb-Douglas specification.



(a)

(b)

Note: (a) Scatter plot of TFP in levels: OP vs. SFA. (b) Scatter plot of TFP changes: OP vs. SFA.

Figure 2.2 shows the correlation of TFP estimates using the modified OP procedure and using SFA with Battese and Coelli's time variant inefficiency term specification. The correlation of TFP levels using different methodologies is obvious (0.71 correlation). When we compare the changes in TFP using the modified OP with the changes in TFP using SFA, we find an even a stronger correlation (0.77). This result shows that the both methods produce similar results in levels and in the changes in TFP. This indicates that productivity trends in Figure 2.1 are not just similar on aggregate but the productivity levels and changes are also similar for individual farmers across both models.

2.4.4 Analysis of productivity trends

Despite considerable differences in the underlying assumptions of each model, the productivity indices are very similar up to 2006. TFP changes over the 2001-2006 time period can mainly be attributed to demand shocks in international milk markets and weather conditions. However, different models depict different TFP changes for 2007: OP with a correction for selection bias estimates a decline in TFP while SFA and OP without correcting for selection bias estimate an increase.

The divergence in TFP trends can largely be explained by the different capital coefficients in the estimated production functions. In 2007, the capital stock of our analysed farms increased by more than 30 percent on average (compared to 2005), mostly encouraged by the availability of capital good grants (see Table A 2.2 and Figure A 2.1 for more details) and higher output prices. Since the models estimated using SFA produce smaller capital coefficients due to the possible selection bias problem, capital as an input is not considered to be as important as it is where OP estimation with the correction for selection bias is applied. The huge increase in capital and small increase in output therefore leads to a decrease in TFP levels using the OP approach with the correction for selection bias. Meanwhile SFA models weight capital with less importance in the production process, and the increase in output accompanied by a relatively smaller increase in other inputs (except capital) yields an increase in the level of TFP.[12]

2.4.5 Analysis of variation in farm-level productivity

Before analysing the decoupling effect on dairy farmers' productivity, it is important to understand the environment in which the dairy farmers operated during the 2005-2007 period. Uncertainty about the SFP scheme in 2005 and increased milk price volatility potentially had an influence on farmers' confidence/motivation. This uncertainty possibly encouraged many dairy farmers to postpone capital investment (investment in new buildings dropped by 3 percent in 2005). In 2006, capital investment in new buildings jumped to almost 5,560 euros from 3,850 euros per farm as farmers' confidence in business prospects and the reformed agricultural policy improved (see Table A 2.2 and Figure A 2.1). 2007 was unprecedented for dairy farmers as milk prices increased dramatically, boosting confidence even further[13]. Investment in new buildings jumped to 18,800 euros per farm.[14] Meanwhile, output increased just marginally. It could be that the huge fluctuations in capital investment during the 2005-2007 period led to negative productivity changes, which dominated possible productivity increases due to the introduction of decoupling in 2005. Possible channels for these productivity improvements due to decoupling include reductions in production costs due to the increased competition in the milk product market, increased specialisation in more profitable products, more profitable product introduction in farm production or ceasing production of less profitable farm products.

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[12] Another possible reason for the upward trend in the SFA models is the restrictive functional form of the inefficiency term in Battese and Coelli's (1992) SFA specification: efficiency can only move in one direction (see equation 3).

[13] Note that the high investment levels may also be explained by the Irish economic boom and very cheap and easily accessible loans.

[14] In 2007 investment in new buildings increased fivefold and grants in relation to new farm buildings increased by 18 times compared to 2005 (see Table A 2.2). All numbers related to new investments and new investment grants are estimated by the authors using the NFS data.

The effect of subsidy decoupling on dairy farming productivity changes is explored empirically using the following regression:

$$\begin{aligned} pr_{it} &= \alpha_0 + \alpha_t Time_t + \alpha_{dd} DD_t + \alpha_p \ln P_t + \alpha_i \ln I_{i,t-1} \\ &\quad + \alpha_t \ln INT_t + \alpha_{wd} WD_t + \alpha_z Z_{it} + \zeta_{it} \end{aligned} \tag{2.16}$$

where pr_{it} is estimated productivity using the OP approach with the correction for selection bias; $Time_t$ is a time trend; DD_t is a dummy variable which represents the effect of the decoupling policy implemented in 2005, 2006 and 2007; lnP_t is an annual average milk price which controls for demand and supply shocks; $lnI_{i,t-1}$ is lagged farm net investment (without grants); Z_{it} controls for farm specific features/environment; $lnINT_t$ is a butter intervention price indicator which is used as a proxy for price uncertainty and volatility associated with the decrease in milk price support policy; and WD_t is a bad weather dummy for 2002 and 2005.

The possible overinvestment/underinvestment can be captured by lagged net investment. Bouamra-Mechemache et al. (2008) show that the Luxembourg reform has a significant impact on the EU-25 milk price. The butter intervention price ($lnINT_t$) is expected to be positive, capturing the increased uncertainty in milk prices (price volatility) due to changes in the milk price support policy, amongst other factors, during 2004-2007[15].

The first column of Table 2.5 presents the results of the productivity model given in Equation (2.16), excluding the intervention price and lagged investment. We find that during the decoupling period productivity is lower as indicated by the negative and significant coefficient on the decoupling dummy. However, after controlling for the increased price uncertainty using the intervention prices, we find a positive and significant decoupling policy effect on productivity. The coefficient on the decoupling indicator in column 3 of Table 2.5 suggests that decoupling increased dairy farm productivity by 7.2 percent, on average. The coefficient on lagged investment indicates that the actual

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[15] The existence of dairy quotas is an important constraint in Irish dairy farming. As the milk quota system has become less restrictive in recent years, the intervention prices are used as a proxy for a general move towards a more liberal dairy farming environment. See Newman and Matthew (2006) for more discussion on the effect of the milk quota system on Irish farm productivity.

investment had a negative impact on farm productivity. The 1 percent increase in investment is associated with 0.02 percent decrease in productivity. This finding supports the idea that the generous capital investment grants and small capital cost for farmers, associated with these capital investment schemes, encouraged dairy farmers to overinvest in capital stock, making farms less productive, i.e. allocatively inefficient. The coefficient on the intervention price associated with market uncertainty indicates that price uncertainty matters. The 1 percent decrease in the butter intervention price decreases dairy farm productivity by 0.6 percent.

Table 2.5 Analysis of the effect of decoupling on productivity

	1	2	3	4	5	6
Coefficients	Full sample			Balanced sample		
lnP	-0.2104***	-0.2025***	-0.0863	0.0031	0.0191	0.0519
	0.0492	0.0548	0.0537	0.0424	0.0455	0.0487
Time	0.0113***	0.0038	0.0224***	0.0036	-0.0015	0.0038
	0.0042	0.0043	0.0079	0.0042	0.0046	0.0065
DD	-0.0290*	0.0054	0.0722**	-0.0069	0.0100	0.0293
	0.0164	0.0175	0.0302	0.0151	0.0162	0.0227
SOIL1	0.0377**	0.0424**	0.0422**	0.0446	0.0460*	0.0460*
	0.0181	0.019	0.0189	0.0277	0.0262	0.0262
SOIL3	-0.0278	-0.0302	-0.0303	-0.0720	-0.0685	-0.0686
	0.0289	0.0303	0.0303	0.0478	0.0487	0.0487
CHILD	0.0322**	0.0318**	0.0325**	0.0017	0.0013	0.0015
	0.0149	0.0157	0.0158	0.0233	0.0221	0.0221
OFFFARM	-0.0156	-0.0279	-0.0284	-0.0622	-0.0559	-0.0556
	0.0235	0.0241	0.024	0.0392	0.0388	0.0389
WD	-0.0177*	-0.0208*	-0.0377**	-0.0094	-0.0142	-0.0190
	0.01	0.0118	0.0154	0.0085	0.0089	0.0096
$lnI_{i,t-1}$	-	-0.0225***	-0.0226***	-	-0.0200***	-0.0200***
	-	0.0047	0.0047	-	0.0059	0.0059
lnINT	-	-	0.6367***	-	-	0.1823
	-	-	0.2204	-	-	0.1552
Constant	-22.0505***	-6.7947	-49.5712***	-7.2123	3.1849	-9.0428
	8.4918	8.553	17.525	8.4234	9.2682	14.0406
No. of obs.	1959	1519	1519	707	687	687

Note: Robust standard errors (clustering by the individual farms, weighting by population representing weights) in parentheses (*** $p<0.01$, ** $p<0.05$, * $p<0.1$).

A possible reason why the positive decoupling policy effect is confounded by the increased price uncertainty is that dairy farmers use their single farm payments (SFP) as a buffer for milk price volatility. As milk price support mechanisms and the quota system are eventually abolished, the risk of milk price volatility will increase. Dairy farmers, having observed the increased milk price volatility in recent years, could subsidise their main farming activity using the SFP. As a result, aggregate productivity growth of the sector is suppressed due to a slower selection process: farmers who are unprofitable choose not to exit dairy farming, but to subsidise their dairy business in anticipation of increases in milk prices in the future.

The results are very similar using the balanced sample (columns 4 to 6 of Table 2.5). After controlling for the increased price uncertainty, we again find that the decoupling dummy is positive but not significant. This result not only gives us confidence in the previous results using the full sample, but also shows that the source of the positive decoupling policy effect is not just the selection process (when the less productive farms exit), but also the production decision adjustment of the remaining farmers, making farms more market-orientated and, consequently, more productive.

2.5. Conclusions

With the number of dairy farms decreasing rapidly, and projections that this trend will continue into the future, possible selection bias in estimating production function parameters has the potential to be very important. To illustrate, we use stochastic frontier analysis (SFA) and a modified Olley and Pakes (OP) technique to estimate TFP trends in Irish dairy farms for the 2001-2007 period. SFA does not explicitly take into account the possible simultaneity and selection biases in estimating the parameters of the production function and TFP estimates. By comparing productivity estimates obtained by the modified OP and SFA techniques we observe similar trends in these estimates up to 2006. As the modified OP method with correction for selection bias produces a higher elasticity estimate for the capital input, the large changes in the capital stock between 2006 and 2007 have a large effect on productivity levels. The SFA Battese and Coelli (1992) time variant inefficiency model, commonly used in agricultural productivity/efficiency literature, suggests an increase in TFP of 6.3 percent (equivalent to 1.02 percent CAGR), while OP estimates suggests an increase of 1.45 percent (equivalent to 0.24 percent CAGR) over the 2001-2007 period.

After controlling for increased capital investment, due to generous capital investment schemes, and increased price uncertainty, we find that the decoupling policy had the expected positive and significant effect on aggregate productivity in the dairy sector. Our findings suggest that generous capital investment grants led to overinvestment in the sector and had a negative effect on productivity. Moreover, uncertainty about the introduction of decoupling in 2005 and increased milk price volatility had a negative effect on productivity which can be explained by the effect of uncertainty on farmers' confidence and motivation. Once both of these factors are controlled for, the expected positive effect of decoupling on productivity is observed. Future work is needed to disentangle the source of this productivity effect. There is also room for future research to extend this analysis to other EU countries.

2.6. Appendices

Table A2.1 The production function estimates using the balanced panel data. Standard errors in parentheses.

	OLS_CD	SFA_PL	SFA_BC	OP no corr.	OP with corr.
lnD	0.3762***	0.3089***	0.3089***	0.3441***	0.3441***
	0.0135	0.0079	0.0079	0.0135	1.0135
lnH	0.6826***	0.6827***	0.6827***	0.6633***	0.6633***
	0.0201	0.0136	0.0137	0.0205	1.0205
lnL	0.0422***	0.0487***	0.0487***	0.0639***	0.0639***
	0.0101	0.0048	0.0048	0.0105	0.0105
lnC	0.0593***	0.0486***	0.0486***	0.0254	0.2155
	0.0067	0.0041	0.0041	0.0405	1.0405
lnA	-0.0505***	0.0075	0.0075	0.0731**	-0.1567
	0.0161	0.0147	0.0148	0.0371	1.0957
T2	-0.0236*	-0.0277***	-0.0277***	-	-
	0.0127	0.0077	0.0077	-	-
T3	0.0247**	0.0102	0.0102	-	-
	0.0124	0.0077	0.0079	-	-
T4	0.0668***	0.0463***	0.0464***	-	-
	0.0126	0.0081	0.0085	-	-
T5	0.0393***	0.0251***	0.0251***	-	-
	0.0127	0.0077	0.0082	-	-
T6	0.0411***	0.0336***	0.0336***	-	-
	0.0130	0.0083	0.0092	-	-
T7	0.0535***	0.0425***	0.0426	-	-
	0.0133	0.0085	0.0098***	-	-
lnC1	-	-	-	0.0808	0.0808
	-	-	-	0.0711	0.0711
lnC2	-	-	-	0.0437*	0.0437*
	-	-	-	0.0260	0.0260
lnC3	-	-	-	0.0037	0.0037
	-	-	-	0.0123	0.0123
lnC4	-	-	-	-0.0009	-0.0009
	-	-	-	0.0028	0.0028
lnCDEL1	-	-	-	-0.7533	-0.7533
	-	-	-	0.4745	0.4745
lnCDEL2	-	-	-	0.1359	0.1359
	-	-	-	0.0906	0.0906
lnCDEL3	-	-	-	-0.0103	-0.0103
	-	-	-	0.0075	0.0075
lnCDEL4	-	-	-	0.0003	0.0003
	-	-	-	0.0002	0.0002
LCLCD1	-	-	-	0.0025	0.0025
	-	-	-	0.0076	0.0076
LCLCD2	-	-	-	-0.0002	-0.0002
	-	-	-	0.0003	0.0003
LCLCD3	-	-	-	0.0000	0.0000
	-	-	-	0.0000	0.0000
lnA1	-	-	-	-0.1356	-0.1356

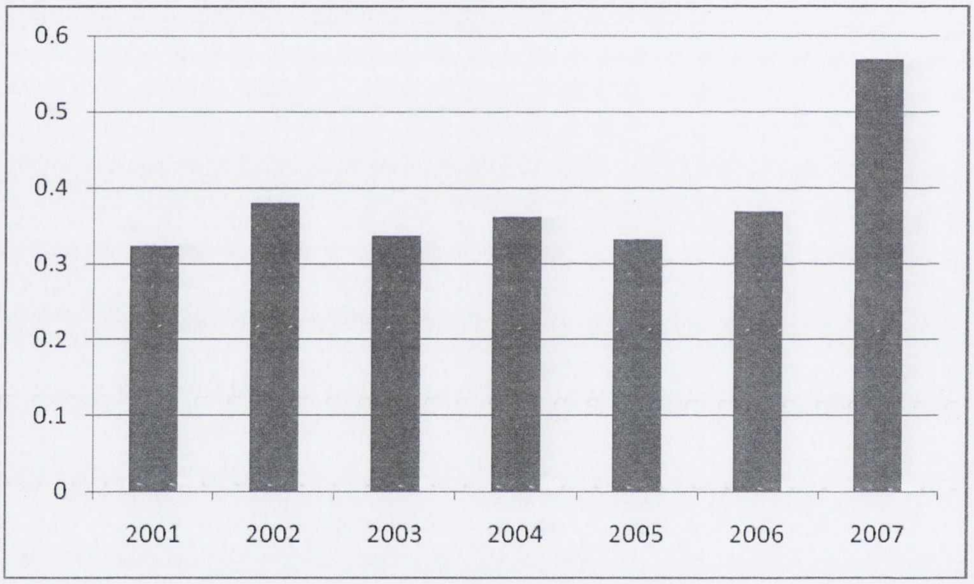
	-	-	-	0.1023	0.1023
lnA2	-	-	-	-0.1725***	-0.1725***
	-	-	-	0.0653	0.0653
lnA3	-	-	-	0.0047	0.0047
	-	-	-	0.0431	0.0431
lnA4	-	-	-	0.0548***	0.0548***
	-	-	-	0.0190	0.0190
LALCD1	-	-	-	0.0112	0.0112
	-	-	-	0.0111	0.0111
LALCD2	-	-	-	0.0003	0.0003
	-	-	-	0.0006	0.0006
LALCD3	-	-	-	0.0000	0.0000
	-	-	-	0.0001	0.0001
LALC1	-	-	-	-0.0222	-0.0222
	-	-	-	0.0214	0.0214
LALC2	-	-	-	0.0027	0.0027
	-	-	-	0.0188	0.0188
LALC3	-	-	-	-0.0034	-0.0034
	-	-	-	0.0050	0.0050
CHILD	-	-	-	0.0188***	0.0188***
	-	-	-	0.0070	0.0070
OFFFARM	-	-	-	-0.0040	-0.0040
	-	-	-	0.0114	0.0114
SOIL1	-	-	-	0.0475***	0.0475***
	-	-	-	0.0076	1.0076
SOIL3	-	-	-	-0.0310**	-0.0310**
	-	-	-	0.0145	0.0145
Constant	-0.0325***	0.1695***	0.1695***	1.4366	1.4366
	0.0088	0.1695	0.0074	0.9044	0.9044
Observations	1959	1959	1959	1959	1959

Note: *** p<0.01, ** p<0.05, * p<0.1.

Table A 2.2 The dynamics of the average Irish dairy farm capital stock, investment and grant availability in 2001-2007 (estimated using population weights).

Year	Capital stock	Net investment	Grants in relation to farm buildings	Cost of new buildings (during acc.year)
2001	51014.4	11478.0	-	-
2002	50324.5	12003.3	-	-
2003	49187.3	11335.0	-	-
2004	54750.4	13799.6	444.4	3979.7
2005	58578.2	14805.8	133.3	3846.7
2006	61653.7	15418.6	263.2	5564.4
2007	77801.4	31580.2	2443.6	18860.5

Figure A 2.1 Net investment to family farm income ratio



Note: dynamics amongst Irish dairy farms from 2001 to 2007 (estimated using population weights). Even after accounting for the significant increase in family incomes due to an exceptional year in 2007 for dairy farming, it is obvious that capital investment in 2007 was much larger than the historical average.

CHAPTER 3

3. The impact of decoupled direct payments on structural change and productivity growth in agriculture: a cross-country analysis using micro-data

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Abstract

The decoupling of direct payments from production, introduced in the recent reform of the Common Agricultural Policy (CAP) is expected to make production decisions more market-oriented and farmers more productive. However, ex-post analyses of the productivity of farms have yet to uncover any evidence of a positive impact of the decoupling policy on farm productivity. Using Irish, Danish and Dutch farm level data, we identify whether the decoupling policy has contributed to productivity growth in agriculture and to what extent enterprise switching and specialisation are important productivity improving mechanisms. We find some evidence that the decoupling policy and related farm enterprise specialisation had significant positive effects on farm productivity.

Keywords: productivity, subsidy decoupling, semi-parametric estimation, switching, specialisation

JEL classifications: D24, Q12, Q18

3.1. Introduction

The recent reforms of the Common Agricultural Policy (CAP) have exposed the European agricultural sector to a new set of constraints and challenges. The major CAP reform was decided in 2003, the main feature of which was the Single Payment Scheme (SPS) implemented between 2005 and 2007. The decoupling of direct payments from production is expected to make production decisions more market-oriented as farmers move from mainly subsidy revenue maximisation objectives toward demand-oriented profit maximizing behaviour. Economic theory suggests that the decoupling of subsidies should lead to a reduction in the efficiency losses associated with coupled subsidy policies (Chambers 1995; Serra et al. 2006). In this article, we explore the effect of these reforms on productivity in the Irish, Dutch and Danish agricultural sectors. In particular, we focus on enterprise switching and specialisation as productivity improvement mechanisms. These three case studies present an interesting setting for studying the dynamics of farms' adjustment processes in a changing agricultural policy environment, in particular, in relation to productivity changes, given that the decoupling policy was implemented in different ways in each country. Ireland introduced a full decoupled payment policy in 2005 based on subsidy payments made in the reference years 2000 to 2002. Denmark also switched to decoupling in 2005, but the decoupled payments are based on a flat-rate per hectare on top of an additional amount based on the historical entitlements, also with 2000-2002 as the reference period. In the Netherlands, the single farm payments are based on historical entitlements from 2006.

The first objective laid down for the CAP in the Treaty of Rome is to "increase productivity, by promoting technical progress and ensuring the optimum use of the factors of production". The empirical literature analyzing how *coupled* subsidies, the main instrument of the CAP, affect farm productivity is summarised by McCloud and Kumbhakar (2009) concluding that little empirical work has found evidence that CAP has been useful in this regard; many previous empirical studies have found that farm subsidies have a negative impact on technical efficiency or productivity (Piesse and Thirtle 2000; Giannakas et al. 2001; Rezitis et al. 2003; Iraizoz et al. 2005; Karagiannis and Sarris 2005; Hadley 2006; Skuras et al. 2006).

Following from the 1996 Federal Agricultural Improvement and Reform Act and the 2002 Farm Security and Rural Investment Act in the US, a large literature emerged analyzing the impact of *decoupled* payments on farm outcomes. In general, this literature suggests that decoupled payments can still distort farm behaviour. For example, Hennessy (1998), shows that support policies that are decoupled affect the decisions of risk-averse producers when there is uncertainty (ex-ante). Goodwin and Mishra (2005; 2006) find that the Agricultural Market Transition Act Payments led to statistically significant (although modest) distortions in acreage allocations. Chau and de Gorter (2005) show that decoupled payments allow some farms to remain in business even if it is not profitable to do so by covering fixed costs. Femenia, Gohin and Carpentier (2010) find that direct payments induce a wealth effect that alters farmers' attitudes toward risk which in turn can lead to production responses. Key, Lubowski and Roberts (2005) find that participation in government schemes, including the 1996 FAIR Act actually increased production levels among participants in the program.

The empirical research on farm subsidy decoupling and its impact on productivity in an EU context are scarce. Andersson (2004) and Happe et al (2008) highlight the fact that understanding the impact of decoupling on structural change and productivity in the EU agricultural sector has largely been neglected. Some exceptions include Sckokai and Moro (2009) who find that policy changes that do not affect price uncertainty (such as an increase in the Single Farm Payment) will have a small impact on investment. Moreover, Howley, Hanrahan and Donnellan (2009) use a partial equilibrium model to project the impact of decoupled payments on Irish agricultural production. By comparing actual observed market data with projections from their model between 2005 and 2008, they find that decoupled payments continue to have a strong effect on agricultural production in many sectors, although this effect is less than if the subsidy payments were still fully coupled. Carroll, Newman and Thorne (2008) analyse (*ex-post*) the recent decoupling effect on Irish farm efficiency and find that in the cattle rearing, cattle finishing and sheep sectors decoupling has led to improvements in efficiency. *Ex-post* analyses of dairy farm productivity, conducted since the introduction of the SPS, have produced weak or no evidence of any positive effect of the decoupling policy on dairy farm productivity (Carroll et al. 2008; Kazukauskas et al. 2010). Zhu and Lansink (2010) analyse the impact of CAP reforms using FADN data (period 1995–2004) on crop farms in Germany, the Netherlands and Sweden. They find that the share of crop subsidies in total subsidies (their proxy for the farm subsidy *coupling* rate) has a mixed effects on technical efficiency across countries. Some evidence outside of the US and EU also exists. For example, Paul, Johnston and Frengley (2000) investigate the impact of dramatic agricultural policy reforms towards market liberalisation in the 1980s on the efficiency of farms in New Zealand. They find evidence that liberalisation did change the composition of farm output but did not stimulate farm technical efficiency.

One possible reason why empirical studies have failed to uncover a significant relationship between decoupling and productivity in an EU context is that the policy change is too recent for farmers to react and so loss-making farms persist in the sector (Breen et al. 2006). It is also possible, however, that more subtle changes are taking place in the sector that aggregate productivity analyses do not reveal. In this article we explore one possible dimension, namely to what extent farm switching behaviour in terms of product adding, dropping, swapping and/or specialisation of farm activities has contributed to productivity growth in the sector. Our basis for expecting such a relationship to exist stems from recent literature analyzing firm dynamics in the manufacturing sector which has emphasised changes in product mix by surviving firms as the main channel of productivity growth (see for example Bernard, Redding and Schott (2010), Goldberg et al. (2010)). While it is clear that the nature and flexibility of production is very different in the agricultural sector as compared with manufacturing, there is no reason to believe that agricultural enterprises might not be as dynamic as manufacturing firms. Ahearn, Yee and Korb (2005) examine whether government policies affect productivity and farm structure for the period 1982 to 1997 in the US and find that in most cases government policy has a productivity enhancing effect by allowing farm enterprises to grow in scale and specialise. In this article we attempt to establish whether such a dynamic is present (through either switching or specialisation) and how it contributes to productivity growth post CAP reform.

Using the Irish National Farm Survey (NFS), Danish and Dutch farm level data, we investigate whether the decoupling policy has contributed to productivity growth in agriculture and to what extent switching behaviour and specialisation is the source of such productivity improvements. The article contributes to both the policy debate on the impact of CAP reform on the agricultural sector and to the literature on productivity estimation in the following ways: first, few studies to date have analysed the ex-post effect of CAP reform on total factor productivity of the agricultural sector, particularly from a cross-country perspective; second, this is the first study which tries to identify switching behaviour and specialisation as a productivity improving mechanism explicitly incorporating this mechanism into the analysis of farm productivity; third, we modify and apply the semi-parametric productivity measurement methodologies introduced by Olley and Pakes (1996) for the estimation of productivity in agriculture;[16] fourth, we present a feasible alternative for estimating productivity using the semi-parametric productivity estimation approaches where actual market exit data are not available.

The paper is organised as follows. Section 3.2 presents the methodological approach. Section 3.3 describes the data. Section 3.4 presents the results and Section 3.5 concludes.

3.2. Methodological approach

In this section, we develop an empirical model for estimating individual productivity levels for each farm in our sample. The empirical estimation of production functions and productivity has become a standard exercise in the applied economics literature. We follow De Loecker (2009), Olley and Pakes (1996), Levihnson and Petrin (2003) and Ackerberg et al. (2007) in our approach. First, we assume a production function:

$$Y_{it} = f(X_{it})e_{it} \tag{3.1}$$

Where Y_{it} is the farm's output level, X_{it} is a vector of production inputs (capital, labour etc.) and e_{it} might represent management quality, productivity differences between farms, or sources of shocks caused by demand changes, weather, machine breakdowns, etc. Marshak and Andrews (1944) were the first to highlight that direct OLS estimation of Equation (3.1) is problematic due to simultaneity bias. The problem is that the choice of inputs is related to the farm's productivity level. If the farmer has prior knowledge of his productivity, which is embedded in e_{it}, then the input choices will be correlated with e_{it}.[17]

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[16] The stochastic frontier approach (SFA) is typically applied for analyses of agricultural productivity (see, for example, Newman and Matthews (Newman and Matthews 2006; 2007) for applications to Irish agricultural productivity and Carroll, Newman and Thorne (2011) for a comparison of the various SFAs). The application of Olley and Pakes' (1996) approach is a departure from this trend. For a comparison between the SFA and the Olley and Pakes approach see Kazukauskas, Newman and Thorne (2010).

[17] The standard approach in the agricultural economics literature is to use a stochastic frontier approach that deals with the simultaneity problem by imposing a structure on the distribution of the part of the error term that captures technical efficiency. However, as discussed in Kazukauskas, Newman and Thorne (2010), the assumption of an independently and identically distributed efficiency term may be incorrect, particularly if

There is a second endogeneity problem present when using OLS to estimate Equation (3.1). If farms have some knowledge of their productivity level, which is part of e_{it}, prior to exiting the sector, farms that continue to produce will be a selected group which will be partially determined by fixed inputs such as capital: farms with a higher capital stock are expected to have a smaller probability of exiting the sector. This endogeneity problem can cause a downward bias in the coefficients on fixed inputs such as capital (Ackerberg et al. 2007).

The third problem that arises when using OLS to estimate the production function given in Equation (3.1) is that demand shocks across individual farms will be captured in the unobserved productivity/error term (e_{it}). In our case farmers will have very different product mixes and production patterns, for example, production specialisation levels, and so will be affected differently by aggregate demand shocks. The presence of such shocks will cause two problems: first, the coefficients of the production function will be biased (due to the omitted variable problem); and second, the estimated productivity term will capture demand variations as well as productivity differences. Failing to control for these demand shocks across individual producers may lead us to infer relationships between productivity and policy changes that are merely reflecting variations in exogenous demand factors (De Loecker 2009). For example, demand shocks in the form of price changes may induce technological progress and so will affect individual farm productivity changes, though we might not expect this to be instantaneous. Paris (2008) provides a summary of the literature on price-induced technological progress. Controlling for the demand shocks (i.e. prices) may allow us to obtain more robust estimates of the effect of the decoupling policy on productivity.

Olley and Pakes (OP) (1996) and Levihnson and Petrin (2003) tackle the simultaneity bias by assuming that the productivity term follows a first order Markov process and investment or intermediate input information is used as a proxy for this term. The OP method addresses the selection bias problem by estimating the probability of exit using

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inefficiency is a function of farm specific variables or previous period efficiency levels. Furthermore, this approach does not account for selection bias which is problematic where we expect policy reform to lead to resource reallocations within the sector. (See Kazukauskas, Newman and Thorne (2010)) for a full discussion and empirical exposition of the differences between these approaches).

firm/farm market exit data. Endogeneity that arises due to unobserved demand shocks is addressed by De Loecker (2009). In order to single out the productivity response to a policy change we control for the demand shocks by including expected output prices directly in the production function as technology shifters.

We assume a translog specification (TL) for the production function:

$$y_{it} = \beta_0 + \sum_{x\in X} \beta_x x_{it} + 0.5 \sum_{x\in X} \sum_{z\in X} \beta_{xz} x_{it} z_{it} + \beta_\tau \tau_{it} + w_{it} + \lambda_t + \epsilon_{it} \tag{3.2}$$

Where y_{it} is the farm's output level in logs, x_{it} are capital, land and labour variables in logs which are assumed to be quasi-fixed and which can be adjusted in two periods; w_{it} is the productivity term which is observable by farmers but not observable by the econometrician; ϵ_{it} is unobserved farm production shocks; τ_{it} are farm specific characteristics (such as age, farm system dummies[18]); and λ_t are time dummies.

De Loecker (2009) notes that the use of farm product mix information in estimating productivity has important advantages. In particular, it enables us to construct segment specific demand shifters. As farms operate in almost a perfectly competitive environment, i.e. farms are output price-takers, we can use agricultural product price information to control for demand changes. We construct the farm specific demand shifters p_{it} as a Tornqvist price index.[19] The demand shift p_{it} for an individual farm will depend on the market price for a particular farm product and how important that product price is for the farm's revenue generating capacity. As the best information available about future output prices are the prices from the previous period, we use lagged demand shifters (p_{it-1}).

In line with Levihnson and Petrin (2003), we use the farmer's choice of intermediate inputs to control for unobserved farm individual productivity (ω_{it}).[20] We assume that the demand

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[18] Farm system dummies are based on FADN Type of Farms (TF) clustering methodology.

[19] The geometric average of agricultural product prices relative to the base period prices weighted by the arithmetic average of the particular farm product value shares for the analysed time period.

[20] We use intermediate inputs as a proxy for farm productivity instead of farm investment decisions because of many non-positive observations on investment in our data.

for intermediate inputs is given by $m_{it} = m(k_{it}, a_{it}, l_{it}, w_{it}) - \beta_p p_{it-1} - \beta_{dr} dr_{it}$, where k_{it}, a_{it}, l_{it} are capital. land and labour, respectively. Under some weak conditions, the intermediate input demand equation is a monotonically increasing function of productivity (w_{it}). We assume that not only are intermediate input choice decisions dependent on quasi-fixed inputs, but also on the introduction of the decoupling policy (dr_{it}) and farm product demand changes (p_{it-1}). To quantify the potential effect of the policy change on farm's intermediate input decision we use a decoupling rate dr_{it} given by Equation (3.3).[21]

$$dr_{it} = \left[1 - \frac{total\_farm\_direct\_payments_{it} - decoupled\_payments_{it}}{total\_farm\_output_{it}}\right] \qquad (3.3)$$

Using this decoupling rate variable as a proxy for the decoupling policy has some advantages over simply using a time dummy variable to capture its effect[22]. Since we do not observe the farm's expectations about the implementation of the decoupling policy, the ex-ante behaviour of farms that may have pre-empted the change in the business environment as a result of the policy change and altered their behaviour accordingly will not be captured by the inclusion of a simple decoupling dummy variable. Bhaskar and Beghin (2010) find that expectations about future policy decisions do influence farmers' production decisions. Moreover, farms may delay their response to the policy change until they are convinced that the new policy is a lasting commitment. Thus, the effects of the decoupling policy on farm behaviour may be evident before the policy is actually implemented or may take some time after the intervention to be observed.

Since productivity is unobserved we back it out by taking the inverse of the intermediate input function which is a function of unobserved productivity. Productivity can be expressed as an unknown function of intermediate inputs, capital, land, labour and the

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[21] The decoupling rate variable (dr_{it}) ranges in value from 0 to 1. A value close to 0 means that the farm's decoupling rate is very low, i.e. farm direct payments are coupled to production and the farm's dependency on coupled subsidies relative to farm total output is very high. A value of 1 means that the farm is fully decoupled from subsidies and the farm does not receive any *coupled* farm subsidies.

[22] It could be argued that some variation in the "decoupling rate" (dr) across farms might be related to the farmers' individual decisions about which goods to produce and this may cause an endogeneity problem in our empirical estimations. As a robustness test we have considered a lagged "decoupling rate" variable in our estimations and our main results hold.

decoupling rate (dr_{it}), i.e. $w_{it} = m^{-1}(k_{it}, a_{it}, l_{it}, m_{it}) + \beta_p p_{it-1} + \beta_{dr} dr_{it}$. This approach relies on the assumption that intermediate inputs are increasing in w_{it}. Substituting this expression into the production function given in Equation (3.2) gives the estimating equation (Equation (3.4)).

$$y_{it} = \beta_0 + \varphi(k_{it}, a_{it}, l_{it}, m_{it}) + \beta_p p_{it-1} + \beta_{dr} dr_{it} + \beta_\tau \tau_{it} + \lambda_t + \epsilon_{it} \tag{3.4}$$

Where $\varphi(.) = \sum_{x \in X} \beta_x x_{it} + 0.5 \sum_{x \in X} \sum_{z \in X} \beta_{xz} x_{it} z_{it} + m^{-1}(k_{it}, a_{it}, l_{it}, m_{it})$. The unknown function $\varphi(.)$ is approximated by a fourth order polynomial to capture possible fourth order non-linearities. This model can be estimated using OLS and can include farm specific fixed effects. The coefficient β_{dr} will quantify the effect of the introduction of the decoupling policy on farm productivity. The model (Equation (3.4)) can also be used to test the hypothesis that farm product switching behaviour and changes in farm product specialisations are the mechanism through which productivity increases in response to the decoupling policy change[23].

To construct the agricultural productivity indices, however, we also need to estimate the coefficients on the inputs in the production function specified in Equation (3.2). As we assume that the farmer observes his/her productivity in period *t-1* when he/she makes decisions regarding quasi-fixed inputs, we assume that the productivity term follows an exogenous first order Markov process, i.e. current productivity is a function of past productivity. Using non linear least squares techniques, while approximating the function $g(.)$ by the fourth order polynomial, the parameters of the production function can be estimated using Equation (3.5):

$$y_{it+1} - \hat{\beta}_0 - \hat{\beta}_p p_{it} - \hat{\beta}_{dr} dr_{it+1} - \hat{\lambda}_{t+1} - \hat{\beta}_\tau \tau_{it+1} = \sum_{x \in X} \beta_x x_{it+1} + 0.5 \sum_{x \in X} \sum_{z \in X} \beta_{xz} x_{it+1} z_{it+1} + g(\widetilde{m}^{-1}(.)) + \kappa_{it}$$

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[23] Note that our assumption about a single production function may have implications for the estimated impacts of switching and specialisation on productivity. To mitigate this impact we use a very flexible production function (a forth order polynomial of all inputs). A single production function is a necessary assumption when farm switching and specialisation effects on farm productivity levels are analysed.

$$(3.5)$$

Where $\widetilde{m}^{-1}(.) = \hat{\varphi}(.) - \sum_{x\in X}\beta_x x_{it} - 0.5\sum_{x\in X}\sum_{z\in X}\beta_{xz}x_{it}z_{it}$ and $\hat{\varphi}(.)$ is estimated in the first stage. If no farms exit the sector, we can estimate consistent parameters on capital, labour and land in this production function using this technique.

Where we have exiting farms we also have to correct for the selection bias that this introduces. In this case, the current productivity level depends not just on the previous productivity level, but also on the farm's decision to stay in business. This leads us to the following production function in place of Equation (3.5):

$$y_{it+1} - \hat{\beta}_0 - \hat{\beta}_p p_{it} - \hat{\beta}_{dr} dr_{it+1} - \hat{\lambda}_{t+1} - \hat{\beta}_\tau \tau_{it+1} = \sum_{x\in X}\beta_x x_{it+1} + 0.5\sum_{x\in X}\sum_{z\in X}\beta_{xz}x_{it+1}z_{it+1} + \phi(\widetilde{m}^{-1}(.), \hat{P}_{it}) + \kappa_{it} \tag{3.6}$$

Where $\hat{P}_{it}$ is an estimated probability of farm survival. OP uses the probability of firm survival based on actual market exit data. In the absence of market exit data, we use farm land reduction information as a proxy for a farms' probability of staying in business (P_{it}). We estimate the probability of survival using a probit model:

$$DISLAND_{it} = \sum \theta_\tau \tau_{it} + \theta_p p_{it-1} + \Gamma(k_{it}, a_{it}, l_{it}, m_{it}) + \zeta_{it} \tag{3.7}$$

Where $\Gamma(k_{it}, a_{it}, l_{it}, m_{it})$ is a fourth order polynomial function which we use to capture the threshold productivity below which a farm will exit; and $DISLAND_{it}$ is a dummy variable for the farmland reduction decision.[24] The predicted values of the probit model ($\hat{P}_{it}$) are used to proxy the probability of survival. The production function coefficients can be estimated in the last step using NLLS. The estimated coefficients and Equation (3.2) are used to calculate the productivity term (tfp_{it}) for each farm *i* in each time period *t*. Once

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[24] Previous empirical applications have shown that non-linearities play a significant role with respect to the effect of productivity on farm behaviour and vice versa. Having modelled the decision by alternative type of polynomials we found that a fourth order polynomial most accurately approximates such non-linearities in our empirical case.

the farm specific productivity estimates are uncovered they are used to construct country specific agricultural productivity indices.

3.3. Data

Irish, Danish and Dutch farm data are obtained from Teagasc (the National Farm Survey) for the 2001-2007 period, the Institute of Food and Resource Economics (FOI) for the 2001-2006 period and the Agricultural Economics Research Institute (LEI) for the 2002-2007 period, respectively. Farms are selected by data collection agencies to obtain a representative sample for each agricultural sector.

Farm output for Ireland and the Netherlands is deflated according to EUROSTAT price indices. The value of output is chosen over quantity due to the fact that output differs in quality across farms. The deflated value of output takes into account such quality differences.

Labour, capital, direct costs and land are used as the production inputs. Family, casual and hired labour are used as the labour inputs. The value input was chosen over a labour unit variable to control for quality differences. The quality of casual and hired labour is quite different across farms. These labour quality differences are reflected in different wage rates. The direct cost input includes expenses on concentrates, feeds, fuels, electricity, vet services/medicines and other miscellaneous direct costs. The capital input in Ireland and the Netherlands includes the replacement value of machines, buildings and livestock. In Denmark, buildings and machinery depreciation is used as a proxy for the capital input. All variables in the case of Ireland and the Netherlands are deflated using price indices which are available from EUROSTAT except for the Irish farmers' labour input variable which is deflated by the agricultural average wage rate (AAWR).

The Danish data only include full-time farms, defined as farms with a standard labour requirement of 1,665 hours or more. The prices used for deflating the Danish data are taken from the yearly Agricultural Price Statistics from the Institute of Food and Resource Economics (FOI).[25]

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[25] For more detailed price indices and for information on the construction of the variables see Rasmussen (2008).

Summary statistics for each of the variables used in the analysis, the estimates of the production function and the population weighted farm productivity trends for Ireland, Denmark and the Netherlands are presented in Appendix.

3.4. Results

In this section we first provide an overview of the pattern of switching and specialisation observed in our data before presenting our findings on the relationship between decoupling and productivity.

3.4.1. Farm system switching and changing patterns of specialisation

There are common patterns among countries when we consider the sorts of products which are dropped from production and the sorts of products which are added to production. After decoupling, no farmer from our sample added milk production to its production mix. A number of Irish, Dutch and Danish farmers abandoned milk production completely after the decoupling policy was introduced. There is some evidence to suggest an increase in innovative activity of farmers in recent years. For example, many have added products to their production activities which are usually classified as 'other' products, such as horses, forestry, vegetables, seeds, etc. Also of note is the addition of products associated with bio-fuels such as oilseeds, wheat, etc. to the production mix of farmers. In Section 3.4.3 we explore the extent to which product switching of this kind contributed to productivity improvements in the aftermath of the implementation of the decoupling policy.

Changes in farm specialisation may be another response of farmers to policy changes. For example, the decoupling of payments encourages farmers to increase their production in more profitable products and decrease their production in less profitable products. The pattern of farm specialisation and its dynamics are revealed in Table 3.1. During the 2001-2007 time period changes in the pattern of specialisation varies across countries with no clear pattern emerging. In Section 3.4.4 we explore the contribution of changes in the pattern of specialisation to productivity growth, in particular, post-decoupling.

Table 3.1 Farm specialisation pattern

Ireland		2001	2002	2003	2004	2005	2006	2007
Milk	mean	0.305	0.259	0.270	0.255	0.258	0.264	0.241
	s.d.	0.341	0.332	0.342	0.340	0.347	0.364	0.358
Cattle	mean	0.530	0.569	0.561	0.558	0.573	0.546	0.556
	s.d.	0.331	0.334	0.344	0.346	0.351	0.361	0.367
Crop	mean	0.051	0.048	0.051	0.054	0.043	0.057	0.063
	s.d.	0.160	0.153	0.161	0.164	0.143	0.176	0.193
Sheep	mean	0.105	0.107	0.106	0.110	0.101	0.117	0.114
	s.d.	0.218	0.217	0.218	0.219	0.216	0.234	0.231
Denmark		2001	2002	2003	2004	2005	2006	2007
Milk	mean	0.489	0.494	0.484	0.468	0.494	0.499	
	s.d.	0.347	0.348	0.357	0.357	0.384	0.390	
Crop	mean	0.180	0.169	0.180	0.182	0.212	0.212	
	s.d.	0.215	0.211	0.219	0.214	0.254	0.260	
The Netherlands		2001	2002	2003	2004	2005	2006	2007
Milk	mean		0.287	0.301	0.276	0.283	0.279	0.253
	s.d.		0.217	0.225	0.221	0.222	0.240	0.229
Cattle	mean		0.051	0.050	0.045	0.056	0.059	0.050
	s.d.		0.102	0.103	0.094	0.116	0.129	0.127
Crop	mean		0.194	0.197	0.203	0.221	0.215	0.223
	s.d.		0.311	0.321	0.319	0.345	0.325	0.326

3.4.2. The effect of the decoupling policy on productivity

As discussed in Section 3.2, it may be difficult to identify the effect of the introduction of the decoupling policy using a single time dummy variable. Furthermore, a simple dummy variable capturing the implementation of the decoupling policy may be confounded by changing macro-economic factors, weather or environmental factors. As such, we construct a decoupling *rate* variable (dr_{it}) as our main indicator of the policy change (see Equation (3.3)). First, we identify the extent to which the decoupling rate has impacted on the productivity of farmers using the regression given in Equation (3.8).

$$y_{it} = \alpha_i + \beta_{dr} dr_{it} + \beta_p p_{it-1} + \lambda_t + \varphi(k_{it}, a_{it}, l_{it}, m_{it}) + \epsilon_{it} \tag{3.8}$$

Where dr_{it} is the decoupling rate given in Equation (3.3) and α_i are farm specific intercept terms.[26] The results of this model are presented in Table 3.2, columns 1-3.

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[26] As we use fixed effects estimation, farm specific variables such as age, soil quality, etc are not relevant.

Table 3.2 Farm product demand and decoupling rate effects on farm productivity

Variables	IE 1	DK 2	NL 3	IE 4	DK 5	NL 6
Dr	0.238***	0.830*	0.130	0.333***	1.024	0.053
	(0.038)	(0.473)	(0.086)	(0.049)	(0.636)	(0.085)
Lagged Tornqvist price index				-0.714***	-0.868***	-0.915***
				(0.162)	(0.242)	(0.094)
time dummies	yes	yes	yes	yes	yes	yes
polynomial	yes	yes	yes	yes	yes	yes
Constant	yes	yes	yes	yes	yes	yes
Observations	8192	4754	2844	7144	3576	2138
R-squared	0.312	0.366	0.471	0.318	0.390	0.529
Number of farms	1895	1718	685	1596	1266	591

Note: Robust standard errors are in parenthesis; *** $p<0.01$, ** $p<0.05$, * $p<0.1$; fixed effects estimation.

The decoupling rate variable captures the importance of *coupled* subsidies in total farm output and is expressed as *one minus the ratio of subsidies to total farm output* so that as payments become decoupled this variable will increase in value. As such we might expect a positive relationship between this variable and productivity. In other words, the decline in importance of *coupled* subsidies as a result of decoupling (i.e., increase in dr_{it}) should lead to improvements in productivity. However, only for Ireland do we find a positive and significant relationship between the decoupling variable and productivity at the conventional 95 percent confidence level. This suggests that as *coupled* subsidies decline in importance for Ireland, productivity improves. We do find a significant effect of decoupling on productivity in Denmark but only at the 90 percent confidence level. All point estimates are in the expected direction indicating that the decoupling policy might be associated with farm productivity improvements across all countries.

As mentioned in the previous section, controlling for the demand shocks may allow us to obtain more robust estimates of the decoupling policy effect. Given that CAP reform might have affected agricultural product price levels and volatility and given that expectations about future output prices affects farm behaviour and farm production, it is important to control for them in the analysis. Table 3.2, columns 4-6, show the effect of output prices on farm productivity. We find that output prices have a highly significant and consistently negative effect for all countries. This result might be explained by the timing of farming decisions. Farmers expecting higher prices in the future may overinvest in the farm's capital base or employ too much of the other quasi-fixed inputs. In the aftermath of an unexpected price shock, these sub-optimal decisions will be reflected in lower productivity levels.

As our analysed countries have chosen different strategies for the implementation of the decoupling policy, we have a chance to compare the outcomes of these different implementation strategies on productivity, although it should be noted that causal links cannot be established within this framework. Ireland introduced a fully decoupled payment in 2005 based on the subsidy payments made in the pre-determined reference years of 2000-2002. Ireland is also the only country where a positive and significant relationship between decoupling and productivity improvements is observed. Denmark also switched to decoupling in 2005, but the decoupled payments are based on a flat-rate per hectare payment on top of an additional amount based on historical entitlements with 2000-2002 as the reference period. The fact that the decoupling policy had no effect on the productivity of Danish farmers while having a significant effect on Irish farmers suggests that basing decoupling fully on historical entitlements induced a different decision making process than the flat-rate per hectare system adopted in Denmark. Given that the flat-rate per land unit system is very similar to the direct subsidy payment system in its nature, one could argue that farmers in Denmark did not have to experience the huge administrative and psychological changes associated with adapting to the new policy. If this is the case then it may be that Danish farmers have fewer reasons to consider the goals of the reform and how the new policy may impact on their farming incentives than their fellow farmers in Ireland.[27] In the Netherlands the single farm payment was also based on historical entitlements from 2006 but with a longer policy adoption period. One possible explanation for decoupling not to have an effect on Dutch farmers is that they had longer to adapt and alter expectations in the run up to the policy change but also they depend less on *coupled* subsidies before the reform and so the impact in practice may not have been that great.

3.4.3. Switching behaviour and specialisation as productivity improving mechanisms

First, we attempt to identify the *unconditional* effects of product switching behaviour (in terms of product dropping, adding and swapping) on productivity by estimating the model given in Equation (3.9). In this first instance we ignore the possibility that pre-decoupling and post-decoupling switching behaviour may have had different effects on productivity.

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[27] The fact that we have just two years data after decoupling may be another explanation for the insignificant results for Danish and Dutch farms.

Table 3.3 Farm product switching and specialisation changes and the decoupling policy effects on farm productivity

Variables	IE	DK	NL	IE	DK	NL
	1	2	3	4	5	6
Dr	0.230***	0.708	0.031	0.096	0.970	0.068
	(0.055)	(0.487)	(0.088)	(0.131)	(0.905)	(0.231)
Lagged Tornqvist price index	-0.524***	-1.031***	-0.906***	-0.518***	-0.394	-0.889***
	(0.170)	(0.235)	(0.098)	(0.180)	(0.242)	(0.101)
lagADD	0.011	-0.006	0.015	0.063	-0.020	0.121
	(0.009)	(0.007)	(0.016)	(0.073)	(0.404)	(0.131)
lagSWAP	-0.004	-0.009	-0.018	-0.033	-0.508	-0.293*
	(0.014)	(0.011)	(0.038)	(0.101)	(0.623)	(0.167)
lagDROP	0.007	-0.005	-0.003	-0.061	-0.089	-0.114
	(0.009)	(0.007)	(0.015)	(0.064)	(0.305)	(0.152)
ShMilk	0.310***	0.465***	0.101	-0.0707	-5.463***	0.174
	(0.081)	(0.101)	(0.278)	(0.154)	(1.275)	(0.464)
ShCattle	-0.243***		-0.677***	-0.375***		-1.642***
	(0.076)		(0.178)	(0.133)		(0.499)
ShCereal	-0.235***	-0.512***	-0.053	-0.192	-0.008	0.328
	(0.067)	(0.117)	(0.100)	(0.161)	(1.181)	(0.333)
ShSheep	-0.318***			-0.438**		
	(0.092)			(0.180)		
dr*lagADD				-0.062	0.012	-0.133
				(0.081)	(0.413)	(0.144)
dr*lagSWAP				0.033	0.512	0.300
				(0.116)	(0.637)	(0.183)
dr*lagDROP				0.077	0.085	0.119
				(0.070)	(0.312)	(0.162)
dr*ShMilk				0.397***	5.969***	-0.066
				(0.140)	(1.298)	(0.453)
dr*ShCattle				0.150		1.048*
				(0.123)		(0.544)
dr*ShCereal				-0.032	-0.424	-0.438
				(0.149)	(1.235)	(0.355)
dr*ShSheep				0.132		
				(0.159)		
time dummies	yes	yes	yes	yes	yes	yes
polynomial	yes	yes	yes	yes	yes	yes
Constant	yes	yes	yes	yes	yes	yes
Observations	6339	2688	2138	6339	2688	2138
R-squared	0.358	0.495	0.550	0.359	0.519	0.557
Number of farms	1435	935	591	1435	935	591

Note: Robust standard errors; *** p<0.01, ** p<0.05, * p<0.1; fixed effects estimation.

$$y_{it} = \alpha_i + \beta_{dr} dr_{it} + \sum \beta_{switch} SWITCH_{it-1} + \sum \beta_{share} Share_{it} + \beta_p p_{it-1} + \lambda_t + \varphi(k_{it}, a_{it}, l_{it}, m_{it}) + \epsilon_{it} \tag{3.9}$$

Where $SWITCH_{it-1}$ are binary variables indicating the switching behaviour of farm *i* (adding, dropping or swapping products) at time *t-1*.[28] If we find that the coefficients on the switching variables (β_{switch}) are positive and significant we will have evidence that product switching leads to productivity improvements.

Another possible way that farmers can adjust to the incentives created by the decoupling policy is to change their production specialisation, i.e. by increasing the production share of more profitable products and decreasing the production share of less profitable products that in the past were associated with production subsidies. We explore this possible adjustment process by considering the relationship between the share of total output by different enterprises ($Share_{it}$) and productivity.[29] If we find that the coefficients on the product share variables (β_{share}) are positive and significant we will have evidence that specialisation in certain products leads to productivity improvements.

The coefficients on the policy variable (dr_{it}) in columns 1-3 of Table 3.3 are similar to those found for the baseline model presented in Table 3.2 suggesting that the decoupling policy had a positive and significant unconditional effect on farm productivity in Ireland but not in Denmark and the Netherlands, though the point estimates of the decoupling policy variable are still positive for all countries. However, with regard to product switching behaviour, we do not find that product swapping has a significant effect on productivity at the conventional 95 percent confidence level.

Table 3.3 also shows us the unconditional marginal effect of the product share in different enterprises on productivity. These results are consistent across all three countries. The results indicate that a higher share of cattle production negatively and significantly impacts on Irish and Dutch farm productivity. As expected, a higher share of milk production positively affects farm productivity across all countries. Only in the Netherlands is this effect insignificant at the conventional confidence levels. A higher farm crop share has a negative effect on farm productivity in all countries, although, this effect is not significant for Dutch farmers. Our results also suggest that sheep farming is not a productive farming activity in the Irish case.

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[28] Lags of the switching variables are used to avoid potential endogeneity problems.

[29] Using the lagged product share variables yield similar results.

3.4.4. Productivity post-decoupling

In this section we consider the marginal effects of farm switching behaviour on productivity *conditional* on the extent of the impact of the decoupling policy by including interactions between the decoupling variable and the switching behaviour terms (Equation (3.10)). This will allow us to determine the extent to which productivity improvements post-decoupling occur due to switching behaviour and specialisation.

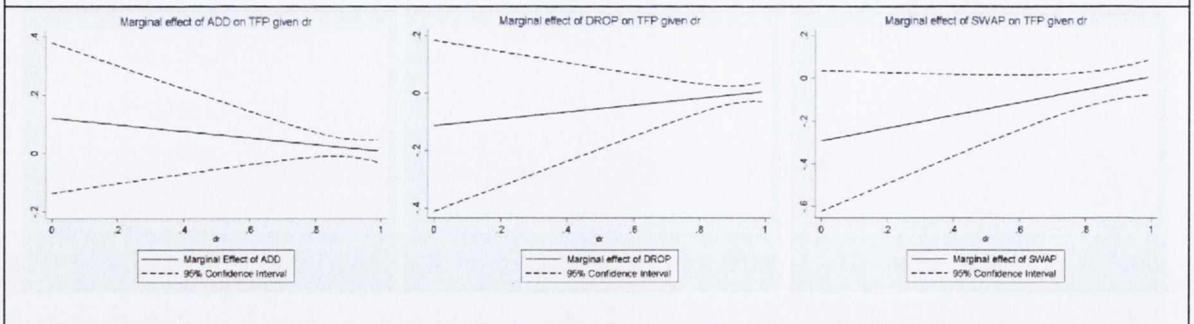
First, in order to establish whether product switching associated with decoupling leads to improvements in productivity we explore the marginal effects of switching on productivity for different rates of decoupling (that is, taking into account the coefficients on the interactions between the decoupling policy and the switching variables, β_{switch}). Second, we also explore the possible policy adjustment process by including interaction terms between the specialisation variables ($Share_{it}$) and the decoupling policy variable (dr_{it}):

$$
\begin{aligned}
y_{it} = \alpha_i + \beta_{dr} dr_{it} + \sum \beta_{switch} SWITCH_{it-1} + \sum \beta_{share} Share_{it} \\
+ \Sigma \beta_{dsw} dr_{it} * SWITCH_{it-1} + \Sigma \beta_{dsh} dr_{it} * Share_{it} + \beta_p p_{it-1} + \lambda_t \\
+ \varphi(k_{it}, a_{it}, l_{it}, m_{it}) + \epsilon_{it}
\end{aligned}
\qquad (3.10)
$$

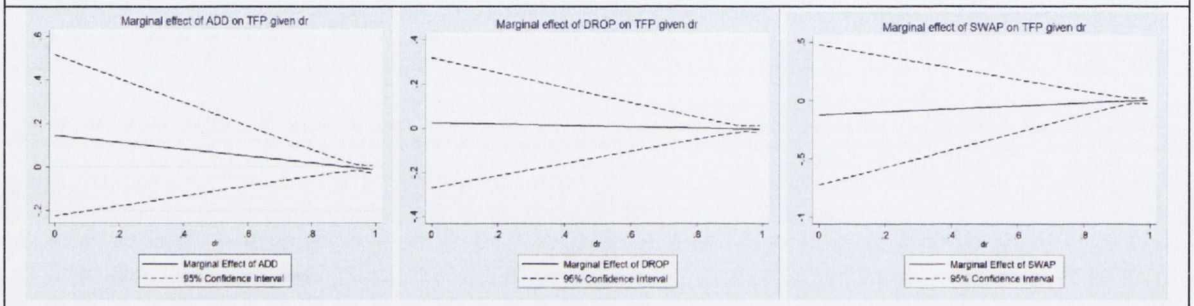
The results for each model are presented in Table 3.3 but given the inclusion of interaction terms we focus here on the marginal effects. We explore the marginal effect of product switching behaviour on productivity for different rates of decoupling in Figure 3.1. We find that product adding, dropping or swapping has no significant marginal effect on productivity for any given level of decoupling rate at the conventional 95 percent confidence level. For the case of Ireland we find that unprofitable product dropping causes a positive and close to significant effect on farm productivity at high levels of the decoupling rate. This result can be explained by the possibly high production adjustment costs associated with product switching. These results suggest that the overall positive and significant effect of decoupling on productivity cannot be explained by the farm product switching channel. Farm *specialisation* as opposed to product switching due to the reform of the decoupling policy might be a less “painful” process for farms in the short term and might produce positive results sooner given that this kind of change requires lower capital, knowledge and technology adjustment costs.

Figure 3.1 Marginal effects of product switching on TFP given different levels of decoupling rate (*dr*)

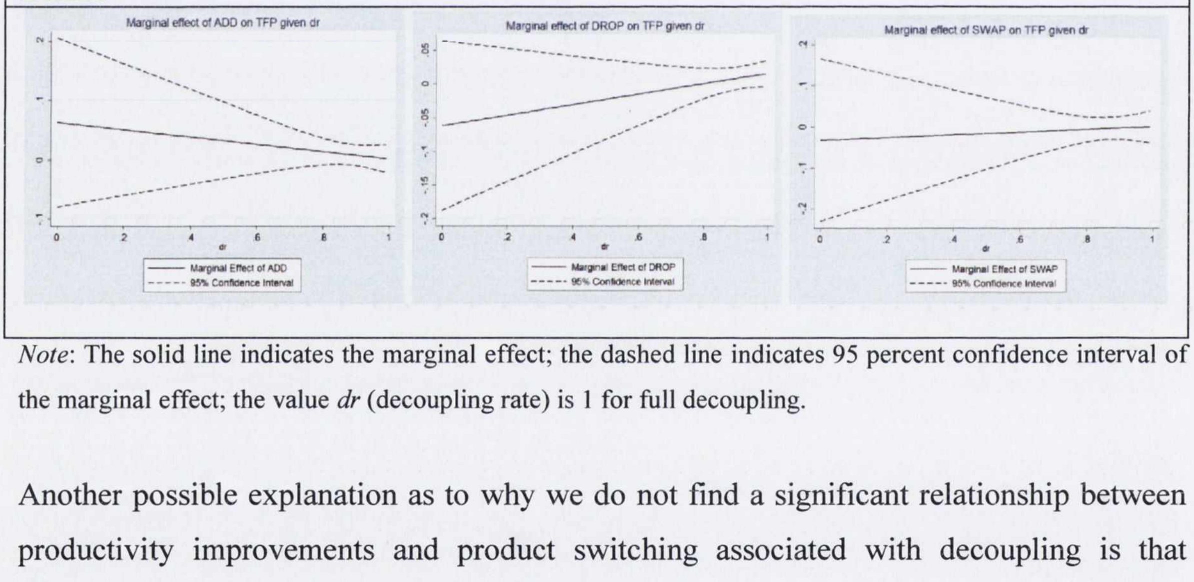
Netherlands



Denmark



Ireland



Note: The solid line indicates the marginal effect; the dashed line indicates 95 percent confidence interval of the marginal effect; the value *dr* (decoupling rate) is 1 for full decoupling.

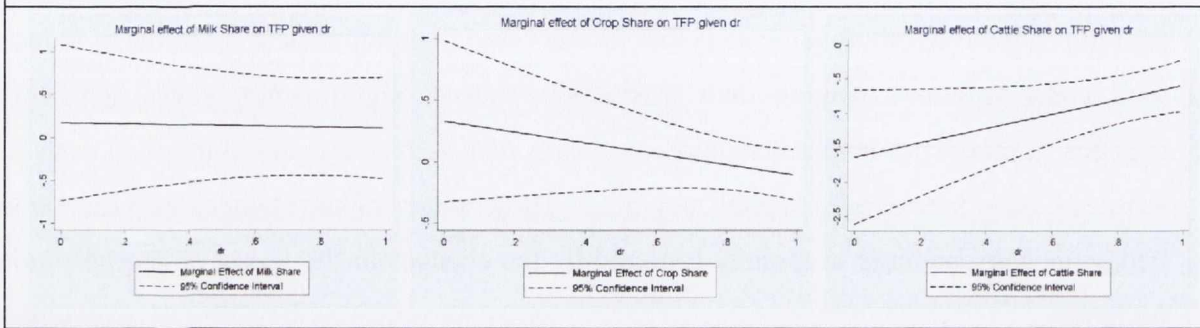
Another possible explanation as to why we do not find a significant relationship between productivity improvements and product switching associated with decoupling is that farmers may be very conservative and unwilling to alter their production behaviour. The extensive literature explaining behavioural changes due to innovations may therefore be relevant in this case. Sauer and Zilberman (2010), as well as Sunding and Zilberman (2001) provide surveys on the general technology adoption literature. Young (2009) emphasises that the adoption to new information (innovation) should be examined in conjunction with other information about the specific nature of the process. The classic Bryce Ryan and Neal C. Gross (1943) study of the diffusion of hybrid corn in the 1920s and 1930s among farmers in the USA shows how long it takes to adopt new technologies, what the adoption path is and what the driving forces behind the behavioural changes are.

Ryan and Gross (1943) stress that natural conservatism (i.e. inertia) was one of the main reasons why farmers delayed in adopting innovations which could increase their profit substantially. It may be the case that this finding, although dated, also explains the slow behavioural changes associated with the decoupling policy found in this article. One of the possible explanations as to why we find a positive and significant effect of the decoupling policy on productivity but that product switching behaviour due to this reform does not lead to productivity improvements is that farmers start their adjustment by trying to reduce their costs without changing their production patterns significantly, since significant changes in production patterns require low levels of risk aversion and high initial costs in terms of new knowledge, capital and time. These more subtle changes in production behaviour may be more accurately captured by the changes in the levels of specialisation on farms.

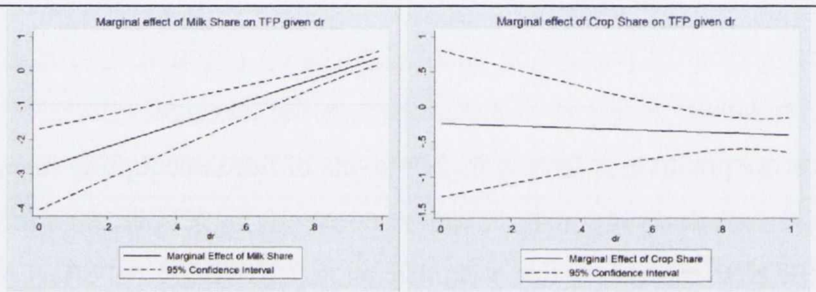
The marginal effects of production share changes on productivity for different levels of decoupling are shown in Figure 3.2. In all cases the marginal effects of milk production specialisation are positive, at least at higher levels of farm decoupling rates, although in the Netherlands these effects are insignificant at conventional 95 percent confidence levels. In the case of the Netherlands we find a significant negative marginal effect of the cattle share on productivity at all decoupling rate levels. Under full decoupling this negative marginal effect is smaller than at lower decoupling rates. The marginal effects of crop share on productivity are insignificant at all levels of decoupling rates. In Denmark the marginal effect of the milk share becomes positive and significant at full decoupling levels, while the conditional marginal effect of the crop share becomes negative and significant at higher levels of decoupling. As in the Netherlands the marginal effect of the cattle share on the productivity of Irish farms is negative and significant at all levels of decoupling, with the negative effect diminishing with the increasing level of decoupling in Ireland. The marginal effect of the crop share on productivity is negative and significant in Ireland. It is worth noting that for almost all cases the effect of specialisation on productivity is positive and at an increasing rate with the extent of decoupling (see Figure 3.2), although some effects are statistically insignificant. These results provide strong evidence for the hypothesis that the decoupling policy impacts on productivity through farm specialisations in more productive production areas[30].

Figure 3.2 Marginal effects of farm product specialisation changes on TFP for different levels of decoupling rate (*dr*)

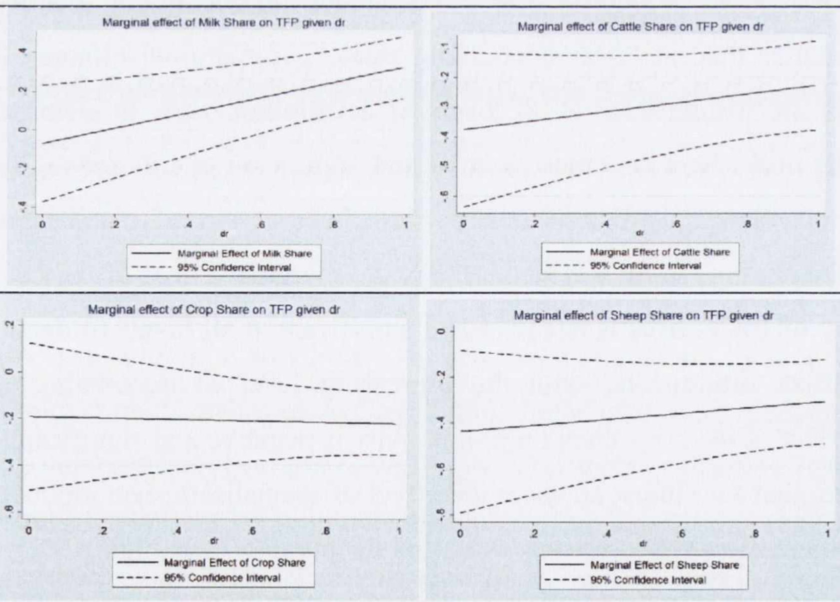
Netherlands



Denmark



Ireland



Note: As for Figure 3.1.

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[30] The specialisation and productivity levels were quite different across countries prior to the implementation of the decoupling policy, thus, *a priori*, the potential productivity improvements that could be attained through specialisation are also substantially different and may explain some of our findings.

3.5. Conclusions

Using the Irish National Farm Survey (NFS), Danish and Dutch farm level data, we investigate whether the decoupling policy has contributed to productivity growth in agriculture and to what extent switching behaviour and changing patterns of specialisation are sources of such productivity improvements. The article contributes to both the policy debate on the impact of CAP reform on the agricultural sector and to the literature on productivity estimation.

We find strong evidence to support the fact that the decoupling policy has had positive and significant effects on productivity, particularly in Ireland. In an attempt to uncover the source of productivity improvements we consider both product switching and changing patterns of specialisation. We do not find product switching behaviour associated with decoupling to be an important source of productivity improvements. We do find evidence, however, that increased specialisation in more productive farming activities is an important productivity transmission mechanism post-CAP reform. A possible explanation for the inertia of farmers in product switching behaviour observed in this article is that farmers may have started their behavioural adjustment to the introduction of the decoupling policy in less significant and less expensive ways, such as, simply increasing their production in more profitable and productive products before implementing more drastic measures such as changing production system or the farm's product mix.

3.6. *Appendices*

Table A 3.1 Summary statistics of the used variables

	IE			DK			NL		
Variable	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.
Decoupling rate	8192	0.872	0.152	4754	0.901	0.092	2844	0.926	0.091
Output (Euro)	8192	77685	75044	4754	400733	316793	2844	256322	193749
Capital (Euro)	8192	123028	118491	4754	46321	35211	2844	336076	265977
Land, ha	8192	52.0	41.8	4754	147.0	127.7	2844	60.7	47.5
Labour (Euro)	8192	19738	10798	4754	60247	37130	2844	79670	38316
Direct cost (Euro)	8192	15973	20483	4754	29887	37966	2844	78317	72020
Investment (Euro)	8192	9679	23121	4754	100620	384082	2844	72318	436904
Age	8192	51.9	12.1	4754	46.4	9.8	2844	50.5	10.5
ADD	7144	0.073	0.261	3576	0.254	0.435	2138	0.064	0.245
DROP	7144	0.084	0.279	3576	0.327	0.469	2138	0.084	0.277
SWAP	7144	0.023	0.150	3576	0.091	0.288	2138	0.014	0.116
Milk share	8192	0.264	0.346	4754	0.488	0.363	2844	0.279	0.227
Cattle share	8192	0.556	0.348				2844	0.052	0.113
Cereal share	8192	0.052	0.165	4754	0.189	0.229	2844	0.209	0.325
Sheep share	8192	0.108	0.222						

Table A 3.2 Average input elasticities, i.e. production function derivatives with respect to each input.

	Labour	Capital	Land	RTS
IE	0.234	0.448	0.192	0.874
DK	0.336	0.496	0.297	1.129
NL	0.207	0.48	0.349	1.036

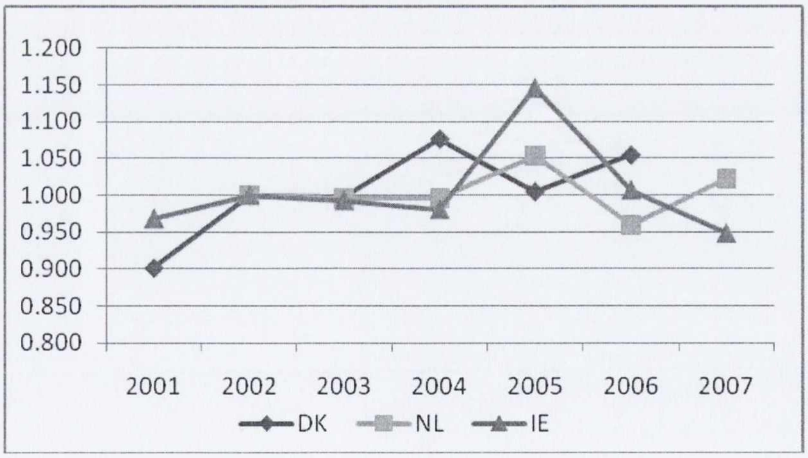
Note: RTS is a return to scale estimate.

Table A 3.3 Translog production function estimates

	IE		DK		NL	
	coef.	s.e.	coef.	s.e.	coef.	s.e.
Capital	0.5854	0.0487	0.4986	0.0687	0.4498	0.0301
Land	0.1445	0.0521	0.2818	0.0654	0.3067	0.0289
Labour	0.1259	0.0589	0.3264	0.0876	0.2022	0.0599
capital^2	0.1979	0.0190	-0.0330	0.0822	0.0545	0.0067
land^2	0.0021	0.0342	-0.2426	0.1134	0.0122	0.0019
labour^2	0.0799	0.0256	-0.2920	0.1922	0.0286	0.0198
capital*land	-0.0543	0.0326	0.1802	0.1240	-0.1911	0.0353
capital*labour	-0.1856	0.0413	-0.2057	0.2044	-0.0757	0.0493
land*labour	-0.19729	0.0494	0.4612	0.2160	0.0365	0.0385

Note: Production functions are estimated separately by country; sector dummies are included in the production function estimations but they are not reported due to space constraints.

Figure A 3.1 The farm productivity indices for Denmark, the Netherlands and Ireland



Note: Productivity indices are estimated using farm individual population weights.

CHAPTER 4

4. Understanding gradual farm exit decisions post CAP reform: a quasi-experimental approach

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Abstract

As a consequence of the recent reform of the Common Agricultural Policy the agricultural sector throughout the EU is undergoing a process of major structural change. The removal of direct payments and price support policies are expected to change farmers' behaviour and force them to reconsider their participation in agricultural production. In this paper we perform an *ex-post* cross-country farm level empirical analysis of farmers' market exit behaviour in response to these reforms. Using a panel dataset for the EU15 countries for the period 2001-2005, we apply quasi-experimental empirical methods to identify the causal relationship between the decoupling policy and farm market exit. Our analysis shows that, contrary to *a priori* expectations, the probability of farm exit decreased due to the policy change, particularly for farms where payments are only partially decoupled. We also find, however, that the reform facilitated exit for farms that had already made the decision to leave the sector.

Keywords: Common Agricultural Policy, subsidy decoupling, farm exit, difference-in-differences

JEL classifications: D22, Q12, Q18

4.1. Introduction

As a consequence of recent reforms of the Common Agricultural Policy (CAP) the EU agricultural sector is undergoing a process of major structural change. The removal of direct payments coupled to production is expected to change farmers' behaviour and force them to reconsider their participation in agricultural production. In this paper, we analyse the impact of the introduction of decoupling on one component of the dynamics of the sector, namely farm exit behaviour, using quasi-experimental methods. We exploit the variation across countries in the timing of the implementation of the policy to identify the causal relationship between the decoupling of direct payments and farmers' decisions to exit production. We find evidence that farm exit behaviour did change due to decoupling policy change but not always in the direction that we might expect.

The 2003 reform of the CAP changed the way that the EU supports the agricultural sector and resulted in the majority of subsidies for agriculture in the EU15 being paid independently of the volume and type of production. In implementing the reforms, Member States had considerable flexibility in choosing the extent of decoupling, including the possibility of partial subsidy decoupling, and could choose the date of the introduction of the policy (2005-2007). Although some of the implementation options are unique to single countries, there are several distinct groups of countries that adopted similar approaches. The variation in the implementation strategy across EU countries allows us to identify the effects of the policy reform on structural change in agriculture, in particular, farm exits.

Economic theory suggests that agricultural production levels should fall in response to the decoupling of production from subsidy payments (Hennessy and Rehman 2006).[31] Andersson (2004) identifies two kinds of adjustments to policy change in the agricultural sector: changes in the level of production and changes in farm numbers. Both adjustment processes are interlinked given that an overall fall in the quantity of output being produced should have a negative effect on the number of farms continuing production since loss

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[31] Chau and de Gorter (2005) propose that it is the *removal* of decoupled payments that will lead to farm exit.

making farms will be forced to exit farming[32]. However, agricultural markets might be distorted in different ways and these distortions might mitigate or even reverse the expected effects. Burfisher and Hopkins (2003) examine the US experience with decoupled payments and find that decoupled payments are more likely to change farm production behaviour when the market in which farmers operate are free of other market distortions such as credit constraints, weak financial systems, and rigid labour markets. Andersson (2004) also noted that the indirect effects of the various types of policy supports offered to farmers, which he categorises into income effects, risk related effects and dynamic effects, may mean that the relationship between even fully decoupled lump-sum payments and the level of production persists.

Swinbank et al. (2004) provide an overview and discussion of the wide range of theoretical reasons for expecting the decoupling of farm subsidies to have a limited effect on farm production decisions in the EU. They also consider reasons why decoupling may actually encourage a greater level of production. First, payments, while decoupled from production, remain tied to farming land and this has an “incentive effect” on farm production. Second, quasi-fixed farm assets (both farm-specific assets, and the human capital embodied in the farmer) typically have a low liquidation value. Thus, the adjustment costs to the new policy might be very high for farmers, meaning that farmers will continue their usual farming practice. Third, farmers may not be profit maximisers and decoupled payments provide an income cushion that helps maintain the revenue flow of the business and prolong the policy adjustment process. Moreover, Swinbank et al. (2004) also provide evidence of market imperfections and market distorting factors in the sector which may mitigate the expected decoupling policy effects including hobby farming, insurance and wealth effects[33] and limited capital constraints.

Overall, the theoretical literature suggests that the effect of the decoupling policy on the behaviour of farms will be distorted by the presence of other market imperfections. However, very little empirical evidence exists to suggest this to be the case. Andersson

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[32] Note that farm exit and farm resource consolidation might be desirable or not desirable depending on circumstances. Farm consolidation or unproductive farm exit may bring productivity increases in the sector but these productivity improvements may be counterweighted by the social cost associated with, for example, long term unemployment in rural areas, costs associated with land abandonment such as biodiversity loss, or losses in traditional farming heritage.

[33] See Serra et.al. (2006) for a review of the literature on the wealth effects of decoupling.

(2004) and Happe et al (2008) highlight the fact that understanding the impact of decoupling on structural change and productivity of the EU agricultural sector have largely been neglected. Happe et al (2008) suggest that one of the reasons for the scarce empirical research on this issue is that econometric approaches are generally unsuitable for analysing the impact of the introduction of decoupling given that there is no historical precedent for this kind of policy. More recently, a literature has emerged that attempts to address these difficulties. For example, Happe et al (2008) employ an agent-based modelling approach and find that if farm payments are no longer tied to production but remain tied to land, the structure of the agricultural sector is hardly affected by decoupling as compared with the business-as-usual scenario. Kazukauskas et al (2010) and Kazukauskas et al (2011b) analyse the effect of decoupling on productivity using a modified version of Olley and Pakes (1996) methodology for estimating productivity in a dynamic setting and find that decoupling had a significant and positive effect on the productivity of farms in Ireland, Denmark and the Netherlands. Clancy et al (2010) provide a comprehensive cross-country descriptive study on structural change due to decoupling concluding that, in line with theoretical predictions, farmers made only minimal changes to production plans. Goodwin and Mishra (2006) analyse the effect of decoupled farm payments on farm production in the US and find that decoupled payments may lead to increased farm production. Paul et.al (2000) investigate the impacts of dramatic agricultural policy reforms towards market liberalisation in the 1980s on the farm efficiency of farms in New Zealand and find evidence that the liberal reforms did change farm output composition but did not stimulate farm technical efficiency. The scarcity of cross-country *ex-pos*t research on the impact of the decoupling policy and, in particular, its impact on structural change in the EU agricultural sector, indicates a clear need for *ex-post* studies of the kind presented in this paper.

In this paper we provide an empirical cross-country analysis of the effect of the decoupling of direct payments on farmers' market exit behaviour. We use an extensive farm level panel dataset for the EU15 countries for the period 2001-2005 and exploit the variation in the timing of the implementation of the policy change to identify its effect. Using a difference-in-differences approach allows us to separate out the effect of the policy change from other country and farm specific factors that may have impacted on farmers' production decisions. We also make other contributions to the empirical agricultural economics literature by constructing new farm exit proxies that allow us to define *gradual* farm exit and a decoupling rate variable that controls for the fact that farms in different countries and farming systems may rely on subsidy payments to varying degrees. We also extend the model to take account of the fact that the extent to which farms depend on subsidies may also have an impact on how they are affected by the policy change. This allows us to understand better the mechanism through which decoupling impacts on farm exit to a greater extent than in the basic model. In addition, we include a new innovative control for unobserved farm heterogeneity which allows us to control for productivity changes in identifying the policy effect. The findings of this study will be of interest to policymakers concerned with addressing rural development issues arising as a result of CAP reform.

The paper is organised as follows. Section 4.2 presents the policy background to the reform of the CAP and outlines how the treatment and control groups are selected. Section 4.3 presents the empirical approach while Section 4.4 presents data and the descriptive statistics of the main variables used. Section 4.5 presents and discusses the results and Section 4.6 concludes.

4.2. Policy background

On 26 June 2003, EU farm ministers adopted a fundamental reform of the CAP.[34] The reform completely changes the way the EU supports the agricultural sector. The new CAP is geared towards consumers and taxpayers, while giving EU farmers the freedom to produce what the market wants. The majority of subsidies are paid independently from the volume of production. To avoid abandonment of production, Member States may choose to maintain a limited link between subsidies and production under well defined conditions and within clear limits. These new 'single farm payments' (SFP) will be linked to the maintenance of environmental, food safety and animal welfare standards. Severing the link between subsidies and production should make EU farmers more competitive and market oriented, while providing necessary income stability.

Farmers are allotted payment entitlements based on reference amounts, calculated through different options depending on the individual Member State. Each entitlement is calculated by dividing the reference amount by the number of hectares which gave rise to this amount

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[34] For a more complete background on the CAP and its reform see European Commission press release (2004), Halmai and Elekes (2005) and the Dutch Council for Rural Areas (2008).

in the reference years. Payments are granted where farmers have eligible hectares at their disposal to activate the appropriate number of entitlements. Eligible hectares normally include all types of agricultural land except land used for permanent crops and forestry. Entitlements are activated annually by matching them with a corresponding number of eligible hectares. In general, transfer of entitlements is allowed once the SPS is introduced, but only within Member States and in some cases only within regions (Member States decide within EU rules). Transfers without land are allowed, but farmers taking over payment entitlements can only receive payment if the number of entitlements is matched by the correct number of eligible hectares.

With regard to the implementation of the reform, the Commission has chosen to do this by way of three Commission Regulations. Regulation 1 covers the provisions concerning cross compliance, controls and modulation. The provisions with regard to cross compliance are one of the new key elements in the CAP reform, which make the future Single Farm Payment dependant on farmers respecting public health, animal health, environmental and animal welfare, EU norms and good agricultural practice. Regulation 2 embodies the key element in the reform of introducing a Single Farm Payment, where the payment is no longer linked to production (decoupling), allowing farmers to have their incomes ensured and steering their production towards the needs of the markets and the demands of the consumers. Payments are, however, only paid in full if the above cross compliance provisions are respected. Regulation 3 covers those areas of support, which are still product specific, or where the Member States have the option to retain a certain element of support coupled in the future. Such possibilities have in particular been foreseen in the area of animal premia (beef and sheep), where the concern with regard to the effect on production and decoupling has been most pronounced.

Although there is a common policy for agriculture across the EU-27, this does not mean that the agricultural sectors in the individual Member States are all similar. Due to varying physical, climatic and socio-economic conditions in the EU Member States, agriculture has evolved from a wide range of different circumstances. Member states have considerable flexibility in applying the Single Payment Scheme (SPS), and they are allowed to maintain some production linked payments in order to avoid abandonment of production. The main difference is whether they base the SPS on what direct payments individual farmers received in the historic reference period, thus producing different subsidy levels for each farmer, or whether all payments are averaged out over a state or region. Another major choice is the timing of the introduction of the SPS. Within the EU-15, Member States were required to introduce the SPS before January 2007.[35]

The 2003 CAP reforms have provided a large space for national manoeuvre. Decoupling has been made less strict than the European Commission originally proposed and many elements of the reform fall within national competence, including: the possibility of partial decoupling; the determination of the date of introduction (2005-2007); limited freedom to select the single farm payment (SFP) calculation model (historic, regional or hybrid); and the reallocation of part of the support through the national envelope. Therefore, instead of a simplification of the support system, different decoupling models and the possibility of partial decoupling have resulted in a very complex system with a wide range of national diversity.

As regards the SFP model there are two basic approaches. The *historic model* creates entitlements to support based on the average level of subsidies claimed in the livestock and arable sectors during the 2000- 2002 reference periods. The number of entitlements allocated to each farmer is set equal to the average area of land giving rise to a subsidy in addition to all pasture land during that same period. The value of each entitlement is established by dividing the average amount of subsidy claimed by the farmer by the number of entitlements awarded. The *regional (area-based) model* operates by basing the entitlements payable to farmers on the area of eligible land that they declare in 2005. The value of all entitlements within a region is then set at a single, common rate.

A third approach to decoupling is also possible by combining the historic and regional approaches into what is termed a *hybrid model*. This can be done in different ways to create various forms of hybrid. Essentially, there are two broad hybrid classes – *horizontal* and *vertical*. A horizontal hybrid is created by putting a set proportion of the decoupled budget arising from each coupled regime into a regional element, with the balance of the budget allocated according to historical claim patterns. A vertical hybrid is created by putting specific coupled schemes, or proportions thereof, into the area based component, with the balance allocated according to historical claims patterns. Also, the ratio of regional and historical elements of hybrid models can vary in later years. If the ratios do

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[35] New Member States (NEU-12) who were applying the Single Area Payment Scheme (SAPS) upon accession can introduce the SPS at any time. They are not included in our analysis.

not change in the future, the model is static, while if the model incorporates changing ratios the model is dynamic. 'Dynamic hybrid' systems can act as a vehicle to transit from the historic to the regional model approach.

Table 4.1 Maximum rate of coupled support, selected products

Supported Product	Maximum rate of coupled support (%)
Cereals and oilseeds	25
Rice	42
Protein crops	100
Sheep	50
Beef	
Option 1	
Slaughter Premium	40
Suckler Cow Premium	100
Option 2	
Slaughter Premium	100
Option 3	
Special Beef Premium	100

Source: Halmai and Elekes (2005).

Member States may maintain a proportion of product-specific direct aids in their existing form (known as 'partial decoupling'), notably where they believe there may be a disturbance to agricultural markets or an abandonment of production by moving to the SPS. Member States may choose between several options, at national or regional level, but only under well-defined conditions and within clear limits (outlined in Table 4.1). There is no time limit on continuing partial decoupling. Amounts paid out in partially decoupled form come from within national ceilings. Member States may grant 'additional payments' to support agricultural activities that encourage the protection or enhancement of the environment or for improving the quality and marketing of agricultural products. Additional payments may use up to 10 percent of the funds available (under national ceilings) in the SPS, thus reducing the funds available for basic SPS payments and product specific direct aids.

There are various motivations for selecting a particular model, including: using an historic distribution of payments in order to prevent negative income effects; partial coupling in order to maintain certain types of production; partial coupling in order to prevent land abandonment; preventing a large administrative burden or; other reasons, such as providing a better rationale for the provision of farm payments in the long term.

In order to separate countries into suitable treatment and control groups for the purpose of our empirical analysis, we match countries in terms of the timing and way in which the CAP reform policies were implemented. The identification of treatment and control groups will allow us to view the introduction of the decoupling policy as a natural experiment for establishing causal relationships between policy changes and farm exits. Table 4.2 summarises the various implementation policies which Member States have adopted.

Table 4.2 National Implementation Policies

Member State	Year	Model	Coupled Payments
Treatment Group			
Ireland	2005	SPS historical	Full Decoupling
Luxembourg	2005	SPS static hybrid	Full Decoupling
UK (England)	2005	SPS dynamic hybrid	Full Decoupling
UK (Wales)	2005	SPS historical	Full Decoupling
UK (Northern Ireland)	2005	SPS static hybrid	Full Decoupling
Austria	2005	SPS historical	Partial Coupling
Belgium	2005	SPS historical	Partial Coupling
Denmark	2005	SPS dynamic hybrid	Partial Coupling
Germany	2005	SPS dynamic hybrid	Partial Coupling
Italy	2005	SPS historical	Partial Coupling
Portugal	2005	SPS historical	Partial Coupling
Sweden	2005	SPS static hybrid	Partial Coupling
UK (Scotland)	2005	SPS historical	Partial Coupling
Control Group			
Greece	2006	SPS historical	Partial Coupling
Spain	2006	SPS historical	Partial Coupling
Netherlands	2006	SPS historical	Partial Coupling
Finland	2006	SPS dynamic hybrid	Partial Coupling
France	2006	SPS historical	Max Possible Coupling

Source: European Commission (2008).

Although some of the implementation options are unique to a single country, there are several distinct groups of countries which adopt similar approaches to the implementation of the CAP reforms. Our core analysis is based on a separation of treatment and control groups based on the timing of the change to full or partial decoupling. The treated farm group consists of farms which are exposed to the decoupling policy in the year 2005 (both full and partial decoupling) while the control farm group consists of farms that were not exposed to the decoupling policy in 2005. As a robustness check, and to further explore the policy implementation options, we also consider the treated farm group to consist of farms that opted for full decoupling in 2005 as compared with farms not decoupled in 2005 and separately consider an alternative treated farm group consisting of farms that opted for partial decoupling in 2005 compared to the same control group.

4.3. Empirical strategy

Identifying the causal effect of policy changes on outcomes is difficult given that the effect of the change in policy can be hard to separate from other factors that may affect the outcome variable. For example, farm exit may be faster in one country compared with another due to a general lower level of productivity among farmers in that country. If low productivity countries are more likely to introduce decoupling early, then without controlling for these underlying differences across farms a biased positive effect of decoupling on farm exit may be observed. In an attempt to identify a causal relationship between the decoupling of direct payments from production and farm exit, we consider a range of difference-in-differences and fixed effects estimators. Our identifying assumption in each case is that in the absence of decoupling, there are no differences between farms in countries exposed to decoupling in 2005 and those exposed to the policy change at a later date that are not controlled for in the model.

The difficulty in modelling farm exit using farm-level data is that we do not observe the farm once it has exited the sector. As such, we consider three proxy binary variables to capture the probability of a farm exiting: disinvestment and/or farm land reduction.[36] Using these variables allows us to capture the possibility that farms may not want to quit agricultural production in the immediate aftermath of the policy change, even if their profitability suggests that they should[37]. They may, instead, start a gradual process of exiting farming. Impediments to farm exit may include: an unwillingness to move to locations where there are opportunities to start new non-farming activities, difficulties in finding non-farming jobs in local rural areas, pure farming habit ("hobby" farming).

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[36] Sauer and Park (2009) construct binary variables based on farm productivity and financial leverage as proxies for farm exits from organic production.

[37] A number of studies have examined the relationship between firm performance indicators and firm survival probabilities finding that there is a positive correlation between firm exit and indicators such as firm size reduction (see literature review on this topic provided by Kiyota and Takizawa (2007)). Empirical studies on the basis of data on actual *farm* exits also show that the life-cycle pattern of the farm (probability of farm survival) is positively related to farm size increases (see Mishra and El-Osta (2008) for a review of this literature).

Capital disinvestment decisions (selling farm capital) may indicate that a farm has started the gradual process of exiting the sector by reducing capital stock and overall production scale. The reduction in the use of land may also indicate a gradual farm exit decision and/or farm production scale reduction. We also consider a combination of both disinvestment *and* farm land reduction as a third proxy variable for gradual farm exit. By considering this latter measure we eliminate the possibility that the reduction in land or capital investment is a reflection of farmers deciding to substitute inputs (land or capital) for each other. The farmer's decision to reduce land area and capital inputs simultaneously may indicate a real determination to exit farming or at least a real reduction in farm size.

We consider different policy variables to capture the introduction of decoupling in our empirical models. The common difference-in-differences approach uses binary variables to indicate treatment of a particular sub-group of observations. As such, we first consider a binary indicator variable for a country that introduced the decoupling policy in 2005 and identify this group as the treatment group. Various treatment groupings are considered (full-decoupling, partial-decoupling and a combination) as discussed in Section 4.2.

As indicated above, our identifying assumption in each difference-in-differences model is that, once suitable controls are included, the only difference between treatment and control countries is the timing of the policy change. An innovation in our approach is that in addition to controlling for time invariant farm specific effects (age, size, soil quality, etc) we also control for time variant unobserved variables such as farm specific productivity changes. Time varying farm specific unobserved productivity may affect the exit decision of treatment and control farms in different ways and as such controlling for these differences is crucial for our identification assumption. In line with Levihnson and Petrin (2003), we use the farmer's choice of intermediate inputs to control for unobserved farm individual productivity (ω_{it}). We assume that the demand for intermediate inputs is given by $m_{it} = f(\omega_{it}, k_{it-1}, a_{it-1})$, where m_{it} are intermediate inputs, k_{it} is capital and a_{it} is land. We also assume that intermediate input demand is monotonic and increasing in ω_{it}. Inverting this function will give us an expression for $\omega_{it} = f^{-1}(m_{it}, k_{it-1}, a_{it-1})$ that can be used to control for productivity in the exit model.[38]

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[38] We use lagged capital and land variables to avoid endogeneity problems which may arise in our empirical estimation.

4.3.1. Modelling the probability of gradual farm exit

The first stage of this analysis constructs a model of the probability of farm exit focusing on the role of policy changes in this decision. The underlying exit decision is modelled as

$$EXIT_{it}^{*} = \mathbf{z}_i\boldsymbol{\beta} + \mathbf{x}_{it}\boldsymbol{\gamma} + \eta_i + u_{it} \tag{4.1}$$

where $EXIT_{it}^{*}$ is a latent variable that underlies an observed indicator variable that captures whether or not a farm exits production according to the following rule:

$$EXIT_{it} = \begin{cases} 1 & EXIT_{it}^{*} > 0 \\ 0 & otherwise \end{cases} \tag{4.2}$$

and

$$Pr(EXIT_{it} = 1 | z_i, x_{it}, \eta_i) = \Phi(\mathbf{z}_i\boldsymbol{\beta} + \mathbf{x}_{it}\gamma + \eta_i) \tag{4.3}$$

where $\mathbf{z}_i$ are farm specific time invariant variables; $\mathbf{x}_{it}$ are farm specific time variant variables (such as capital, land etc); and η_i are farm specific unobserved heterogeneity effects (random effects).

Controlling for unobserved heterogeneity in probit models is complicated. In the linear model, unobserved heterogeneity can be controlled for by including fixed farm-specific effects. In non-linear models, however, any attempt to estimate fixed unobserved heterogeneity effects (η_i) will lead to the incidental parameters problem, resulting in biased and inconsistent estimates (Neyman and Scott 1948; Newman et al. 2008). However, using random effects requires the assumption that the random effects are not correlated with the explanatory variables in the model. This is a restrictive assumption, particularly in the context of the model we are attempting to estimate where farm specific variables, such as choice of capital inputs and farm characteristics, are likely to be correlated with the unobserved heterogeneity.[39]

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[39] Foltz (2004) uses a random effects probit model to estimate a model of farm entry and exit but does not control for the potential correlation between the random effects and the independent variables.

To control for potential correlations between the random effects and the other exogenous variables, an alternative option is to model the unobserved heterogeneity (random effects) as a function of the means of the time varying explanatory variables (Wooldridge 2005).[40]

$$\eta_i = a_0 + \bar{x}_i\psi + a_i \tag{4.4}$$

where $\bar{\mathbf{x}}_i$ is an average of $\mathbf{x}_{it}$ over time for each individual and a_0 is a constant term. We assume that time invariant a_i is distributed as $N(0, \sigma_a^2)$ and is uncorrelated with $\mathbf{x}_{it}$ and other time invariant exogenous variables.

The model can now be written as:

$$Pr(EXIT_{it} = 1 | z_i, x_{it}, \bar{x}_i, a_i) = \Phi(z_i\beta + x_{it}\gamma + a_0 + \bar{x}_i\psi + a_i) \tag{4.5}$$

As indicated, differences in the timing and nature of the reform policies implemented across the EU-15 countries are used as a natural experiment for establishing causal policy relationships. As discussed in Section 4.2, countries are grouped in terms of the timing of the implementation of the policy changes and treatment and control groups are identified on the basis of this grouping. This is incorporated into the random effects probit model in the following way:

$$\begin{aligned} Pr\left(EXIT_{it} = 1 \middle| \mathbf{z}_i, \mathbf{x}_{it}, \bar{\mathbf{x}}_i, a_{i,} \lambda_t, T_i\right) &= \Phi(\lambda_t + \kappa\, T_i + \theta(Y05_t * T_i) \\ &\quad + z_i\beta + x_{it}\gamma + a_0 + \bar{x}_i\psi + a_i) \end{aligned} \tag{4.6}$$

Where T_i is a binary treatment indicator of decoupling; $Y05_t$ is a time dummy for the year of the policy implementation (specifically, in our case, for 2005); and λ_t are time dummies by year for the other time periods. We are interested only in the sign and significance of θ

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[40] See Newman et al (2008) for an applied example.

as this will give us the difference between the treatment and control groups in the probability of exit before and after the introduction of the decoupling policy.[41]

In our analysis, we also consider the possibility that the extent to which farms depend on subsidy payments might have an effect on their exit probability. Goetz and Debertin (2001) find that farmers exit production at a faster rate the more they depend on government assistance. We introduce a farm decoupling rate dummy variable defined by Equation (4.7).

$$dr_{it} = \left[1 - \frac{total\_farm\_direct\_payments_{it} - decoupled\_payments_{it}}{total\_farm\_output_{it}} \right] \tag{4.7}$$

As discussed in Section 4.2, EU countries adopted different decoupling policy implementation strategies. Some countries switched to full decoupling from 2005 while others opted for a slower decoupling policy implementation strategy having partially decoupled direct farm payments in 2005. Furthermore, different countries might have a greater reliance on subsidies than others. The variation in the implementation strategy and in the types of farm production systems across countries might invoke different reactions among farmers to the introduction of the decoupled payment. Moreover, farmers might be less responsive to policy changes if farm incomes are not significantly dependent on subsidies or the SFP. The decoupling rate variable (dr_{it}) is denominated by total farm output, so it takes into account the extent to which farms are dependent on farm subsidies/decoupled payments.[42] The inclusion of this variable therefore controls for the fact that the exit behaviour of farms may depend on the extent to which they rely on subsidies/direct payments. We may also expect, however, that the effect of the decoupling

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[41] Ai and Norton (2003) highlight the fact that the coefficients on interaction terms included in non-linear models are often misinterpreted in applied research. Puhani (2008) shows that while the cross difference does not represent the treatment effect and is not an interesting parameter in a nonlinear difference-in-differences model, but it is correct to focus on the sign of the interaction term coefficient.

[42] The decoupling rate variable (dr_{it}) ranges in value from 0 to 1. A value close to 0 means that the farm's decoupling rate is very low, i.e. all farm direct payments are coupled to production and/or the farm's dependency on coupled subsidies relative to farm total output is very high. A value close to 1 means that the farm only receives decoupled payments and/or the coupled direct farm payments are very low relative to the farm's total output, so the farm's dependence on subsidies for income is low.

policy on exit behaviour will also depend on their reliance on subsidies and payments. We therefore also introduce this variable into the difference-in-differences model.

$$Pr\left(EXIT_{it} = 1 \middle| z_i, x_{it}, \bar{x}_i, a_i, \lambda_t, T_i, dr_{it}\right) = \Phi(\lambda_t + \kappa\, T_i + \theta(Y05_t * T_i) + \delta_0 dr_{it} + \delta_1(Y05_t * dr_{it}) + \delta_2(T_i * dr_{it}) + \delta_3(Y05_t * T_i * dr_{it}) + z_i\beta + x_{it}\gamma + a_0 + \bar{x}_i\psi + a_i) \tag{4.8}$$

In this model we control for whether the decoupling rate (or reliance on subsidies) has an effect on exit but also explicitly model the extent to which the effect of subsidies changes post-decoupling relative to the control group. This will be determined by the sign and significance of δ_3.

4.3.2. Modelling the intensity of gradual farm exit

In the second stage we utilise information about the levels of disinvestment and/or land reduction to establish the extent to which causal links between policy changes and gradual farm exit can be established as measured by farm capital disinvestment or farm land reduction decisions. For this purpose we consider just the farms that disinvested or reduced their land use.[43] The model we estimate is given by Equation (4.9).

$$exit\_intensity_{it} = \square(T_i, x_{it}, \gamma_i, \varrho_i, \lambda_t) \tag{4.9}$$

The specific linear difference-in-differences model estimated is given by Equation (4.10).[44]

$$exit\_intensity_{it} = \gamma_i + \lambda_t + \varrho_i + \kappa\, T_i + \theta\,(T_i * Y05_t) + x_{it}\delta + \varepsilon_{it} \tag{4.10}$$

where $Y05_t$ is a time dummy for the implementation of the policy (for 2005); T_i is a binary decoupling policy treatment variable; γ_i are country specific fixed effects; λ_t are time dummies by year for every time period; and ϱ_i are farm sector specific fixed effects.

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[43] Controlling for sample selection bias is not required in this model as we are explicitly modelling the behaviour of those farms which have strategically chosen to exit farming (based on our proxy variables).

[44] Note that exit intensity is measured in Euros when we use disinvestment as the proxy for farm exit and in hectares when we consider farm land reduction as the proxy for farm exit.

We may also expect that the effect of the decoupling policy on exit intensity will also depend on the reliance of farmers on subsidies and payments and so we also include the decoupling rate measure, *dr*, defined in Equation (4.7)

$$\begin{aligned} exit\_intensity_{it} &= \gamma_i + \lambda_t + \varrho_i + \kappa\, T_i + \theta(Y05_t * T_i) + \\ &\boldsymbol{\delta_0 dr_{it} + \delta_1(Y05_t * dr_{it}) + \delta_2(T_i * dr_{it}) + \delta_3(Y05_t * T_i * dr_{it}) + x_{it}\delta + \varepsilon_{it}} \end{aligned} \tag{4.11}$$

The average policy treatment effect, taking into account decoupling rate differences, will be determined by the sign and significance of δ_3.

We include farm system and country fixed effects to control for exogenous differences between the treatment and control groups. As a robustness check, we also include farm sector and country specific time trends in these models. This allows treatment and control countries to follow different trends thus further strengthening our identification assumption (Angrist and Pischke 2009). The motivation for including these variables comes from the fact that countries have slightly varying national agricultural policies, different socio-economic conditions and climates which may affect farm exit trends across EU countries. A similar motivation exists for the inclusion of farm sector time trends given that the EU CAP reform policies affect farms in different ways depending on their farm sector. We also consider different treatment groups as a robustness check. Conditional fixed effects logit models and a simple linear fixed effects model are used as robustness checks for our random effects probit model specifications.

4.4. Data

Farm Accounting Data Network (FADN) farm level data on all EU15 countries covered by the CAP for the 2001-2005 time period are used The full list of variables with summary statistics for each country are presented in Table A 4.1 of the Appendix. Descriptive statistics for each of the dependent and independent variables used in the analysis are presented in Table 4.3.[45] The share of disinvesting farms decreased in both control and

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[45] Descriptive statistics disaggregated by partial and full decoupling are presented in

Table A 4.2 of the Appendix.

treatment groups but the decrease was larger in the treatment group. In contrast, the share of farms that reduced the amount of land allocated to farming increased for both groups but more significantly for the treatment group. Meanwhile the share of observations that disinvested capital *and* reduced farming land simultaneously increased marginally for both groups.[46]

The average level of capital disinvestment increased between the pre and post decoupling period for both treatment and control groups, but the increase was much greater for the treated farms. Also of note is that for the control group the average area of land farmed increased between the pre and post decoupling periods while for the treated group a reduction in farm land of almost 35 percent is observed.

Descriptive statistics for the decoupling rate variable (*dr* described in Equation (4.7)) reveal that for the treated group the decoupling rate increased from 74 percent to 89 percent. This means that after the decoupling policy was implemented (2005) the average farm dependency on coupled subsidies relative to total farm output decreased from 26 percent to almost 11 percent for the treatment group. In contrast, the average farm dependency on *coupled* subsidies increased slightly for the control group.

Descriptive statistics for the other main control variables are also presented. Of particular note is the fact that farms in the treatment and control groups are different in terms of size (both output and size of farmland used) and so it is important to control for farm heterogeneity in our model.

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[46] Actual farm exits might influence the amount of farms that disinvest or reduce farm land. However, we do not have data on farm exits. We consider farm sample exit as a proxy for actual exit as an additional robustness check in the empirical section. The pattern of farm exit from the sample across countries is presented in Table A 4.3 of the Appendix and reveals that sample exit is similar in the treatment and control groups.

Table 4.3 Descriptive Statistics

	Control		Treatment	
Dis-investment	%	n	%	n
Pre-decoupling	12.65	85,794	16.35	134,553
Post-decoupling	11.88	21,492	12.88	33,002
Total	12.50	107,286	15.67	167,555

	Control		Treatment	
Land Reduction	%	n	%	n
Pre-decoupling	17.82	85,794	14.76	133,389
Post-decoupling	18.28	21,492	16.80	33,002
Total	17.91	107,286	15.17	166,391

Dis-investment and	Control		Treatment	
Land Reduction	%	n	%	n
Pre-decoupling	2.10	85,794	2.44	133,389
Post-decoupling	2.23	21,492	2.62	33,002
Total	2.13	107,286	2.48	166,391

Dis-investment	Control			Treatment		
(EUR)	Mean	Std.	n	Mean	Std.	n
Pre-decoupling	9272	55,100	10855	9,281	54,868	22,003
Post-decoupling	13688	88,486	2554	17,932	126,183	4,250
Total	10113	62,861	13409	10,682	71,487	26,253

Land Reduction	Control			Treatment		
(hectares)	Mean	Std.	n	Mean	Std.	n
Pre-decoupling	5.92	61.35	15,287	6.45	32.04	19,693
Post-decoupling	4.84	63.88	3,928	8.65	27.23	5,545
Total	5.70	61.87	19,215	6.94	31.06	25,238

Decoupling rate	Control			Treatment		
(dr)	Mean	Std.	n	Mean	Std.	n
Pre-decoupling	0.7211	0.2924	85,788	0.7365	0.2763	134,546
Post-decoupling	0.7061	0.3004	21,492	0.8908	0.1934	32,997
Total	0.7181	0.2941	107,280	0.7669	0.2692	167,543

Other control	Control		Treatment	
variables	Mean	Std.	Mean	Std.
Output, EUR	114,000	211,833	161,368	44,1882
Investment, EUR	18,111	102,774	20,417	98,136
UAA, hectares	54.88	84.63	75.57	207.39
Subsidies, EUR	17,663	25,747	26,720	77,023
Payments, EUR	23	62	4,167	28,631
Capital, EUR	113,075	202,079	178,332	361,678
Direct Cost, EUR	84,720	167,357	117,339	405,645

Note: The pre-treatment period is from 2001 to 2004 while the treatment period is 2005.

4.5. Empirical results

4.5.1. Gradual farm exit dynamics

Before estimating the main difference-in-differences regression models, we examine how the probability of gradual farm exit and the intensity of exit vary over time. The results are presented in Table 4.4. The first three columns of Table 4.4 show how the probability of gradual farm exit varies over time. We observe a significant change in disinvestment behaviour in 2005 when the increasing trend in disinvestment between 2001 and 2004 is reversed. This is in line with Andersson (2004) who found that farm investment is likely to be greater after decoupling than in the absence of such payments. In contrast, however, the probability of reducing farm land increased significantly in 2005. Once reductions in capital and farming land are taken together as indicators of farm exit we find an increasing trend over time. We observe a similar pattern for farm exit intensity. Conditioning on farms that disinvest, we find that the *intensity* of disinvestment and land reduction increased over time.

Table 4.4 The probability of gradual farm exit and farm exit intensity

	Probit models			Fixed effect models	
	Dis-investment	Land reduction	Dis-inv & land reduction	Dis-investment, EUR	Land reduction, ha
	1	2	3	4	5
y2002	0.045***	-0.001	0.033*	-1322	0.637
y2003	0.046***	0.028***	0.041**	-543	0.902**
y2004	0.054***	0.014	0.049***	3059*	1.203***
y2005	-0.028**	0.038***	0.051***	7852***	2.983***
Country dummies	yes	yes	yes	-	-
Farm system dummies	yes	yes	yes	-	-
Polynomial	yes	yes	yes	yes	yes
R-squared	0.139	0.0654	0.058	0.008	0.2987
No. of observations	21,5122	215,122	215,122	30,820	44,382

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

These results provide some evidence that between 2001 and 2005 the probability and intensity of farm exit was on an increasing trend. The one exception is a reversal of this trend when farm investment decisions are considered in isolation post CAP reform. While this suggests that the decoupling policy may have changed farmers' exit decisions, lowering the probability of exit, this analysis does not allow us to credibly identify such a policy effect. As discussed in Section 4.3, to identify causality in this setting, given that there may be other factors that influence the probability and pace of farm exit within countries, we consider two distinctive farm groups – those exposed to the policy change in 2005 (treatment group) and those that are not (control group). Using difference-in-differences and controls for farm specific heterogeneity allows us to identify the causal effect of the policy.

4.5.2. Probability of gradual farm exit

We consider two types of difference-in-differences models, as discussed in Section 4.3: first, a simple difference-in-differences model where a binary variable is used to capture the policy effect (taking a value of one if the farm is affected by the decoupling policy in 2005); and second, an expanded difference-in-differences model which takes into account farm heterogeneity in terms of farm dependency on coupled farm direct payments where the control variable is defined as the ratio of coupled subsidies to total output (*dr*). Table 4.5 summarises the main results with a more detailed exposition presented in Table A 4.4 and Table A 4.5 of the Appendix. As discussed in Section 4.3, we use a random effects probit model with controls for potential correlations between the random effects and the time varying independent variables. This approach, however, affects our interpretation of the coefficients in the model and in particular on the interaction terms which in our case is the main effect of interest (the interaction between the treatment dummy and the policy intervention). As discussed by Puhani (2008), where average treatment effects are the main effects of interest in a non-linear setting, only the sign and significance is of relevance and as such this is all that we report in Table 4.5.

Table 4.5 Effect of decoupling on the probability of farm exit

	Dis-investment		Land reduction		Dis-inv & land reduction	
	DD	*DD*dr*	*DD*	*DD*dr*	*DD*	*DD*dr*
	(1)	(2)	(3)	(4)	(5)	(6)
Policy effect	negative	negative	negative	negative	negative	negative
Significance	***	***	*	**	**	-
Time dummies	yes	yes	yes	yes	yes	yes
Country dummies	yes	yes	yes	yes	yes	yes
Farm system dummies	yes	yes	yes	yes	yes	yes
Polynomial	yes	yes	yes	yes	yes	yes
X means	yes	yes	yes	yes	yes	yes
Country specific time trends	yes	yes	yes	yes	yes	yes
Sector specific time trends	yes	yes	yes	yes	yes	yes
Log likelihood	-73,214	-73,200	-96,819	-96,808	-25,993	-25,980
No. of observations	215,122	215,110	215,122	215,110	215,122	215,110

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Each model is estimated using a random effects probit approach. A 4th order polynomial is included to capture productivity changes. *x means* are means of time varying variables within farms included to capture the possible correlation between farm random effects and time varying variable (land, capital, etc.). *DD* is the interaction of the treatment variable and treatment time dummy ($Y05 * T$). Columns with *DD*dr* indicate difference-in-differences models where we control for farm heterogeneity in terms of farm dependency on coupled subsidy payments.

Columns 1 and 2 of Table 4.5 show the effect of decoupling on capital disinvestment decisions. For the simple difference-in-differences model (column 1) and the model which controls for coupled payments dependency (column 2) we find that decoupling had a negative and significant effect on the probability of a farm disinvesting, or exiting production. Two possible explanations for this result emerge. First, the decoupling of payments from production increases the certainty of income flows and so may make farmers more likely to invest (or cease disinvestment). If farmers are risk averse and prefer certain income (decoupled payments) to uncertain income (coupled payments), then the decoupling of payments may encourage them to undertake new investments (Hennessy, 1998). Second, increased certainty relaxes capital credit constraints. As studies by Swinbank et al (2004), Andersson (2004) and others indicate, decoupled payments offer a better form of collateral to credit institutions than subsidies coupled to production given the increased certainty of farm income cash flow. Goodwin and Mishra (2005) use this argument to explain why decoupled farm payments affect farm acreage decisions in the US. Furthermore, decoupled payments may also increase the value of land (Brady et al. 2009), further improving the availability of collateral for capital credit. Relaxed capital constraints combined with certainty about future income flows may explain why the probability of disinvestment declines as a result of decoupling.

Columns 3 to 4 of Table 4.5 show how the probability that farms reduce their land holdings is affected by decoupling. We find that, in contrast to the time dynamics presented in Table 4.4, the probability of gradual farm exit in the form of land reduction decreased for the treated farm group in response to the policy change. The significance level, however, is marginal. This result may be explained by the fact that while payments are decoupled from production, farmers remain tied to eligible land. As discussed by (Swinbank et al. 2004) direct payments linked to even one production input might dampen the decoupling policy effect. While we might expect decoupling to offer farms an incentive to cease production, if these payments remain tied to the land, exit is less likely.

Our final model considers a more stringent proxy for farm exit that accounts for the fact that capital and land might be input substitutes and that the policy change might encourage farms to adjust their input allocation. If this is the case then the results presented in columns 1 to 4 might be capturing changes in input allocation in response to decoupling rather than actual farm exit. The variable takes a value of one for farms that disinvest *and* reduce their land holdings simultaneously. As revealed in columns 5 to 6 of Table 4.5 we do find some evidence that the probability of gradual farm exit decreased due to the policy change when we use both disinvestment and land reduction as a proxy for farm exit, though the statistical significance of this result is not as strong as for the other model specifications.

4.5.3. Gradual farm exit intensity

In this section we consider the change in farm exit intensity induced by the CAP reform using the same policy treatment variables as in the previous section. To proxy farm exit intensity we use the level of disinvestment and land reduction. Our hypothesis is that the decoupling policy might encourage farms considering exiting production to intensify this process and so we select farms that have already made the decision to disinvest or reduce their land allocations.[47] Table 4.6 summarises our findings from the difference-in-differences and fixed effects model specifications. The estimated policy effects are expressed in terms of euro in the case of disinvestment or hectares in the case of land reduction. More detailed results for these model specifications are presented in Table A 4.6 of the Appendix.

Table 4.6 Effect of decoupling on the intensity of farm exit

	Disinvestment (EUR)				Land reduction (ha)			
	DD	*DD*dr*	*DD*	*DD*dr*	*DD*	*DD*dr*	*DD*	*DD*dr*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Policy effect	2105	1285	1276	980	3.20	-0.08	3.88	-0.42
Significance	-	-	-	-	**	-	***	-
Time dummies	yes	yes	yes	yes	yes	yes	yes	yes
Country dummies	yes	yes	-	-	yes	yes	-	-
Farm system dummies	yes	yes	-	-	yes	yes	-	-
Polynomial	yes	yes	yes	yes	yes	yes	yes	yes
Fixed effects	no	no	yes	yes	no	no	yes	yes
R-squared	0.089	0.089	0.008	0.009	0.259	0.263	0.300	0.303
No. of observations	30,820	30,820	30,820	30,820	44,382	44,382	44,382	44,382

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. *DD* is the interaction of the treatment variable and treatment time dummy ($Y05 * T$). Columns with *DD*dr* indicate difference-in-differences models where we control for farm heterogeneity in terms of farm dependency on coupled subsidy payments.

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[47] We do not control for sample selection in this model and so our results should be interpreted as being relevant to farms that have already decided to exit agricultural production. It should be noted in interpreting these results that only farms that are in decline are investigated and so the results do not apply to growing farms.

We find some evidence that the intensity of land reduction increased in response to the introduction of the decoupling policy, even when we control for farm fixed effects (columns 5 and 7 of Table 4.6). We find that when exposed to decoupling, land reduction increases by between 3.2 and 3.9 hectares, however, we find no significant effect when we control for farm subsidy dependency. On the basis of these results we conclude that there is some evidence to suggest that farms intensify the farm exit process (in terms of farm land reduction) in response to the decoupling policy but in general the evidence is far from conclusive.

We find no significant effect of the policy change on the intensity of disinvestment. This result is consistent across all model specifications (columns 1-4 of Table 4.6), though almost all point estimates suggest that the intensity of disinvestment increased for policy treated farms. Although not statistically significant, it may indicate that some farms intensified their farm exit process in terms of disinvestment. This may be due to the increased certainty in the business environment that came with the introduction of the decoupling policy, helping farms to make the decision to exit, that previously may have postponed this decision due to uncertainties about the policy change.

4.5.4. Robustness checks

The first set of robustness checks are performed as a check on the econometric approach employed. For all random effects probit model specifications presented we estimate both fixed effects logit and linear fixed effects models using identical specifications. In *all* cases, our results are robust to the use of these alternative econometric approaches.[48]

The second set of robustness checks concern the selection of treatment and control groups. Given that some countries opted for full decoupling while others opted for partial decoupling, considering each group as separate treatment groups will serve as a useful robustness check on our results but may also offer new insights into the explanations for the results we observe in our core model. The results for each group considered separately as treatment groups are presented in Table 4.7. For the binary treatment variable we find that farms exposed to partial decoupling are less likely to exit (based on the disinvestment proxy and the proxy variable that considers disinvestment and land reduction – see Panel A). This result is also consistent with the inclusion of controls for farm heterogeneity in terms of dependence on coupled direct payments (Panel B). In contrast, we find no

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[48] Results available on request.

evidence to suggest that full decoupling induces such changes in the behaviour of farmers. In most cases we find that farms exposed to full decoupling are no different to farms not exposed to the policy change in terms of exit decisions. Moreover, we find that farms exposed to full decoupling are more likely to reduce their land holdings in response to the policy change.

Table 4.7 Effect of decoupling on the probability of farm exit (partial vs. full decoupling)

Panel A (DD)	Dis-investment		Land reduction		Dis-investment and land reduction	
	Partial	*Full*	*Partial*	*Full*	*Partial*	*Full*
	(1)	(2)	(3)	(4)	(5)	(6)
Policy effect	negative	negative	negative	positive	negative	positive
Significance	***	-	-	***	*	-
Time dummies	yes	yes	yes	yes	yes	yes
Country dummies	yes	yes	yes	yes	yes	yes
Farm system dummies	yes	yes	yes	yes	yes	yes
Polynomial	yes	yes	yes	yes	yes	yes
X means	yes	yes	yes	yes	yes	yes
Country specific time Trends	yes	yes	yes	yes	yes	yes
Sector specific time trends	yes	yes	yes	yes	yes	yes
Log likelihood	-66,485	-33,949	-90,658	-47,172	-23,722	-11,691
No. of observations	199,987	107,271	199,987	107,271	199,9887	107,271

Panel B (*DD*dr*)	Dis-investment		Land reduction		Dis-investment and land reduction	
	Partial	*Full*	*Partial*	*Full*	*Partial*	*Full*
	(1)	(2)	(3)	(4)	(5)	(6)
Policy effect	negative	negative	negative	negative	negative	negative
Significance	**	-	***	-	-	-
Time dummies	yes	yes	yes	yes	yes	yes
Country dummies	yes	yes	yes	yes	yes	yes
Farm system dummies	yes	yes	yes	yes	yes	yes
Polynomial	yes	yes	yes	yes	yes	yes
X means	yes	yes	yes	yes	yes	yes
Country specific time trends	yes	yes	yes	yes	yes	yes
Sector specific time trends	yes	yes	yes	yes	yes	yes
Log likelihood	-66,480	-33,948	-90,622	-47,172	-23,704	-11,687
No. of observations	199,987	107,271	199,987	107,271	199,9887	107,271

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Each model is estimated using a random effects probit approach. A 4th order polynomial is included to capture productivity changes. *x means* are means of time varying variables within farms included to capture the possible correlation between farm random effects and time varying variable (land, capital, etc.). *DD* is the interaction of the treatment variable and treatment time dummy ($Y05 * T$). Columns titled 'partial' present the difference-in-differences results where the treatment group are those farms exposed to partial decoupling in 2005 with the control group being farms not exposed to any form of decoupling in 2005. Columns titled ‘full’ present the difference-in-differences results where the treatment group are those farms exposed to full decoupling in 2005 with the control group being farms no exposed to any form of decoupling in 2005.

We offer a number of explanations for the finding that decoupling slows the pace of exit: 1) we suggest that it may be due to more certain income flows which provide risk averse farmers with greater incentives to invest; 2) the increased certainty of income, combined with increases in land values, provide more collateral for farmers to borrow to invest; 3) the fact that payments remain linked with land holdings reduces the impact that decoupled payments will have. The fact that this result only appears to hold for partially decoupled payments suggests that subsidies that remain linked to production will discourage farmers from exiting.

Our final robustness check considers actual sample exit as the proxy variable for farms exiting agricultural production. The results are presented in Table 4.8. In line with our previous findings we find evidence to suggest that the introduction of decoupling reduces the probability of a farm exiting the sample.

Table 4.8 Effect of decoupling on the probability of actual sample exit

	(1)	(2)
$dr*Y05*T$	-	-0.117
$T*Y05$	-0.430***	-0.279***
$dr*Y05$	-	-0.324***
$dr*T$	-	-0.083***
dr	-	0.188***
$Y05$	0.044***	0.274***
T	0.081***	0.807***
Year dummies	yes	Yes
Sector dummies	yes	Yes
County dummies	yes	Yes
Polynomial	yes	Yes
X means	yes	Yes
Log likelihood	-81,640	-81,568
No. of observations	210,830	210,818
No. of farms	75,446	75,444

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Each model is estimated using a random effects probit approach. A 4th order polynomial is included to capture productivity changes. *x means* are means of time varying variables within farms included to capture the possible correlation between farm random effects and time varying variable (land, capital, etc.).

4.6. Conclusions

The recent reform of the Common Agricultural Policy (CAP) has exposed the European agricultural sector to a new set of constraints and challenges. In this paper, we explore the effect of these reforms on gradual farm exit behavioural changes. Economic theory suggests that in the absence of market distortions and imperfections agricultural production levels should fall in response to the introduction of subsidies that are decoupled from production and would lead to loss-making farms exiting production. However, as proposed in the theoretical literature analysing the potential impact of the decoupling policy, the existence of other market distortions and imperfections in the sector means that the actual effect that the policy implementation will have is unclear and remains an important puzzle to solve empirically. In this regard, the primary contribution of this paper is an ex-post empirical cross-country analysis of farmers' market exit behaviour after the recent CAP reform. We use a difference-in-differences approach to identify a causal relationship between the introduction of decoupled farm payments and gradual farm exit changes. We also make contributions to the empirical agricultural economics literature by suggesting new farm exit proxies allowing us to define gradual farm exit, and suggest new unobserved farm heterogeneity controls never before considered in models of this kind.

We find evidence that decoupling policy had a positive effect on farm survival probability. This result is robust for almost all model specifications we have explored. This policy effect may in part be determined by: the increased cash flow associated with the payments; the relaxing of capital constraints induced by the increased certainty associated with farm incomes; but also given that decoupled payments are subject to eligible agricultural land area, farms are less likely to exit once the payments are in place. Our results suggest that the reason may be associated with the fact that payments remain linked with production given that only partially decoupled payments have a negative effect on farm exit.

We also find some evidence that land reduction and disinvestment intensity increased for those exiting farms that were 'policy-treated'. This may be explained by the increased certainty in the farm business environment leading farms contemplating exit prior to the policy change to make the decision to exit once the policy is in place.

4.7. *Appendices*

Table A 4.1 The means of the variables used in the analysis, by country

Country	Disinvestment	Land reduction	Disinvestment and land reduction	Disinvestment, EUR	Land reduction, ha	*dr*	Direct costs, EUR	Land. ha	Capital, EUR
BEL	0.188	0.241	0.051	10,571	2.355	0.858	131,309	49	212,456
	5,792	4,628	4,628	1,091	1,117	5,792	5,792	5,792	5,792
DAN	0.128	0.238	0.039	11,260	9.351	0.835	52,089	109	140,506
	9,348	9,348	9,348	1,200	2,224	9,348	9,348	9,348	9,348
DEU	0.144	0.250	0.041	12,454	6.397	0.813	251,925	148	293,799
	32,926	32,926	32,926	4,743	8,223	32,926	32,926	32,926	32,926
ELL	0.143	0.207	0.020	825	2.376	0.646	13,004	11	22,802
	20,512	20,512	20,512	2,926	4,236	20,507	20,512	20,512	20,512
ESP	0.146	0.109	0.016	5,072	15.918	0.764	35,759	48	53,391
	39,761	39,761	39,761	5,791	4,315	39,760	39,761	39,761	39,761
FRA	0.104	0.235	0.028	12,266	2.707	0.715	128,103	90	163,947
	36,843	36,843	36,843	3,840	8,668	36,843	36,843	36,843	36,843
IRE	0.291	0.138	0.040	20,766	7.557	0.536	44,479	52	101,026
	6,078	6,078	6,078	1,767	841	6,078	6,078	6,078	6,078
ITA	0.159	0.090	0.013	5,927	7.676	0.803	61,173	32	129,377
	73,294	73,294	73,294	11,622	6,617	73,285	73,294	73,294	73,294
LUX	0.080	0.325	0.033	8,260	2.268	0.678	108,002	83	350,613
	2,274	2,274	2,274	181	738	2,274	2,274	2,274	2,274
NED	0.092	0.196	0.022	96,023	4.518	0.947	378,391	36	458,086
	6,280	6,280	6,280	575	1,230	6,280	6,280	6,280	6,280
OST	0.078	0.177	0.017	3,290	1.466	0.639	43,554	37	227,977
	9,505	9,505	9,505	742	1,683	9,505	9,505	9,505	9,505
POR	0.221	0.093	0.026	3,252	8.583	0.707	27,575	38	45,546
	9,774	9,774	9,774	2,162	908	9,771	9,774	9,774	9,774
SUO	0.071	0.197	0.016	5,445	2.244	0.292	78,328	56	160,332
	3,890	3,890	3,890	277	766	3,890	3,890	3,890	3,890
SVE	0.121	0.337	0.041	1,345	6.817	0.686	14,397	97	28,995
	4,602	4,602	4,602	559	1,552	4,602	4,602	4,602	4,602
UKI	0.157	0.096	0.020	36,143	14.490	0.655	312,929	177	288,170
	13,962	13,962	13,962	2,186	1,335	13,962	13,962	13,962	13,962
Total	0.144	0.162	0.023	10490	6.401	0.748	104,606	67	152,859
	274,841	273,677	273,677	39,662	44453	274823	274,841	274,841	274,841

Note: Number of observation provided beneath the variable means.

Table A 4.2 Descriptive statistics

		Control group (not decoupled in 2005)	All decoupled farms	Fully decoupled farms	Partially decoupled farms
Disinvestment	Pre	0.1265	0.1635	0.1889	0.1600
		85,794	134,553	16,338	118,215
	Post	0.1188	0.1288	0.1917	0.1198
		21,492	33,002	4,111	28,891
Land reduction	Pre	0.1782	0.1476	0.1277	0.1504
		85,794	133,389	16,338	117,051
	Post	0.1828	0.1680	0.1737	0.1672
		21,492	33,002	4,111	28,891
Disinvestment and land reduction	Pre	0.0210	0.0244	0.0252	0.0243
		85,794	133,389	16,338	117,051
	Post	0.0223	0.0262	0.0387	0.0244
		21,492	33,002	4,111	28,891
Disinvestment (EUR)	Pre	9,272	9,281	24,633	6,776
		10,855	22,003	3,087	18,916
	Post	13,688	17,932	42,627	12,311
		2,554	4,250	788	3,462
Land reduction, ha	Pre	5.92	6.45	7.49	6.33
		15,287	19,693	2,086	17,607
	Post	4.84	8.65	12.36	8.10
		3,928	5,545	714	4,831

Note: The pre-treatment period is from 2001 to 2004 and the treatment period is 2005.

Table A 4.3 Number of farm holdings and growth rate of number of holdings, 2000, 2003, 2005, 2007

	Holdings > 1ESU (1000)				Growth, %		
	2000	2003	2005	2007	2000/2003	2003/2005	2005/2007
EU (15 countries)	5,502	5,054	4,903	4,775	-8.14%	-2.98%	-2.60%
Belgium	58.78	52.67	49.63	46.14	-10.39%	-5.77%	-7.03%
Denmark	57.70	48.60	51.35	44.36	-15.77%	5.66%	-13.61%
Germany	454.76	390.17	371.07	348.52	-14.20%	-4.90%	-6.08%
Ireland	132.53	128.79	125.47	117.89	-2.82%	-2.58%	-6.04%
Greece	661.61	654.88	678.14	711.07	-1.02%	3.55%	4.86%
Spain	1,091.58	978.45	958.98	939.51	-10.36%	-1.99%	-2.03%
France	605.45	566.35	527.37	491.08	-6.46%	-6.88%	-6.88%
Italy	1,525.02	1,428.11	1,381.35	1,383.29	-6.35%	-3.27%	0.14%
Luxembourg	2.62	2.30	2.36	2.23	-12.21%	2.61%	-5.51%
Netherlands	101.44	85.36	81.83	76.74	-15.85%	-4.14%	-6.22%
Austria	162.62	140.63	137.00	130.89	-13.52%	-2.58%	-4.46%
Portugal	313.94	261.59	219.01	181.60	-16.68%	-16.28%	-17.08%
Finland	77.91	74.16	70.03	66.57	-4.81%	-5.57%	-4.94%
Sweden	75.05	60.23	66.32	57.53	-19.75%	10.11%	-13.25%
United Kingdom	181.12	181.82	183.37	178.51	0.39%	0.85%	-2.65%
Treatment	2,964	2,694	2,586	2,490	-9.08%	-4.01%	-3.71%
Control	2,537	2,359	2,316	2,284	-7.04%	-1.82%	-1.35%

Source: EUROSTAT.

Table A 4.4 Effect of decoupling on the probability of gradual farm (excluding controls for *coupled* subsidy dependency)

	Disinvestment			Land Reduction			Disinvestment and Land Reduction		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
*T*Y05*	-0.095***	-0.088***	-0.113***	0.002	-0.007	-0.040*	-0.040	-0.040	-0.112**
T	0.850***	0 .870***	-0.393	0.250***	0.239***	-59.167	0.653***	0.664***	-81.104
2002	0.054***	0.065***	0.057***	-0.001	-0.012	-0.014	0.037*	0.045**	0.017
2003	0.059***	0.076***	0.049***	0 .029***	0.002	-0.002	0.048**	0.056*	-0.002
2004	0.079***	0.109***	0.062***	0.016	-0.020*	-0.026*	0.062***	0.075***	-0.015
2005	0.040**	0.052***	-	0.041***	-0.007	-	0.089***	0.079***	-
Country dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes
Farm system dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes
Polynomial	yes	yes	yes	yes	yes	yes	yes	yes	yes
X means	-	yes	yes	-	yes	yes	-	yes	yes
Country specific time trends	-	-	yes	-	-	yes	-	-	yes
Sector specific time trends	-	-	yes	-	-	yes	-	-	yes
Log likelihood	-74,130	-73,360	-73,214	-101,853	-97,113	-96,819	-26,858	-26,021	-25,993
No. of observations	215,122	215,122	215,122	215,122	215,122	215,122	215,122	215,122	215,122

Note: *** p<0.01, ** p<0.05, * p<0.1.

Table A 4.5 Effect of decoupling on the probability of gradual farm exit probability (including controls for *coupled* subsidy dependency)

	Disinvestment			Land reduction			Disinvestment and land reduction		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
*dr*Y05*T*	-0.264***	-0.232***	-0.254***	-0.268***	-0.276***	-0.146**	-0.170	-0.171	-0.120
T Y05*	0.121*	0.1086438	0.112	0.197***	0.219***	0.080	0.112	0.136	0.031
dr Y05*	0.031	0.021	-0.06482	0.105**	0.074*	0.035	-0.002	-0.037	-0.080
	-								
*dr*T*	0.0016001	-0.01796	-0.010359	0.252***	0.211***	0.199***	0.110*	0.077	0.066
dr	0.036	0.017	0.040	-0.106***	-0.168***	-0.156***	-0.119**	-0.180***	-0.168***
Y05	0.020	0.038	0.197**	-0.030	-0.060*	-0.230***	0.087	0.097	0.111
T	0.833***	0.876***	-17.771	0.091**	0.141***	-57.588	0.625***	0.695***	-96.016
y2002	0.054***	0.065***	0.095***	0.002	-0.010382	-0.064***	0.037*	0.044**	0.032
y2003	0.061***	0.076***	0.125***	0.031***	0.003	-0.103***	0.048**	0.053**	0.029
y2004	0.080***	0.109***	0.176***	0.019*	-0.019*	-0.178***	0.061***	0.072***	0.032
Sector dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes
County dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes
Polynomial	yes	yes	yes	yes	yes	yes	yes	yes	yes
X means	-	yes	yes	-	yes	yes	-	yes	yes
Trends	-	-	yes	-	-	yes	-	-	yes
Log likelihood	-74121	-73353	-73200	-101816	-97096	-96808	-26853	-26007	-25980
No. of observations	215110	215110	215110	215110	215110	215110	215110	215110	215110
No. of farms	77763	77763	77763	77763	77763	77763	77763	77763	77763

Note: *** p<0.01, ** p<0.05, * p<0.1.

Table A 4.6 Effect of decoupling on the intensity of gradual farm exit intensity (including controls for *coupled* subsidy dependency)

	Disinvestment				Land reduction			
	OLS	FE	OLS	FE	OLS	FE	OLS	FE
*dr*T*Y05*	-	-	8,293	6,327	-	-	-0.48	-2.69
	-	-	11,981	18,093	-	-	7.52	12.94
*T*Y05*	2,105	1,276	-7,123	-5,547	3.20**	3.88***	-0.48	4.71
	4,036	5,972	5,912	7,920	1.22	1.00	7.13	11.92
*dr*T*	-	-	8,335	15,088	-	-	3.35	-0.53
	-	-	7,091	15,467	-	-	2.70	0.67
*dr*Y05*	-	-	8,122**	8,967	-	-	11.83	4.06
	-	-	3,283	5,787	-	-	8.34	3.70
dr	-	-	-1,366	-9,049**	-	-	9.25**	6.43***
	-	-	2,380	3,595	-	-	4.48	2.15
Y05	3,742	7,218	-1,832	-3,115	-0.04	1.11**	-2.06	1.57**
	2,768	4,542	2,814	6,303	1.20	0.45	2.15	0.64
T	-79,056***	-	-85,945***	-	-0.81	-	-14.83	-
	2,329	-	4,404	-	1.61	-	9.13	-
Time dummies	yes	yes	yes	yes	yes	yes	yes	yes
Polynomial	yes	yes	yes	yes	yes	yes	yes	yes
Country dummies	yes	yes	yes	yes	yes	yes	yes	yes
Sector dummies	yes	yes	yes	yes	yes	yes	yes	yes
No. of observations	30,820	30,820	30,820	30,820	44,382	44,382	44,382	44,382
No. of farms	21,035	21,035	21,035	21,035	30,091	30,091	30,091	30,091
R-squared	0.089	0.008	0.089	0.009	0.259	0.3	0.263	0.303

Note: Robust clustered (by regions) standard errors are presented beneath coefficient estimates (*** p<0.01, ** p<0.05, * p<0.1).

CHAPTER 5

5. The effect of cross-compliance on the environmental performance of farms: a case study of the EU

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Abstract

The EU farmers are subject to cross-compliance measures requiring them to meet a set of environmental conditions to be eligible for public support. Environmental cross-compliance obligations reinforce incentives for farmers to change their behaviour towards the environment. We apply quasi-experimental methods (difference-in-difference) to measure the causal relationship between cross-compliance and farm environmental performance. We find that cross-compliance has a positive effect on EU farmers' environmental outcomes in terms of fertiliser and pesticide reduction. This result also holds for farmers who participate in other voluntary agro-environmental schemes. Our results do not support our expectations that farmers who rely on larger shares of public payments have a stronger motivation to improve their environmental performance.

Keywords: agriculture, common agriculture policy, cross-compliance, environment, EU

JEL: Q12, Q15, Q18, Q58

5.1. Introduction

With increased pressure to integrate environmental concerns into agricultural policy, environmental cross-compliance is increasingly being used as a policy tool for improving the environmental quality of farm management. Cross-compliance means to make the receipt of public support payments contingent on compliance with environmental and other requirements. Environmental cross-compliance, first explicitly introduced in the 1985 US Farm Bill, has become a popular measure in the European Union (EU), after the failure of more voluntary approaches (Osterburg et al. 2005). The EU Common Rules Regulation (1259/1999), also referred to as the Horizontal Regulation, provides a possibility for introducing cross-compliance measures. However, up to 2005 such measures were optional for EU Member States but they became mandatory with the 2003 Common Agricultural Policy (CAP) reform for all European farmers applying to all direct payments from 2005. Member States must now set farming standards in relation to 19 EU regulations and directives (Statutory Management Requirements or SMRs) and define Good Agricultural and Environmental Conditions (GAECs).

Environmental cross-compliance strategies have considerable appeal in that they remove some of the inconsistencies of previous agricultural policies. Previously, one agricultural program rewarded a farmer for non-conservation behaviour (e.g. subsidies dependant on production) while another encouraged conservation (e.g. EU Nitrate Directive). Moreover, by shifting from a policy of paying farmers to reduce their pollution to requiring them to comply with environmental standards using the reduction of support payments as an additional sanction, somewhat implements the "polluter pays" principle in the agricultural sector[49].

The effectiveness of any cross-compliance programme depends on numerous factors. Winter and May (2001) discuss some of these factors. In principal, regulated farms comply with a given regulation when they conclude that the benefits of compliance (here, received

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[49] The "polluter pays principle" requires the polluter to internalise the cost of pollution and its main goal is society welfare maximisation. In 1972, the Organisation for Economic Co-operation and Development (OECD) articulated the principle explicitly and in 1989 indicated that it should be applied to agriculture (Grossman 2007). The nature of agricultural production makes the "polluter pays principle" difficult to apply, and it therefore does not always apply to agriculture. See Tobey and Smets (1996) for more discussion on the difficulties in adopting the "polluter pays principle" to the agricultural sector.

subsidies), exceed the costs of compliance (here, costs of improving environmental conditions). A second motivation for compliance comes from regulated farmers' combined sense of moral duty and agreement with the importance of a given regulation. Awareness of what a given regulation is requiring is also a prerequisite for compliance. In the context of the recently introduced European environmental cross-compliance, incentives to comply will be highest for farmers that receive the highest subsidy payments (Bennett et al. 2006). Likewise, the more decoupled the payments are from production, the more responsive farmers are likely to be in their reaction to the cross-compliance requirements (Webster and Williams 2002). This suggests that EU Member States that decoupled subsidies from production the most, and farmers that rely on the larger shares of direct subsidies, are likely to achieve the biggest environmental improvements. Nevertheless, Juntti (2006) argues that the likelihood of achieving significant environmental improvements in Europe with cross-compliance is low. The reason for this is an apparent mismatch between the aspirations set out by the 2003 CAP reform to simultaneously liberalise the agricultural sector, secure high international competitiveness and at the same time to enhance environmental standards. According to Juntti (2006), these multiple aims limit the capacity of cross-compliance to properly secure environmental objectives.

To date, the overall effect of environmental cross-compliance on environmental outcomes is not clear. The existing studies on the environmental benefits arising from cross-compliance are few and mainly based on either expert judgement or simulation models rather than direct measurement of environmental outcomes. Brady et al. (2009) assess the long-term effects of the 2003 Reform on farm structure, landscape mosaic and biodiversity using a spatial agent-based model for a sample of EU regions. They find that GAEC measures did not prove to be a sufficient measure to avoid all of the environmental consequences of decoupling (their other results show that decoupling would, in some regions, have resulted in land abandonment, resulting in an even greater loss in mosaic and biodiversity values). Also, they show that environmental outcomes greatly depend on the regional characteristics, and this calls for spatially differentiated environmental policy instruments.[50] Mosnier et al. (2009) employ a farm-level bio-economic model to estimate the effect of decoupled payments and cross-compliance measures for two typical arable farms in the Southwest of France. Their results show that if cross-compliance measures are

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[50] The major shortcoming of cross-compliance is that it does not take into account differences between farms and the effect of farmers on the environment.

imposed, a small reduction in the cultivated area of irrigated crops is observed and environmental indicators at farm level are improved. In Switzerland (not an EU member), a similar policy (Proof of Ecological Performance) has been shown to be effective in reducing diffuse nitrogen and phosphorus pollution from agriculture although some goals were not reached (Herzog et al. 2008).

To the best of our knowledge, this paper is the first attempt to empirically evaluate the impact of the newly reorganised European agricultural policy on farmers' environmental performance. Swales (2006) stresses that cross-compliance does not seek to address all environmental issues in agriculture. Thus, following him, we should judge the environmental effectiveness of cross-compliance only in relation to its objectives and the framework available to meet these objectives. One of the main cross-compliance environmental issues is water pollution, soil quality and the protection of biodiversity features. Thus, in this paper we focus on specific quantitatively measurable and available environmental indicators related to the above mentioned primary cross-compliance environmental issues. The farm's usage of artificial fertilisers and pesticides are our environmental indicators (proxies) for cross-compliance effectiveness.

The effect of the cross-compliance policy on farm environmental performance is identified using a differences-in-differences method, where we investigate the response of farms subject to *national* cross-compliance measures introduced *before* the introduction of the *EU-wide* cross-compliance policy in 2005.[51] Our main hypothesis is that compulsory cross-compliance measures should improve environmental performance in the form of fertiliser and pesticide reduction. To sharpen the identification, we take into account farms' dependency on overall subsidies and also participation in other agro-environmental schemes. We account for observed and unobserved farm-level heterogeneity by controlling for farm productivity changes and other farm and/or time specific characteristics.

Our main results are summarised as follows. The pre-2005 cross-compliance measures had a positive effect on EU farmers' environmental performance in terms of fertiliser and pesticide reduction. This result also holds for farmers who participated in other voluntary

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[51] To distinguish between cross-compliance measures introduced before 2005 and after 2005, we define pre-2005 cross-compliance as *national* cross-compliance, and post-2005 cross-compliance as *EU-wide* cross-compliance.

agro-environmental schemes. However, our results do not support our expectations that farmers who relied more on subsidies and were subject to the pre-2005 cross-compliance measures had stronger incentives to improve their environmental performance.

We proceed as follows. Section 5.2 presents the background on the EU cross-compliance policy. Section 5.3 presents the empirical framework we employ. Section 5.4 presents the data and the descriptive statistics of the main variables. Section 5.5 discusses the main results, and, finally, Section 5.6 concludes.

5.2. Policy background

The concept of cross-compliance refers to the setting of conditions which farmers have to meet to be eligible for public support. It has been discussed in the EU since the early 1990s, and various reforms of the CAP have increased the importance of cross-compliance as a policy tool for environmental integration.

In order to address some of the changes in farming practices which negatively affect the state of the environment, the CAP reform of 1999 (Agenda 2000) introduced for the first time the principle of compliance with environmental requirements. The Horizontal Regulation (Article 3 of Regulation 1259/1999, covering all payments granted directly to farmers) gave an option to Member States to introduce cross-compliance measures, or, as outlined in the regulation, "specific environmental requirements constituting a condition for direct payments", relating to one or more environmental issues.

Nine out of 15 EU Member States introduced some cross-compliance measures following the Horizontal Regulation (see Table 5.1). As it was up to each Member State to decide on a cross-compliance strategy, implementation of this *national* cross-compliance differed across Member States. Most Member States tended to focus cross-compliance on relatively specific farm management activities, and some did not apply cross-compliance at all. Activities that were subject to some cross-compliance measures include soil management to control surface water run-off, animal waste management, sustainable crop rotation and efficient use of fertiliser and pesticides.[52] However, the implementation of *national* cross-

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[52] See Angela Bergschmidt, Heike Nitsch, Bernhard Osterburg (2003) for a comprehensive discussion on the *national* cross-compliance measures introduced across Member States.

compliance measures was below the expectations of the EU Commission, so that in 2005 cross-compliance became an obligatory element of the new agricultural policy reform.

From 2005 onwards, farmers in receipt of CAP direct payments are required to respect a set of statutory management requirements set out in Annex III of Council Regulation (EC) No. 1782/2003. They also have to meet minimum requirements of good agricultural and environmental conditions, to be defined by Member States, on the basis of a Community framework given in Annex IV of the same regulation.

Table 5.1 Implementation of cross-compliance in Member States of EU-15 before 2005

Group	Cross-compliance standards	Countries
THE TREATMENT GROUP	Standards beyond existing legislation	Austria, the Netherlands, Ireland, UK
	Combination of existing legislation and standards beyond	Finland, Greece, Italy, Spain
	Legal standards	France, Denmark (abandoned in 2002)
THE CONTROL GROUP	No cross-compliance	Belgium, Denmark, Germany, Luxembourg, Portugal, Sweden

Note: This table identifies our control and treatment farm groups which are used in our empirical analysis to identify the national cross-compliance effect on our chosen environmental performance indicators.
Source: Adapted from Osterburg et al. (2005).

As summarised by Swales (2006), the recital of Regulation 1782/2003 set out three objectives. The first is to integrate basic standards for the environment, food safety, animal health and welfare and good agricultural and environmental condition in the common market organisation by linking direct aid to rules relating to agricultural land, agricultural production and activity. The use of the word 'basic' is noteworthy. It is apparent that cross-compliance is a mean of enforcing compliance with pre-existing legislation in the agriculture sector and is therefore a tool to help meet the objectives of this body of legislation (cross-compliance covers five pieces of environmental legislation, including the nitrates, birds and habitats directives). A second objective is to avoid the abandonment of agricultural land and ensure that it is maintained in good agricultural and environmental condition. Land abandonment may, alongside other drivers, arise as a result of decoupling. A third objective is to maintain the existing area of permanent pasture as it is regarded to have a positive environmental effect.

The EU-15 Member States are subject to mandatory EU-wide cross-compliance since 2005, although the full set of SMRs was not implemented until January 2007. The Member States that acceded to the EU in 2004 will need to implement the SMRs from 2009, and later still in Bulgaria and Romania, although standards for GAEC have been introduced.

Considerable flexibility (national discretion) is available to Member States to define cross-compliance standards. Only a few concrete farm level SMRs have been legally defined at farm level by the EC, and GAECs leave considerable scope for variation in national definitions. Many Member States appear to have been tempted to define very light standards for cross-compliance to minimise administrative costs and disallowance risks.

As a counter measure to the minimal strategy that many Member States seems to have taken, a higher baseline or more detailed guidance on how to implement cross-compliance could be introduced at EU level. However, if cross-compliance is raised much above legal minima a position could be reached where the boundary between cross-compliance standards and additional voluntary measures (such as the Agro-Environmental Programme under the Rural Development Programme, the Less-Favoured Area support scheme etc.[53]) becomes blurred. This might suggest that, in the long run, the European Union might need to move from voluntary incentive-based environmental policies towards mandatory incentive-based measures in order to improve the environment. Pressure for standardisation amongst Member States also derives from the need to avoid inconsistent implementation and creation of an uneven playing field.

5.3. Empirical identification strategy

Differences in the timing and nature of the reform policies implemented across EU Member States are used as a quasi-natural experiment for establishing causal policy relationships. First, Member States are grouped in terms of the timing of the implementation of the cross-compliance policies. Second, treatment and control groups are identified within the sample of countries (see Table 5.1 for the treatment and the control groups by country; and Figure 5.1 for a simplified graphical representation of the

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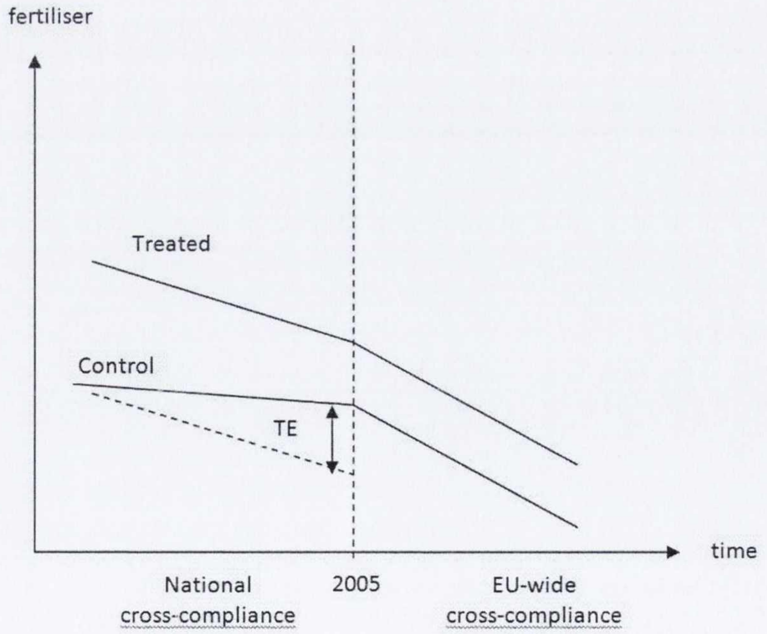
[53] See Stoate, Baldi et al. (2009) for more detailed presentation of agro-environmental policies in the EU.

identification strategy). The empirical identification strategy section closely follows Kažukauskas et al. (2011a) approach.

We use a difference-in-differences identification strategy that is "backward looking" as opposed to the common approach of "forward looking" difference-in-differences methodologies, i.e. having pre-policy time period values as the base reference point for the policy effect. In our case the base reference point is time period (post-2005) when both control and treatment groups have implemented EU-wide cross-compliance policies. The difference between the control and the treatment groups in the pre-2005 time period, taking into account the treatment and the control group differences in the post-2005 time period and the common trends, is our national cross-compliance policy effect. The choice of our "backward looking" identification strategy is determined by the data availability issue.

The difficulty in modelling farm environmental performance using farm-level data is that we do not observe this performance directly. As such, we consider two proxy variables to capture farms' environmental performance, namely, expenditure on pesticides and fertilisers.

Figure 5.1 The graphical representation of the policy effect identification strategy



One of the main concerns regarding our identification assumption is that time variant farm specific unobserved productivity may differ systematically across the treatment and control groups. For example, it might be the case that the decoupling policy changed farmers' individual productivity and this in turn led to changes in farmer's behaviour in relation to environmental indicators (Kazukauskas et al. 2010; Kazukauskas et al. 2011b). In order to isolate the cross-compliance effect we need to control for unobservable farm productivity changes. In line with Levihnson and Petrin (2003) we use the farm's choice of intermediate inputs to control for unobserved farm individual productivity (ω_{it}). We assume that the demand for intermediate inputs is given by $m_{it} = f(\omega_{it}, k_{it}, a_{it})$, where m_{it} are intermediate inputs (such as energy or fuel), k_{it} is capital and a_{it} is land, and that intermediate input demand is monotonic in ω_{it}. Inverting this function will give us an expression for $\omega_{it} = f^{-1}(m_{it}, k_{it}, a_{it})$ that can be used to control for productivity in our difference-in-differences models in a non-parametric way.[54]

As indicated, differences in the timing and nature of the reform policies implemented across the EU-15 countries are used as a natural experiment for establishing causal policy relationships. As discussed in detail in Section 5.2, the Member States are grouped in terms of the timing of the implementation of the cross-compliance measures (see Table 5.1 and Figure 5.1). The treatment and control groups are identified on the basis of this grouping. Countries that are subject to the cross-compliance measures only from 2005 represent the *control* group, and countries that have had the national cross-compliance instruments earlier than 2005 represent the *treatment* group. We also include farm sector and country specific time trends in these models. This allows treatment and control countries to follow different trends thus further strengthening our identification assumption (Angrist and Pischke 2009). The motivation for including these variables comes from the fact that countries have slightly varying national agricultural policies, different socio-economic conditions and climates which may affect the trends in our variables of interest across EU Member States. A similar motivation exists for the inclusion of farm sector time trends given that the EU cross-compliance policies affect farms in different ways depending on

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[54] As our outcome variables (pesticide and fertiliser use) are also farm production inputs that may affect farm productivity we use a lagged productivity term (ω_{it-1}) in our empirical models to avoid endogeneity problems which may arise. As robustness check for this endogeneity problem we also use two time period lagged productivity term in our empirical analyses and we get almost identical results for the results with once lagged productivity term in our models.

their farm sector. This is incorporated into the difference-in-differences model in the following way:

$$\boldsymbol{environ\_indicator}_{it} = \gamma_{0c} + \gamma_{1ct} + \varrho_{0s} + \varrho_{1st} + \lambda_t + \theta_1\, T_i + \theta_2\, Y_t + \theta_3(Y_t * T_i) + z_i\beta + x_{it}\gamma + \alpha$$

(5.1)

Where γ_{0c} are country specific intercepts; γ_{1ct} are country specific time trends; ϱ_{0s} are farm system[55] specific intercepts; and ϱ_{1st} are farm sector specific time trends; T_i is a binary treatment indicator of cross-compliance for countries which implemented the *national* cross-compliance policy pre-2005; Y_t is a time dummy for the year of the *national* cross-compliance policy implementation; and λ_t are time dummies by year; $\mathbf{z}_i$ are farm specific time invariant variables; $\mathbf{x}_{it}$ are farm specific time variant variables (such as capital, land etc); α is a constant. We are interested in the sign and significance of the θ_3 coefficient which will measure the cross-compliance policy effect.

As discussed in Section 5.2, EU countries adapted different decoupling policy implementation strategies. Some countries had *national* cross-compliance requirements before 2005 while others adopted these requirements after 2005 as part of the mandatory *EU-wide* policy. Furthermore, farmers in different countries might have a greater reliance on subsidies than others. Moreover, farmers might be less responsive to policy changes if farm incomes are not significantly dependent on farm direct payments. Our farm direct payment dependency rate variable (dpr_{it}) is denominated by total farm output, so it takes into account the extent to which farms are dependent on farm direct payments:

$$dpr_{it} = \left[\frac{total\, farm\; direct\; payments_{it}}{total\, farm\; output_{it}}\right]$$

(5.2)

The inclusion of this variable in our triple difference-in-differences analysis therefore controls for the fact that the environmental friendly behaviour of farms may depend on the extent to which they rely on farm direct payments:

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[55] Farm system dummies are based on FADN Type of Farms (TF) clustering methodology.

$$\begin{aligned}\boldsymbol{environ\_indicator}_{it} &= \gamma_{0c} + \gamma_{1ct} + \varrho_{0s} + \varrho_{1st} + \lambda_t + \theta_1 T_i + \theta_2 Y_t + \theta_3 (Y_t * T_i) \\ &+ \delta_0 dpr_{it} + \delta_1 (Y_t * dpr_{it}) + \delta_2 (T_i * dpr_{it}) + \delta_3 (Y_t * T_i * dpr_{it}) \\ &+ z_i \beta + x_{it} \gamma + \alpha\end{aligned} \tag{5.3}$$

In this model we check for whether the direct payment dependency rate has an effect on farm environmental performance given the national-wide cross-compliance policy introduction. This effect will be determined by the δ_3 coefficient.

The farm's environmental performance may also be affected by its participation in agro-environmental schemes. To control for this we also consider the following model[56]:

$$\begin{aligned}environ\_indicator_{it} &= \gamma_{0c} + \gamma_{1ct} + \varrho_{0s} + \varrho_{1st} + \lambda_t + \theta_1 T_i + \theta_2 Y_t + \theta_3 (Y_t * T_i) \quad + \tau_0 ENV_{it} \\ &+ \tau_1 (Y_t * ENV_{it}) + \tau_2 (T_i * ENV_{it}) + \tau_3 (Y_t * T_i * ENV_{it}) + \mathbf{z}_i \boldsymbol{\beta} + \mathbf{x}_{it} \boldsymbol{\gamma} \\ &+ \alpha\end{aligned} \tag{5.4}$$

ENV_{it} is a dummy variable for whether the farm participates in agro-environmental schemes. All other variables and coefficients have the same meaning as in the previous equations. In this model, the effect of cross-compliance on farm environmental performance, given farm participation in agro-environmental schemes, will be determined by the τ_3 coefficient.

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[56] The propensity score matching approach could be an alternative estimation strategy to our econometric approach if one wishes to estimate the effect of *voluntary* agro-environmental policies on farm performance (Pufahl and Weiss 2009) However, since we are interested in the effects of the *compulsory* implementation of policy changes (for individual farms), and as farm participation in the agro-environmental schemes is just a control in our empirical strategy, we believe that the presented econometric modelling approach is more suitable for our purposes. We are aware that farms self-select to participate in the agro-environmental schemes which may cause an endogeneity problem. As a robustness test, we exclude the agro-environmental scheme participation indicator from our models and find very similar results for our main variables of interest.

5.4. Data sources and description

For the purpose of this analysis we use the Farm Accountancy Data Network (FADN) farm level data for the EU15 countries for the 2001-2007 time period.[57] The FADN dataset is created by the European Union as an instrument for evaluating the income of agricultural holdings and the impacts of the CAP. Derived from annual national surveys, the FADN data is based on the same bookkeeping principles across all EU countries. Farm holdings for the national surveys are selected to get farm population representative samples at country/region level.

Table 5.2 Descriptive statistics of variables for the EU15 MS separated by the treatment/control groups and by full/balanced samples, 2001-2007

The control group

	Full sample			Balanced sample		
Variable	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev
Pesticide, EUR	295,318	4,065	12,655	92,534	4,417	10,649
Fertiliser, EUR	295,318	4,186	9,011	92,534	4,782	7,895
dpr	295,301	0.278	0.291	92,534	0.319	0.297
Capital, EUR	295,318	127,083	246,943	92,534	122,736	187,523
Intermediate inputs, EUR	295,318	59,984	155,543	92,534	60,590	121,558
Land, ha	295,318	55	116	92,534	64	102
ENV	295,318	0.215	0.411	92,534	0.272	0.445
Farm direct payments, EUR	295,318	18,962	39,460	92,534	21,716	28,118

The treatment group

	Full sample			Balanced sample		
Variable	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev
Pesticide, EUR	90,356	9,578	28,296	34,411	8,469	24,774
Fertiliser, EUR	90,356	8,744	23,368	34,411	7,979	19,722
dpr	90,350	0.239	0.240	34,411	0.247	0.229
Capital, EUR	90,356	336,230	654,813	34,411	231,233	399,693
Intermediate, EUR	90,356	150,468	344,983	34,411	122,197	258,963
Land, ha	90,356	117	288	34,411	111	255
ENV	90,356	0.501	0.500	34,411	0.587	0.492
Farm direct payments, EUR	90,356	43,798	112,014	34,411	40,925	97,544

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[57] We are grateful FADN unit for providing us the dataset and Daragh Clancy with Fiona Thorne from Teagasc for helping us to obtain the access to this dataset.

Notes: Farm holdings from Belgium are not included in the balanced sample due to the changes in Belgian sample selection strategy and the new identification numbers for Belgian farms. All monetary variables are deflated by their country specific deflators from Eurostat.

Our dependent variables are fertiliser and crop protection expenditures which are used as proxies for the farm environmental performance indicators. These variables are deflated using country specific and the farm production input specific deflators from Eurostat. Table A 5.1 in the appendix presents the descriptive statistics for these two variables across all EU Member States for the pre-2005 and post-2005 time periods. The set of control variables and the dependent variables are summarised for the sample as a whole in Table 5.2. Farm dependency on farm direct payments (subsidies and decoupled payments) is measured by our constructed farm subsidy dependency ratio variable (*dpr*). Participation in the agro-environmental schemes is measured by a dummy variable (*ENV*), and all monetary variables (farm capital, intermediate inputs, farm direct payments) are measured in Euros.

Table 5.2 presents the descriptive statistics on the main variables included in the empirical analysis, separated by the treatment and the control groups. Of particular note is the fact that farms in the treatment and the control groups are different in terms of size. On average, the farms in the treatment group are at least twice as big as the farms in the control group in terms of their capital and farming land. Thus, it is important to control for farm heterogeneity differences in our empirical analysis.

Also, the trends in agricultural structural change across the treatment and control groups are significantly different. Table A 5.2 in the appendix indicates much higher farm exit rates and subsequent farm resource consolidation among farms in our treatment group. The faster farm resource consolidation process in the treatment country farm group affects farm input and production decisions and so will also affect our farm environmental performance indicators. The fast consolidation process might be the outcome of higher productivity growth in our treatment group. Thus, it is not only important to control for farm heterogeneity differences but also for the different agricultural structural change patterns (e.g. different pace of productivity growth) across the treatment and the control groups in our econometric models.

The omission of farm exits in the analysis might also mean that we may have selectivity bias in our analysis. To control for the selectivity due to non-random farm exits we use balanced panel data to check our main results. Table 5.2 provides the descriptive statistics for the main variables, separated by the treatment and the control groups, for the balanced panel.

Figure A 5.1 in the appendix depicts fertiliser and pesticide expenditure per hectare for the EU15 Member States during 1999-2007, separated by the treatment and the control groups. We observe somewhat similar trends in the fertiliser and pesticide expenditure for the treatment and the control groups. We also observe some evidence that, during the 2000-2004 time period, the treatment farm group decreased their expenditure on fertilisers and crop protection relative to the control group farms. However, there are substantial differences between the treatment and the control farm groups. Controlling for these factors is essential before we can make any conclusions regarding the effect of cross-compliance on farm environmental indicators.

5.5. Cross-compliance effects

From the data description presented in the previous section, it is not clear whether on average farmers in the treated group reduced their fertiliser and pesticide use in the last years due to cross-compliance. However, the dynamics of fertiliser and pesticide use might depend on many other factors which should be taken into account when measuring policy effects. The results of our difference-in-differences model given in Equation (5.2) which attempts to identify these effects are presented in Table 5.3. Columns (1) to (4) summarise the estimates of ordinary least squares (OLS) and panel fixed effects (FE) models for the unbalanced EU15 sample. It is evident that farmers subject to *national* cross-compliance (our treatment group) before 2005 reduced their fertiliser use by between EUR 419 (OLS) and EUR 454 (FE), and pesticide use by between EUR 611 (OLS) and EUR 496 (FE) relative to our control group in the same time period. This is between 4.8 and 5.2 percent of the average annual fertiliser expenditure and between 6.4 and 5.2 percent of the average annual pesticide expenditure of the treated farms. The results are very similar when the balanced sample is used (see columns (5) to (8)).

It must be noted that our *control* period (post-2005) coincides with the introduction of the farm subsidy decoupling policy. The decoupling policy itself might have changed farm production behaviour. We try to control for this by controlling for farm productivity changes with the inclusion of a polynomial function of the set of farm inputs. Another issue with using 2005-2007 as the control period is that farmers may anticipate the introduction of cross compliance thus biasing the estimated effect of cross-compliance by altering the behaviour of the control group in the treatment period. We perform robustness checks for whether the introduction of the decoupling policy introduction in 2005 and our "backward looking" quasi-experimental approach presented in Table 5.3 are validated by a more usual "forward looking" quasi-experimental difference-in-differences identification strategy for the introduction of *national* cross-compliance policy measures by comparing our treatment and control groups between 1999[58] (pre-treatment year) and 2001 (post-treatment year). The robustness check partially confirms our main results in Table 5.3 but the policy effects are smaller and, in the case of fertiliser use, they are insignificant. See Table A 5.6 for the results of these robustness checks.

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[58] Due to data availability issue for pre-treatment time period we use just one available year (1999).

Table 5.3 Cross-compliance effect on fertiliser and pesticide use

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Outcome variable	fertiliser	fertiliser	pesticide	pesticide	fertiliser	fertiliser	pesticide	Pesticide
Model	OLS	FE	OLS	FE	OLS	FE	OLS	FE
_Y*T_	-454.2**	-419.9***	-611.2**	-496.4**	-561.7***	-476.4***	-541.6*	-389.2*
	(201.5)	(147.1)	(268.7)	(191.2)	(177.5)	(159.9)	(275.9)	(197.8)
_Y_	omitted	omitted	omitted	omitted	omitted	omitted	omitted	Omitted
_T_	132.0	-69.3	749.0*	51.4	531.4*	212.8	7463.6***	5840.5***
	(312.7)	(216.1)	(398.6)	(249.7)	(278.5)	(380.8)	(598.3)	(399.7)
ENV	-840.3***	-1.8	-941.5***	-29.8	-1030.7***	380.9	-1157.4***	-45.6
	(183.8)	(74.3)	(201.6)	(51.4)	(198.9)	(104.0)	(283.2)	(77.3)
Constant	47840.1	177497.3**	-1348838***	-196553.2	-2244717***	100366.6	-6306594***	-516804.6***
	(419459)	(82340.5)	(350902.5)	(164142.8)	(416549.1)	(95062.2)	(608683.9)	(135762.4)
Year effects	yes	yes	yes	yes	yes	yes	yes	yes
Farm fixed-effects	no	yes	yes	yes	no	yes	no	yes
Country*time trend	yes	yes	yes	yes	yes	yes	yes	yes
Sector*time trend	yes	yes	yes	yes	yes	yes	yes	yes
Polynomial	yes	yes	yes	yes	yes	yes	yes	yes
R-squared	0.6809	0.0205	0.6637	0.0271	0.7411	0.0326	0.7286	0.0533
No. of observations	306949	306949	306949	306949	123276	123276	123276	123276
No. of countries	15	15	15	15	14	14	14	14
Panel	unbalanced	unbalanced	unbalanced	unbalanced	balanced	balanced	balanced	balanced

Notes: Standard errors corrected for clustering at the region level are reported in parentheses. T is the binary treatment indicator of cross-compliance; Y is the time dummy for the year of the cross-compliance policy implementation. Belgium drops from the balanced sample. *** p<0.01, ** p<0.05, * p<0.1.

As discussed, incentives to comply with environmental standards might be highest for the farmers that receive the highest subsidy payments. To see whether this is the case we estimate the difference-in-differences-in-differences econometric model which contains the interaction between the farm subsidies to total farm output ratio, the binary treatment indicator and the year dummy variable (see Equation (5.3)). We focus on the coefficient on this interaction term as it represents the impact of the introduction of national cross-compliance given the farm subsidy dependency level.

Table 5.4 highlights that there are no significant differences between treated and control farms across different levels of subsidy dependence. The estimates are insignificant across all models for both the balanced and unbalanced samples. Furthermore, the coefficient on the interaction term for the treatment variable and year (Y^*T) remains negative and statistically significant across almost all models. These results do not support the argument that farmers who rely on larger shares of subsidies in total output have stronger incentives to comply with the cross-compliance measures. On one hand, this result might reflect the nature of this policy in that all farmers, irrespective of the level of subsidy payments they receive, are subject to the same set of environmental requirements. Our reasons for expecting higher levels of farm subsidy dependency to significantly affect farm compliance is that farmers may lose relatively more of their income in the form of fines in the event of non-compliance. The insignificant effect observed here might reflect a low probability of policy enforcement, being checked and punished under this regulation and/or a relatively low non-compliance fine.

Table 5.4 Cross-compliance effect on fertiliser and pesticide use when taking into account farm subsidy dependency

Outcome variable Model	(1) fertiliser OLS	(2) fertiliser FE	(3) pesticide OLS	(4) pesticide FE	(5) fertiliser OLS	(6) fertiliser FE	(7) pesticide OLS	(8) pesticide FE
dpr*Y*T	-221.6	-26.2	-505.3	163.9	-760.4	-125.8	70.4	439.4
	(653.1)	(240.9)	(791.0)	(323.3)	(549.3)	(307.7)	(688.2)	(411.2)
dpr*Y	408.1	155.8	1037.0	416.1	714.8	152.3	416.7	148.0
	(615.8)	(207.7)	(777.5)	(262.8)	(501.0)	(269.7)	(683.6)	(343.9)
dpr*T	72.8	1579.7**	-157.3	1611.1**	722.5	1961.1**	-198.3	1325.8
	(365.8)	(607.9)	(1226.3)	(743.8)	(1365.7)	(828.1)	(1596.0)	(856.8)
Y*T	-420.3*	-419.4**	-526.4*	-563.8**	-414.5	-455.8**	-676.2**	-562.2**
	(227.3)	(169.2)	(268.5)	(226.1)	(250.7)	(203.0)	(281.4)	(280.8)
dpr	-1899.1	-2100.0***	-2740.7**	-2485.5***	-2915.2*	-2479.6***	-3086.2*	-2250.8**
	(1164.3)	(614.9)	(1349.6)	(748.2)	(1570.8)	(836.3)	(1818.4)	(865.6)
Y	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted
T	71.7	-360.9	688.7*	-223.8	386.1	-229.1	7629.4***	5606.7***
	(365.8)	(227.1)	(398.8)	(191.3)	(442.7)	(393.0)	(698.2)	(288.2)
ENV	-653.8***	45.7	-668.3***	28.8	-805.8***	99.9	-864.3***	10.4
	(172.2)	(76.7)	(197.1)	(53.8)	(167.8)	(108.0)	(268.0)	(80.6)
Constant	90889.0	181526.0**	-1334216***	-244192.5	-2331990***	119820.7	-6395192***	-534372.2***
	(442674.6)	(86218.7)	(370762.3)	(159359.4)	(440922.8)	(95164.8)	(663957.9)	(139029.8)
Year effects	yes	yes	yes	yes	yes	yes	yes	yes
Farm fixed-effects	no	yes	no	yes	no	yes	no	yes
Country*trend	yes	yes	yes	yes	yes	yes	yes	yes
Polynomial	yes	yes	yes	yes	yes	yes	yes	yes
Sector*trend	yes	yes	yes	yes	yes	yes	yes	yes
R-squared	0.6816	0.0214	0.6646	0.0281	0.7422	0.0341	0.7299	0.055
No. of observations	306934	306934	306934	306934	123276	123276	123276	123276
No. of countries	15	15	15	15	14	14	14	14
Panel	unbalanced	unbalanced	unbalanced	unbalanced	balanced	balanced	balanced	balanced

Notes: Standard errors corrected for clustering at the region level are reported in parentheses. *dpr* is a ratio of farm direct payments by total farm output; *T* is the binary treatment indicator of cross-compliance; *Y* is the time dummy for the year of the cross-compliance policy implementation. Belgium drops from the balanced sample. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Some farmers participate in other voluntary agro-environmental schemes. We might expect that for these farmers it is easier to conform to cross-compliance requirements due to learning-by-doing effects and also due to a higher probability of being selected for inspection. To see whether this is the case we measure the difference-in-differences-in-differences econometric model which contains the interaction between the environmental subsidy dummy (our proxy for participation in other agro-environmental programmes), the treatment variable and the year dummy (see Equation (5.4)). The coefficient on this term represents the impact of compulsory cross-compliance for farms that are subject to other agro-environmental requirements.[59]

Table 5.5 reveals a negative coefficient on the triple interaction term almost across all models. This finding indicates that farmers in the treated group that participate in other environmental programmes reduce their polluting chemical use by more than those farmers who are not in an environmental programme. The negative coefficient on this interaction term is statistically significant in the four models for fertiliser use only. This finding might suggest that farmers, who participate in additional agro-environmental schemes, have more incentives and knowledge on how to comply with certain environmental standards. Likewise, if we assume that farmers, who are subject to other agro-environmental measures, face more sensitive environmental issues (such as being in Natura 2000 areas, for example), this result might hint at the possibility that the cross-compliance regulation helps to convince farmers to comply with the agro-environmental regulations. Thus we might conclude that cross-compliance reinforces other policies aimed at reducing the impact of farming activities on the environment at least in cases related to fertiliser.

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[59] Note that the policy effects of the empirical models considering farm participation in voluntary agro-environmental schemes might be biased upward due to possible self-selection.

Table 5.5 Cross-compliance effect on fertiliser and pesticide use when taking into account farmer's participation in other agro-environmental schemes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Outcome variable	fertiliser	fertiliser	Pesticide	pesticide	fertiliser	fertiliser	pesticide	pesticide
Model	OLS	FE	OLS	FE	OLS	FE	OLS	FE
*ENV*Y*T*	-1074.1*	-369.0**	-530.5	11.1	-823.0**	-492.7**	-61.1	-168.6
	(584.0)	(162.8)	(666.0)	(223.8)	(342.2)	(204.5)	(583.5)	(219.5)
*ENV*Y*	907.9	161.5	337.6	-57.6	315.3	277.5	-368.1	124.1
	(575.2)	(154.5)	(646.7)	(207.7)	(311.6)	(194.2)	(530.0)	(200.2)
*ENV*T*	734.4	54.9	126.8	-161.3	364.0	-56.4	-480.0	-164.4
	(723.6)	(201.3)	(731.2)	(198.1)	(567.2)	(283.2)	(561.2)	(257.0)
*Y*T*	77.6	-276.2	-373.1	-511.0*	-223.9	-231.6	-614.8	-288.4
	(344.4)	(180.2)	(416.2)	(261.2)	(326.5)	(220.0)	(558.5)	(280.5)
ENV	-1424.3**	-11.5	-1020.6	93.5	-1164.6**	71.6	-671.7	30.4
	(680.9)	(189.6)	(665.0)	(188.9)	(510.3)	(261.9)	(407.2)	(241.7)
Y	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted
T	-474.5	-210.0	501.7	78.5	537.0	342.1	8057.3***	5960.7***
	(466.1)	(262.6)	(515.2)	(326.3)	(474.3)	(545.3)	(595.9)	(543.2)
Constant	-77819.6	145227.1	-1379706***	-189472.8	-2284791***	37356.8	-6295443***	-547619***
	(470040.2)	100544.2	(407836.3)	(171350.3)	(427719.2)	(118344.4)	(622395.3)	(138697.4)
Year effects	yes	yes	yes	yes	yes	yes	yes	yes
Farm fixed-effects	no	yes	no	yes	no	yes	no	yes
Country*trend	yes	yes	yes	yes	yes	yes	yes	yes
Sector*trend	yes	yes	yes	yes	yes	yes	yes	yes
polynomial	yes	yes	yes	yes	yes	yes	yes	yes
R-squared	0.6810	0.0206	0.6637	0.0271	0.7411	0.0330	0.7287	0.1185
No. of observations	306949	306949	306949	306949	123276	123276	123276	123276
No. of countries	15	15	15	15	14	14	14	14
Panel	unbalanced	unbalanced	unbalanced	unbalanced	balanced	balanced	balanced	balanced

Notes: Standard errors corrected for clustering at the regional level are reported in parentheses. *ENV* is a dummy variable for farms receiving compensations for their participation in other agro-environmental schemes; *T* is the binary treatment indicator of cross-compliance; *Y* is the time dummy for the year of the cross-compliance policy implementation. Belgium drops from the balanced sample. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

The above models are estimated only for the EU15 Member States. To see whether cross-compliance has similar effects when we consider all EU Member States, we estimate the same models for the extended balanced sample for the period 2004-2007 that include the Member States that joined the European Union in 2004. The results of all three models are summarised in the tables in the appendix. It shows that the estimates across all models are similar to the estimates for the EU15 sample.

5.6. Conclusion

To date, the overall effect of the CAP reform and newly introduced environmental cross-compliance measures is not clear. The existing studies on environmental benefits arising from cross-compliance are few and mainly based on either expert judgement or simulation models rather than direct measurement of environmental outcomes. To the best of our knowledge, this paper is the first attempt to empirically evaluate the impacts of the newly reorganised European agriculture policy on farmers' environmental performance. Our identification strategy is to use a differences-in-differences approach, where we investigate the differential environmental response of farms subject to the cross-compliance policy implementation relative to the performance of farms that were not subject to the cross-compliance measures. We consider two proxy variables to capture farm environmental performance: expenditure on pesticides and fertilisers. To sharpen the identification of the cross-compliance policy effect, we take into account farms' dependency on overall subsidies and also their participation in other agro-environmental schemes. We also account for observed and unobserved farm-level heterogeneity by controlling for farm unobserved productivity changes, farm fixed effects, etc.

We find evidence that farmers subject to the cross-compliance policy improved their environmental performance by significantly reducing their fertiliser and pesticide use. This effect is approximately 5 percent of the average annual fertiliser expenditure and 6 percent of the average annual pesticide expenditure of the treated farms.

We find no significant differences between treated and control farms when we take into account farm subsidy dependency levels. This might reflect a low probability of being checked and punished under this regulation and a relatively low non-compliance fine. When we take into account farms that participate in other agro-environmental programmes we find evidence that the cross-compliance policy effect is mostly negative and significant for fertiliser allowing us to conclude that the cross-compliance reinforces other policies directed to reduce the impact of farming activities on the environment.

5.7. *Appendix*

Table A 5.1 Descriptive statistics of pesticide and fertiliser expenditure by country (EU25)

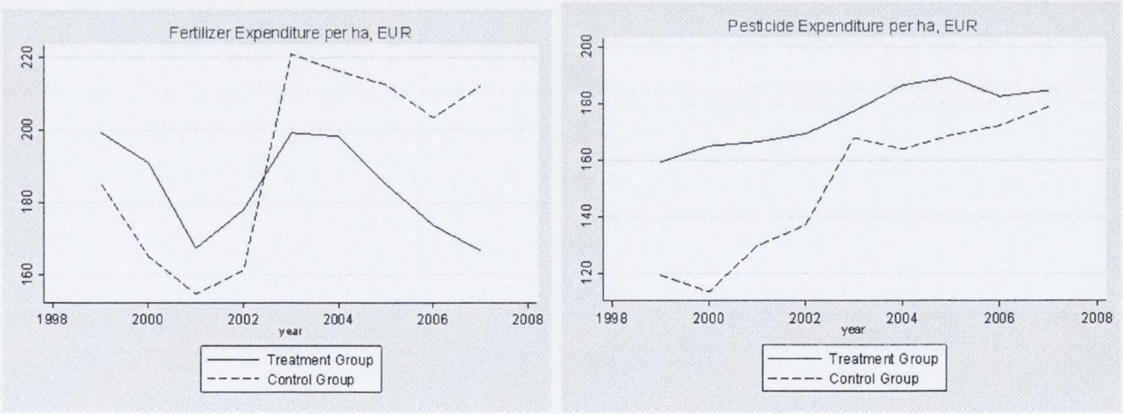
Country	Pesticide expenditure, EUR				Fertiliser expenditure, EUR			
	Pre-2005		Post-2005		Pre-2005		Post-2005	
	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.
BEL	5555	4655	7264	3375	6630	4655	7812	3375
CYP	1684	432	1024	1146	2909	432	1600	1146
CZE	41784	1287	42513	3781	36902	1287	42991	3781
DAN	8337	7554	10310	5350	9860	7554	12282	5350
DEU	11498	26132	14870	21527	11780	26132	17699	21527
ELL	1151	16530	1258	11707	1490	16530	1726	11707
ESP	1677	31643	1710	24456	2867	31643	2966	24456
EST	3427	482	4464	1461	7635	482	11552	1461
FRA	9363	29613	9554	21687	9568	29613	10393	21687
HUN	15884	1841	13679	5549	15962	1841	15166	5549
IRE	1358	4885	886	3585	5541	4885	5300	3585
ITA	2651	59316	3442	42445	2717	59316	3658	42445
LTU	5714	1027	6036	3335	11209	1027	13975	3335
LUX	3675	1830	4585	1338	7095	1830	8011	1338
LVA	6520	779	5972	2869	11062	779	13448	2869
MLT	1180	240	1360	813	1511	240	1776	813
NED	10280	4963	12321	4056	6926	4963	7723	4056
OST	1337	7561	1444	5998	1787	7561	2099	5998
POL	1450	11722	2504	35520	3036	11722	4699	35520
POR	1192	7853	1211	6042	2006	7853	1938	6042
SUO	1587	3045	1635	2559	4967	3045	5894	2559
SVE	2721	3679	3072	2872	6834	3679	8257	2872
SVK	44699	592	46659	1710	37020	592	41713	1710
SVN	605	494	703	2128	1386	494	1508	2128
UKI	9397	11088	9376	8330	12969	11088	13919	8330
Total	5180	239243	6435	225532	5941	239243	8038	225532

Table A 5.2 Number of farm holdings and growth rate of number of holdings

	Holdings > 1 ESU (1000 of farms)				Growth, %		
	2000	2003	2005	2007	2000/2003	2003/2005	2005/2007
EU (15 countries)	5502.13	5054.11	4903.28	4775.93	-8.14%	-2.98%	-2.60%
Belgium	58.78	52.67	49.63	46.14	-10.39%	-5.77%	-7.03%
Denmark	57.70	48.60	51.35	44.36	-15.77%	5.66%	-13.61%
Germany	454.76	390.17	371.07	348.52	-14.20%	-4.90%	-6.08%
Ireland	132.53	128.79	125.47	117.89	-2.82%	-2.58%	-6.04%
Greece	661.61	654.88	678.14	711.07	-1.02%	3.55%	4.86%
Spain	1091.58	978.45	958.98	939.51	-10.36%	-1.99%	-2.03%
France	605.45	566.35	527.37	491.08	-6.46%	-6.88%	-6.88%
Italy	1525.02	1428.11	1381.35	1383.29	-6.35%	-3.27%	0.14%
Luxembourg	2.62	2.30	2.36	2.23	-12.21%	2.61%	-5.51%
Netherlands	101.44	85.36	81.83	76.74	-15.85%	-4.14%	-6.22%
Austria	162.62	140.63	137.00	130.89	-13.52%	-2.58%	-4.46%
Portugal	313.94	261.59	219.01	181.60	-16.68%	-16.28%	-17.08%
Finland	77.91	74.16	70.03	66.57	-4.81%	-5.57%	-4.94%
Sweden	75.05	60.23	66.32	57.53	-19.75%	10.11%	-13.25%
United Kingdom	181.12	181.82	183.37	178.51	0.39%	0.85%	-2.65%
TREATMENT	962.85	815.56	759.74	680.38	-15.30%	-6.84%	-10.45%
CONTROL	4539.28	4238.55	4143.54	4095.55	-6.63%	-2.24%	-1.16%

Note: ESU stands for economic standard unit.
Source: EUROSTAT.

Figure A 5.1 Fertiliser and pesticide expenditure per ha dynamics for EU15, 1999-2007



(a) (b)

Table A 5.3 Cross-compliance effect on fertiliser and pesticide use, the extended sample

	(1)	(2)	(3)	(4)
Outcome variable	fertiliser	fertiliser	pesticide	pesticide
Model	OLS	FE	OLS	FE
*Y*T*	-485.5**	-428.1***	-564.7**	-491.4***
	(203.1)	(145.8)	(244.4)	(188.7)
Y	omitted	omitted	omitted	omitted
T	175.2	-52.7	669.5*	31.5
	(312.1)	(208.6)	(359.9)	(244.2)
ENV	-1035.7***	-60.6	-1198.0***	-45.2
	(234.7)	(85.5)	(263.2)	(67.5)
Constant	-325153.6	9160.4	-1327927***	-334597.2**
	(473435.5)	(84300.1)	(361014.4)	(150845.2)
Year effects	yes	yes	yes	yes
Farm fixed-effects	no	yes	no	yes
Country*time trend	yes	yes	yes	yes
Sector*time trend	yes	yes	yes	yes
Polynomial	yes	yes	yes	yes
R-squared	0.7017	0.0287	0.6900	0.0300
No. of observations	356082	356082	356082	356082
No. of countries	25	25	25	25
Panel	unbalanced	unbalanced	unbalanced	unbalanced

Notes: Standard errors corrected for clustering at the region level are reported in parentheses. *T* is the binary treatment indicator of cross-compliance; *Y* is the time dummy for the year of the cross-compliance policy implementation. *** p<0.01, ** p<0.05, * p<0.1.

Table A 5.4 Cross-compliance effect on fertiliser and pesticide use when taking into account farm subsidy dependency, the extended sample

	(1)	(2)	(3)	(4)
Outcome variable	fertiliser	fertiliser	pesticide	pesticide
Model	OLS	FE	OLS	FE
*dpr*Y*T*	-1056.5	9.8	-775.3	437.5
	(908.2)	(315.6)	(1230.7)	(0.268)
*dpr*Y*	1427.7	149.1	1192.6	131.2
	(997.4)	(270.8)	(1329.8)	(322.5)
*dpr*T*	913.4	1510.8***	-229.0	1003.9**
	(994.7)	(420.8)	(1307.6)	(431.0)
*Y*T*	-237.2	-435.7**	-404.2	-630.1**
	(294.7)	(187.4)	(380.5)	(256.1)
	-	-		
dpr	3034.2***	2028.1***	-2760.7**	-1861.6***
	(1088.1)	(416.6)	(1366.5)	(419.4)
Y	omitted	omitted	omitted	omitted
T	-155.3	-335.5	583.1	-105.2
	(400.5)	(217.4)	(488.5)	(232.4)
ENV	-790.9***	0.8	-900.4***	18.8
	(209.7)	(85.2)	(237.5)	(68.7)
			-	-
Constant	-323667.3	11272.1	1260221***	355404.7**
	(518627.1)	(85319.6)	(418440.2)	(144637.6)
Year effects	yes	yes	yes	yes
Farm fixed-effects	no	yes	no	yes
Country*time trend	yes	yes	yes	yes
Sector*time trend	yes	yes	yes	yes
Polynomial	yes	yes	yes	yes
R-squared	0.7023	0.0297	0.6907	0.0308
No. of observations	356067	356067	356067	356067
No. of countries	25	25	25	25
Panel	unbalanced	unbalanced	unbalanced	unbalanced

Notes: Standard errors corrected for clustering at the region level are reported in parentheses. *dpr* is a ratio of farm direct payments by total farm output; *T* is the binary treatment indicator of cross-compliance; *Y* is the time dummy for the year of the cross-compliance policy implementation. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A 5.5 Cross-compliance effect on fertiliser and pesticide use when taking into account farm participation in other agri-environmental schemes, the extended sample

	(1)	(2)	(3)	(4)
Outcome variable	fertiliser	fertiliser	pesticide	pesticide
Model	OLS	FE	OLS	FE
*ENV*Y*T*	-1603.9**	-482.0***	-1539.8*	-58.8
	(745.0)	(182.5)	(922.6)	(218.1)
*ENV*Y*	13911.0**	267.6	1332.5	2.9
	(717.3)	(172.1)	(873.6)	(199.7)
*ENV*T*	1250.5	219.6	1158.2	-63.7
	(773.5)	(206.0)	(925.3)	(203.3)
*Y*T*	322.5	-226.6	211.9	-473.4*
	(433.9)	(170.0)	(564.1)	(247.2)
ENV	-1913.0***	-176.4	-2015.0**	2.4
	(727.9)	(196.0)	(845.4)	(193.9)
Y	omitted	omitted	omitted	omitted
T	-770.6	-264.6	-236.3	20.4
	(550.4)	(245.3)	(699.4)	(310.8)
Constant	-510151.3	-42491.7	-1502316***	-336136.2**
	(541875.3)	(96442.2)	(437363.9)	158551.8)
Year effects	yes	yes	yes	yes
Farm fixed-effects	no	yes	no	yes
Country*time trend	yes	yes	yes	yes
Sector*time trend	yes	yes	yes	yes
Polynomial	yes	yes	yes	yes
R-squared	0.7018	0.0288	0.6901	0.0300
No. of observations	356082	356082	356082	356082
No. of countries	25	25	25	25
Panel	unbalanced	unbalanced	unbalanced	unbalanced

Notes: Standard errors corrected for clustering at the regional level are reported in parentheses. *ENV* is a dummy variable for farms receiving compensations for their participation in other agro-environmental schemes; *T* is the binary treatment indicator of cross-compliance; *Y* is the time dummy for the year of the cross-compliance policy implementation. *** p<0.01, ** p<0.05, * p<0.1.

Table A 5.6. National cross-compliance effect on fertiliser and pesticide use between 1999 and 2001

	(1)	(2)	(3)	(4)
Outcome variable	fertiliser	fertiliser	pesticide	pesticide
Model	OLS	FE	OLS	FE
Y*T	-192.4	-178.8	-366.0**	-301.3***
	(123.4)	(128.2)	(144.5)	(104.8)
Y	-237.8***	-267.5***	394.2***	343.5***
	(60.9)	(59.8)	(143.2)	(100.8)
			-	
T	-842.4***	175.5	1490.2***	-706.6***
	(251.2)	(258.7)	(97.6)	(130.5)
ENV	-757.9***	-172.4**	-876.6***	2.9
	(158.6)	(68.9)	(227.4)	(68.9)
				-
Constant	201481.3	-359150.1	107983	66563.9**
	(240038.7)	(250061.2)	(94101.3)	(34942.4)
Year effects	yes	yes	yes	yes
Farm fixed-effects	no	yes	yes	yes
Country*time trend	yes	yes	yes	yes
Sector*time trend	yes	yes	yes	yes
Polynomial	yes	yes	yes	yes
R-squared	0.6787	0.0466	0.7478	0.0962
No. of observations	77263	77263	77263	77263
No. of countries	15	15	15	15
Panel	balanced	balanced	balanced	balanced

Notes: Standard errors corrected for clustering at the region level are reported in parentheses. T is the binary treatment indicator of cross-compliance; Y is the time dummy for the year of the cross-compliance policy implementation. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

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