CAP Reform and Its Impact on Structural Change and Productivity Growth: A Cross Country Analysis

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TEP Working Paper No. 0411

February 2011

Trinity Economics Papers

Department of Economics

Trinity College Dublin

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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

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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 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). In this paper, 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 analysing 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 analysing 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 Misra (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 et al. (2010) find that direct payments induce a wealth effect that alters farmers' attitudes toward risk which in turn can lead to production responses. Key et al. (2010) find that participation in government schemes, including the 1996 FAIR Act actually increased production levels among participants in the programme.

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 (2006; 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 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 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 et al. (2008) analyze (*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 et al. (2000) investigate the impact of dramatic agricultural policy reforms towards market liberalization in the 1980s on the efficiency of farms in New Zealand. They find evidence that liberalization 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 paper 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 analysing 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 et al. (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. Ahern et al (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 paper we attempt to establish whether such a dynamic is present (through either switching or specailsation) 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 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 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;[1] 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 2 presents the methodological approach used for estimating productivity and analysing the effect of the decoupling policy on productivity. Section 3 presents data related issues. Section 4 discusses the main results and Section 5 concludes.

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:

$$Y_{it} = f(X_{it})e_{it} \quad \textbf{(1)}$$

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 (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}, when the input choices will be correlated with e_{it}.[2]

There is a second endogeneity problem present when using OLS to estimate equation (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 (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

[1] The stochastic frontier approach (SFA) is typically applied for analyses of agricultural productivity (see, for example, Newman and Matthews (2006; 2007) for applications to Irish agricultural productivity and Carroll et al. (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 et al. (2010).

[2] 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 et al. (2010), the assumption of an independently and identically distributed efficiency term may be incorrect, particularly if 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 et al. (2010)) for a full discussion and empirical exposition of the differences between these approaches).

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 firm/farm market exit data. Endogeneity that arises due to unobserved demand shocks is addressed by De Loecker's (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:

$$y_{it} = \beta_0 + \sum_{x\in X} \beta_x x_{it} + 0.5 \sum_{x\in X} \sum_{z\in X} \beta_{xz} x_{it} z_{it} + \beta_\tau \tau_{it} + w_{it} + \lambda_t + \epsilon_{it} \qquad \textbf{(2)}$$

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[3]); 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.[4] 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}).[5] We assume that the demand for

[3] Farm system dummies are based on FADN Type of Farms (TF) clustering methodology.
[4] 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.
[5] 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.

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 investment decision we use a decoupling rate dr_{it} given by equation (3).[6]

$$dr_{it} = \left[1 - \frac{total\_farm\_direct\_payments_{it} - decoupled\_payments_{it}}{total\_farm\_output_{it}}\right] \quad \textbf{(3)}$$

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. 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 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 (2) gives the estimating equation (equation (4)).

$$y_{it} = \beta_0 + \varphi(k_{it}, a_{it}, l_{it}, m_{it}) + \beta_p p_{it-1} + \beta_{dr} dr_{it} + \beta_\tau \tau_{it} + \lambda_t + \epsilon_{it} \quad \textbf{(4)}$$

Where $\varphi(k_{it}, a_{it}, l_{it}, m_{it}) = \sum_{x \in X} \beta_x x_{it} + 0.5 \sum_{x \in X} \sum_{z \in X} \beta_{xz} x_{it} z_{it} + m^{-1}(k_{it}, a_{it}, l_{it}, m_{it})$. 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 (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.

To construct the agricultural productivity indices, however, we also need to estimate the coefficients on the inputs in the production function specified in equation (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

[6] 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 1 means that the farm is fully decoupled from subsidies and the farm does not receive any *coupled* farm subsidies.

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 (5):

$$y_{it+1} - \hat{\beta}_0 - \hat{\beta}_p p_{it} - \hat{\beta}_{dr} dr_{it+1} - \hat{\lambda}_{t+1} - \hat{\beta}_\tau \tau_{it+1} = \sum_{x \in X} \beta_x x_{it} + 0.5 \sum_{x \in X} \sum_{z \in X} \beta_{xz} x_{it} z_{it} + g(\widetilde{m}^{-1}(.)) + \kappa_{it} \quad \textbf{(5)}$$

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 (5):

$$y_{it+1} - \hat{\beta}_0 - \hat{\beta}_p p_{it} - \hat{\beta}_{dr} dr_{it+1} - \hat{\lambda}_{t+1} - \hat{\beta}_\tau \tau_{it+1} = \sum_{x \in X} \beta_x x_{it} + 0.5 \sum_{x \in X} \sum_{z \in X} \beta_{xz} x_{it} z_{it} + \phi(\widetilde{m}^{-1}(.), \hat{P}_{it}) + \kappa_{it} \quad \textbf{(6)}$$

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:

$$DISLAND_{it} = \sum \theta_\tau \tau_{it} + \theta_p p_{it-1} + \Gamma(k_{it}, a_{it}, l_{it}, m_{it}) + \zeta_{it} \quad \textbf{(7)}$$

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.[7] 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 (2) are used to calculate the productivity term (tfp_{it}) for each farm *i* in each time period *t*. Once the farm specific productivity estimates are uncovered they are used to construct country specific agricultural productivity indices.

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.

[7] 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.

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 (LEI).[8]

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 1.

4. Results

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

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 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 1. During the 2001-2007 time

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

period changes in the pattern of specialisation varies across countries with no clear pattern emerging. In Section 4.4 we explore the contribution of changes in the pattern of specialisation to productivity growth, in particular, post-decoupling.

[INSERT TABLE 1 ABOUT HERE]

4.2 The effect of the decoupling policy on productivity

As discussed in Section 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)). First, we identify the extent to which the decoupling rate has impacted on the productivity of farmers using the regression given in equation (8).

$$y_{it} = \alpha_i + \beta_{dr} dr_{it} + \beta_p p_{it-1} + \lambda_t + \varphi(k_{it}, a_{it}, l_{it}, m_{it}) + \epsilon_{it} \qquad \textbf{(8)}$$

Where dr_{it} is the decoupling rate given in equation (3) and α_i are farm specific intercept terms.[9] The results of this model are presented in Table 2, columns 1-3.

[INSERT TABLE 2 ABOUT HERE]

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 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

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

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.[10] 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 depended less on *coupled* subsidies before the reform and so the impact in practice may not have been that great.

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 (9). In this first instance we ignore the possibility that pre-decoupling and post-decoupling switching behaviour may have had different effects on productivity.

$$y_{it} = \alpha_i + \beta_{dr} dr_{it} + \sum \beta_{switch} SWITCH_{it-1} + \sum \beta_{share} Share_{it} + \beta_p p_{it-1} + \lambda_t + \varphi(k_{it}, a_{it}, l_{it}, m_{it}) + \epsilon_{it} \qquad \textbf{(9)}$$

Where $SWITCH_{it-1}$ are binary variables indicating the switching behaviour of farm *i* (adding, dropping or swapping products) at time *t-1*.[11] 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.[12] 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.

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

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

[12] Using the lagged product share variables yields similar results.

The coefficients on the policy variable (dr_{it}) in columns 1-3 of Table 3 are similar to those found for the baseline model presented in Table 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.

[INSERT TABLE 3 ABOUT HERE]

Table 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.

4.4. Switching behaviour and specialisation as productivity improving mechanism 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 (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}):

$$\begin{aligned} y_{it} = \alpha_i + \beta_{dr} dr_{it} + \sum \beta_{switch} SWITCH_{it-1} + \sum \beta_{share} Share_{it} \\ + \sum \beta_{dsw} dr_{it} * SWITCH_{it-1} + \sum \beta_{dsh} dr_{it} * Share_{it} + \beta_p p_{it-1} + \lambda_t \\ + \varphi(k_{it}, a_{it}, l_{it}, m_{it}) + \epsilon_{it} \end{aligned} \quad \textbf{(10)}$$

The results for each model are presented in Table 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 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.

[INSERT FIGURE 1 ABOUT HERE]

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 paper. 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 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 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.

[INSERT FIGURE 2 ABOUT HERE]

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 paper 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 paper 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.

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Tables and Figures

Table 1. Farm specialisation pattern

Ireland								
		2001	2002	2003	2004	2005	2006	2007
Milk Share	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 Share	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 Share	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 Share	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	
Milk Share	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 Share	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								
			2002	2003	2004	2005	2006	2007
Milk Share	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 Share	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 Share	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

Table 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 Tornqist 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; *** p<0.01, ** p<0.05, * p<0.1; fixed effects estimation.

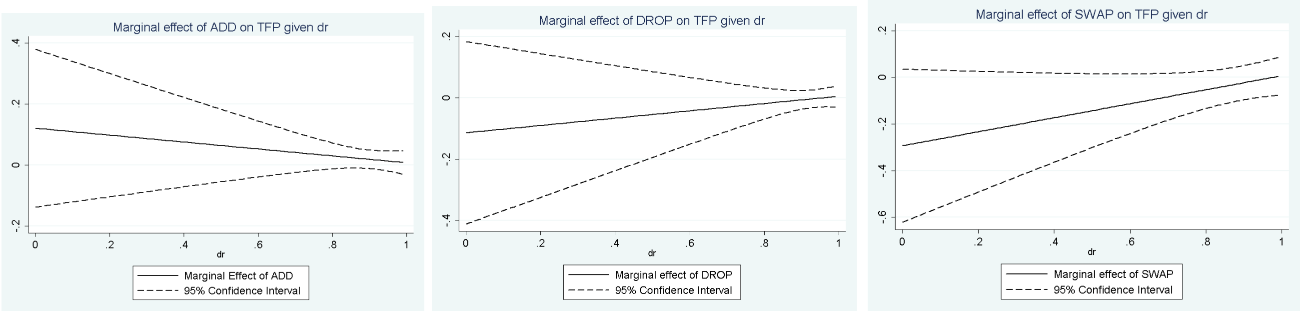
Table 3. Farm product switching and specialisation changes, associated with the decoupling policy, effects on farm productivity

Variables	IE 1	DK 2	NL 3	IE 4	DK 5	NL 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 Tornqist 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

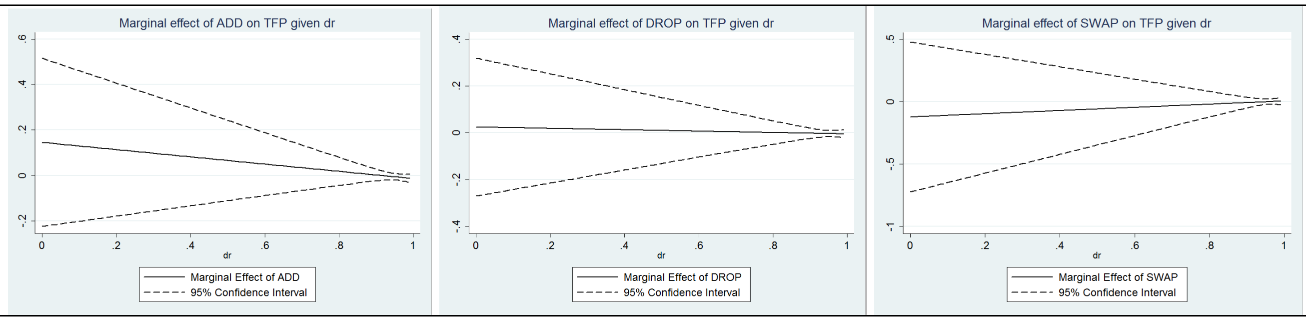
Note: Robust standard errors; *** p<0.01, ** p<0.05, * p<0.1; fixed effects estimation.

Figure 1. Marginal effects of product switching on TFP given different levels of decoupling rate (*dr*)

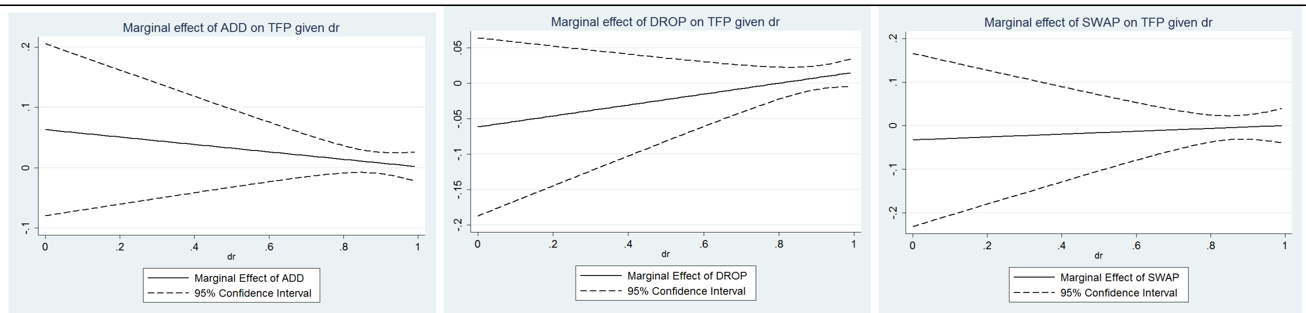
Netherlands



Denmark



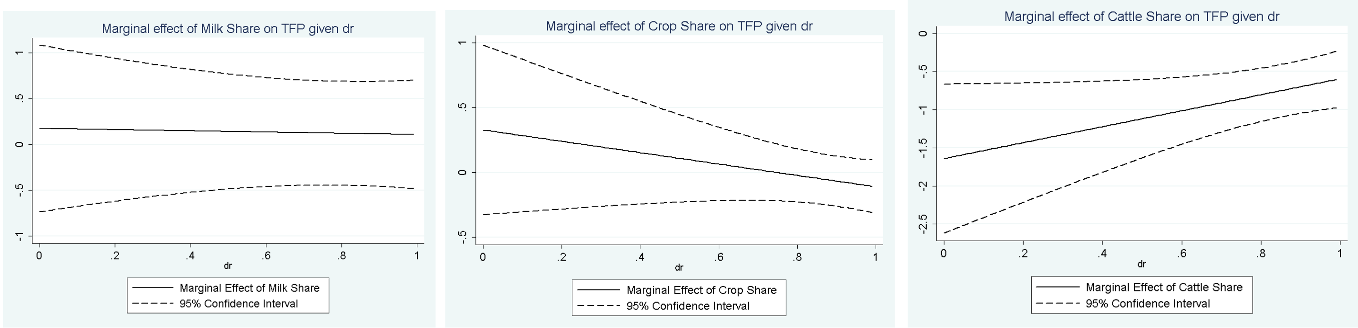
Ireland



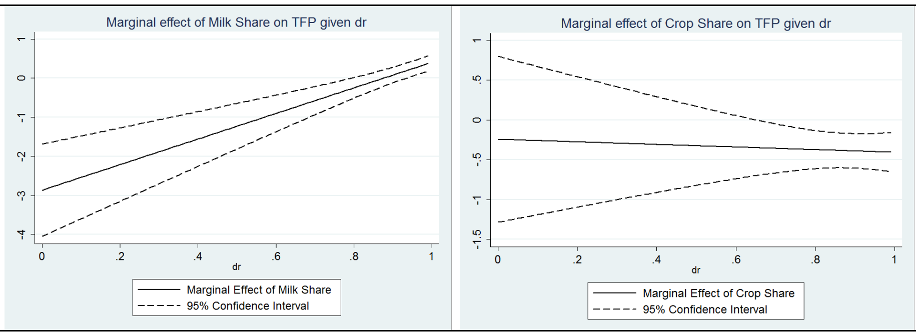
Note: the solid line indicates the marginal effect; the dashed line indicates 95 percent confidence interval of the marginal effect; the value *dr* (decoupling rate) is 1 for full decoupling.

Figure 2. Marginal effects of farm product specialisation changes on TFP for different levels of decoupling rate (*dr*)

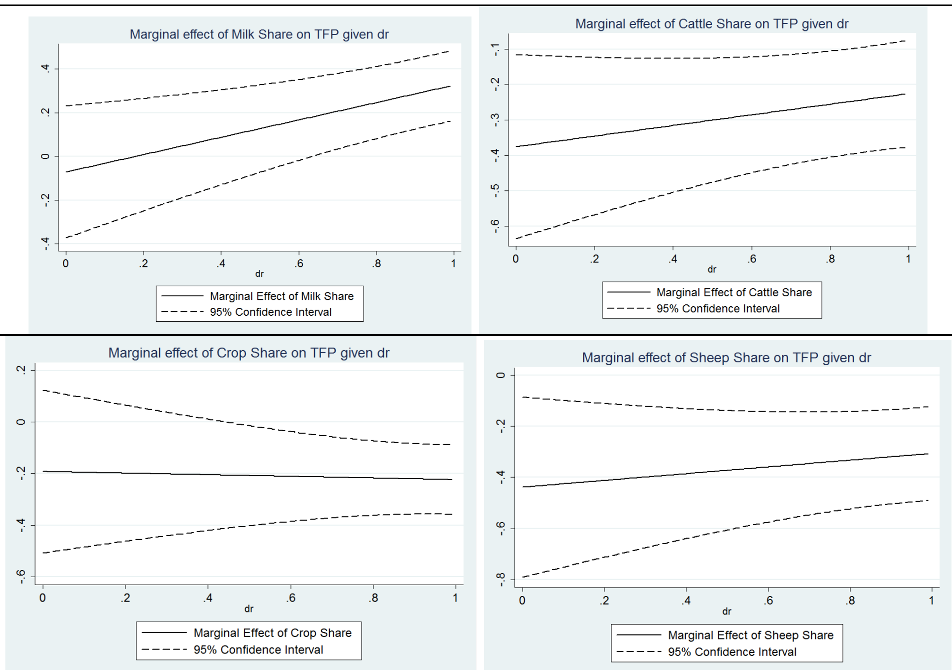
Netherlands



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.

Appendix

Appendix 1a. Summary statistics of the used variables

	IE			DK			NL		
Variable	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.
Decoupling rate (*dr*)	8192	0.872	0.152	4754	0.901	0.092	2844	0.926	0.091
Output	8192	77685	75044	4754	2987872	2362010	2844	256322	193749
Capital	8192	123028	118491	4754	345367	262532.8	2844	336076	265977
Land, ha	8192	52.0	41.8	4754	147.0	127.7	2844	60.7	47.5
Labour	8192	19738	10798	4754	449204	276843	2844	79670	38316
Direct cost	8192	15973	20483	4754	222841	283077	2844	78317	72020
Investment	8192	9679	23121	4754	750228	2863722	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						

Note: output, capital, labour, direct cost and investment are expressed in EUR for Ireland and the Netherlands and in DKK for Denmark. Variables in capital letters are dummy variables.

Appendix 1b. 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

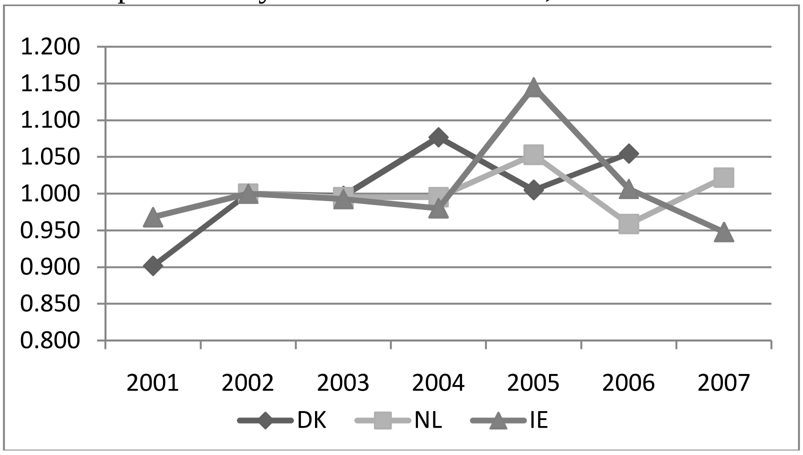
Note: RTS is a return to scale estimate

Appendix 1c. 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

Appendix 1d. The farm productivity indices for Denmark, the Netherlands and Ireland



Note: productivity indices estimated using farm individual population weights