The effect of the implementation of the 2003 Mid-Term Review of the CAP on technical efficiency of beef production. A comparative analysis

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Abstract

The 2003 Mid-Term Review introduced decoupled payments as part of the Common Agricultural Policy; however it allowed the maintenance of limited coupled support. As a result, there are significant differences in subsidies granted in each Member State. We aim to explore the effects on technical efficiency of the different implementations of support payments in the beef sector in selected countries. This analysis contributes to the literature by exploring the effects of both coupled and decoupled support payments on farm level economic performance. For this purpose, country specific output distance functions are estimated together with the effects of a series of technical efficiency drivers, including subsidies, implementing stochastic frontier analysis. Unbalanced panel datasets for France, Ireland, Germany, Scotland and England and Wales are built using Farm Accountancy Data Network information, for the years 2005 to 2012. Our estimates show that decoupled payments had a positive effect on efficiency in all countries, while the retention of coupled support had a significant negative impact on technical efficiency on French beef farms. This suggests that the maintenance of coupled support might compromise farm economic performance in the sector.

Key words: technical efficiency, subsidies, CAP, output distance function, FADN, decoupling, beef production

JEL codes: Q18; Q12

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1. Introduction

One of the objectives of the 2003 Mid-Term Review of the CAP was to contribute to simplify the complex system of payments in place since the 1992 MacSharry Reform, consisting of a series of livestock premia and arable aid payments coupled to agricultural production. After the implementation of the 2003 Reform between 2005 and 2006, all these premia and arable aid were replaced by the Single Payment Scheme (SPS), a unified payment designed to be decoupled from production. However, due to political pressures during the negotiation of the reform, the Mid-Term Review (and also the posterior 2008 Health Check Reform) did not introduce compulsory full decoupling, and it gave options for member states to reintroduce to a limited extent some of the previous coupled payments through the option to implement the SPS only partially. In addition, specific support (also coupled and limited) was allowed for specific types of farming in specific sectors under article 69 (and article 68 after the 2008 Health Check). In light of these different implementations allowed, the aim of this paper is to explore the effects of different types of subsidies on technical efficiency of farms in selected Member States (Ireland, the UK, Germany and France). Comparative analyses are useful in the context of ex-post policy analysis, since it is widely recognised that policy effects vary between countries and even regions and sectors (Arfini and Donati, 2008; Rizov et al., 2013; Minviel and Latruffe, 2016). Very few comparative analyses have explored the effects of the Mid-Term Review on farm technical efficiency. More specifically, this analysis intends to fill a gap regarding the lack of empirical evidence regarding the effect of the maintenance of different levels of coupled payments and/or additional specific support (based on articles 69/68), in addition to decoupled payments, on farm level technical efficiency.

We focus the analysis on the beef sector, since it was heavily affected by partial decoupling and to our best knowledge; no comparative analysis in this sector has been performed to date. In addition, beef production has traditionally been very reliant on subsidies to compensate for poor margins in many European countries (Vrolijk et al., 2010), therefore it is likely to be affected by changes in subsidies more than other sectors. The identifications of any differentiated effects of full decoupling versus partial coupling countries is of interest since the 2013 CAP reform has also allowed for the maintenance of limited coupled support for specific sectors, including beef and veal. Taking advantage of the harmonized financial data for EU farmers offered by the Farm Accountancy Data Network (FADN), we estimate a series of output distance functions together with an inefficiency effects model in order to compare the effects of different levels of subsidy composition and coupling levels in Ireland, Germany, France and the UK between 2005 and 2012. The detailed information recorded in FADN regarding the different types of subsidies received by each farm allows us to consider the effect of several different payments separately, which has not generally been done in the previous literature (Minviel and Latruffe, 2016). Moreover, we include data for several years after the implementation of the Mid-Term Review, which is a novelty in this type of analysis.

The remainder of this paper is organised as follows. Section 2 contains a description of the different beef subsides in the countries compared in this analysis. In Section 3 an overview of previous comparative analyses of decoupled payments in the EU is offered. The theoretical model and the data used are described in Sections 4 and 5 respectively, while the econometric model estimated is explained in Section 6. The main results are then discussed in Section 7. Finally, we provide some concluding comments in Section 8.

2. Policy background

The 2003 Mid-Term Review (MTR) introduced for the first time decoupled payments as part of the Common Agricultural Policy (CAP). As opposed to the previous design of direct payments, which were coupled to production, the Single Farm Payment (SFP) is decoupled from production by design because the possession of an entitlement (calculated based on direct payments received by farmers during the reference period 2000-2002), and not actual agricultural production, is what gives right to receive the payment[1].

However, an exception to full decoupling was allowed in articles 64 to 68 of Regulation (EC) No 1782/2003, where member states were given the option to maintain coupled aid for regions facing difficulties and sectors considered to be at risk of abandonment of production as a result of the move to the SPS, in order to prevent adverse social, economic and environmental consequences (European Court of Auditors, 2012). These payments essentially maintained a similar design to the pre-MTR in the form of arable payments and livestock premia[2]. For the specific case of beef production, article 68 of Regulation (EC) No. 1782/2003 outlined the different combinations of coupled payments that could be granted,

[1] Subject to cross-compliance rules, which imply an obligation of maintain the land farmed in Good Agricultural and Environmental Conditions (GAEC).

[2] Other aspects were also left to the choice of each Member State were the implementation system for the calculation of entitlements for the SFP (historical, static or dynamic hybrid or regional models), the conditions for access of new entrants, the definition of the minimum agricultural activities that have to be carried out on the land declared or the conditions for benefiting from the consolidation of entitlements (European Court of Auditors, 2011). Additionally, the MTR also maintained limited market support.

consisting of a slaughter premium for claves plus a suckler cow premium and a slaughter premium for bovine animals (other than claves), or a slaughter premium for bovine animals (other than claves), or a special male premium (EUR-Lex, 2003). However, in the MTR coupled support allowed was limited. Each coupled payment maintained had a fixed ceiling, equal to or less than the component of each type of pre-MTR direct payment used to calculate the national ceilings[3] (EUR-Lex, 2003). The total amount of fixed ceilings was deducted from the national ceilings. Additionally, countries were also given the option to implement limited (to 10% of national ceilings) specific support allowed under article 69 of Regulation (EC) No. 1782/2003 (EUR-Lex, 2003), which in practice were also coupled to production. However, as opposed to coupled support previously described, these payments targeted specific types of farming instead of farming sectors. In addition, article 69 set out specific objectives that these payments had to fit into, being the enhancement or protection of the environment; or the improvement of quality of agricultural products.

In the 2008 Health Check of the CAP further decoupling of direct payments was agreed, and most of beef payments were integrated into the Single Payment Scheme (with the exception of the suckler cow premium). However the Health Check maintained the limited[4] additional payments for specific sectors, with the legal base contained in article 68 of Regulation (EC) No. 73/2009 (EUR-Lex., 2009). The justifications for granting these additional payments were broadened with respect to those contained in article 69 in Regulation (EC) No. 1782/2003. Among the newly introduced rationale behind article 68 payments were for example improving animal welfare, improving the marketing of agricultural products or insurance for crops and animals. These additional payments were generally given per head of animal and could also be considered to be coupled to production (although some of these payments in certain member states were designed to be decoupled[5]). These additional payments were granted based on certain eligibility criteria[6] decided on by the Member States (European Commission, 2015a). Despite these legal requirements, several evaluations

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[3] National ceilings were specified for each member state in Regulation (EC) No. 1782/2003 (EUR-Lex, 2003), which could not be surpassed by the total reference amounts for the SFP, coupled support, additional specific support, etc. granted in each member state. National ceilings were calculated for each state as the sum of funds granted in each for pre MTR direct payments during the reference period (2000-2002).

[4] The 10% of national ceilings limit was also maintained and; in addition, it was lowered to the 3.5% when these specific payments were designed coupled to production.

[5] For example, Hungary implemented a decoupled bovine extensification supplement under article 68 (European Commission, 2015a).

[6] 24 member states implemented payments under this article, which total to 113 different measures all together (European Court of Auditors, 2013). These eligibility criteria were set by each member state for each specific measure they implemented, therefore the outline of each of them is impractical and only the criteria for the specific cases of France and Scotland are provided below in this section.

(European Commission, 2015a and European Court of Auditors, 2013) argued that in most cases the criteria established for measures under article 68 lacked adequate description and justification (for example, in France some additional payments imposed quality requirements that already corresponded to the ongoing industry requirements).

A summary of the MTR implementation in the countries included in the analysis can be found in the table provided in Appendix I, which shows the changes in composition of payments between 2005 and 2012. Beef production remained heavily supported by coupled payments in several EU member states, including France. Since 2006, France retained the maximum level of coupled support allowed for the beef sector in the form of a suckler cow premium, a slaughter premium for claves and a slaughter premium for bovine adults. After the 2008 Health Check was implemented in 2010, the suckler cow premium was maintained while the rest were integrated in the SPS. France also gave additional support for beef farmers, under article 68 of Regulation (EC) No. 73/2009, between 2010-2013 in the form of a per head payment. These payments were granted for calves from suckler cows and specifically labelled organic calves, on the grounds of the vulnerability of these types of production (art. 68(1)(b)). Other countries opted for full decoupling in this sector, such as Ireland, Germany or the UK. Despite implementing full decoupling, Ireland and Scotland also granted additional support for beef farmers between 2008-2012 and 2012-2013 respectively. The legal basis for Scottish additional beef aid was also article 68 of Regulation (EC) No. 73/2009 and was also given per head of animal to support suckler cow calves born in Scotland, in order to maintain a sector considered as vulnerable (art. 68(1)(b)). However for the case of Ireland, the legal basis was on article 40 of Council Regulation (EC) 1698/2005 rather than on articles 69 or 68. Despite the legal differences, Irish payments were also given per head of animal; therefore we also include them in the analysis. Finally, Germany and England and Wales opted for full decoupling of the sector with no additional support during the period analysed.

3. The Mid-Term Review and farm economic performance

The effect of agricultural subsidies on farm economic performance has been addressed in numerous empirical analyses through the years (Minviel and Latruffe, 2016), however most of them have focused on single country analyses. Despite being less popular, comparative studies have the advantage that they allow the comparison of policy effects in a consistent way since the same model is estimated for samples of farmers in a given sector in different countries (Latruffe et al., 2016). Few comparative analyses have been carried out of the effects of CAP subsidies in place before the implementation of MTR. Among the studies that have been conducted results have proved equivocal about significance and direction of subsidy effects, depending on the county and sector analysed. For example, positive effects on farm technical efficiency were found for Swedish crop (Zhu and Lansink, 2010) and dairy farms (McCloud and Kumbhakar, 2008); and also dairy farms in Finland and Denmark (McCloud and Kumbhakar, 2008). On the other hand, negative effects on technical efficiency of livestock farms in German and Spanish farms (Kleinhanss et al., 2007), of dairy and cereal farms in France and Hungary (Fogarasi and Latruffe, 2009) and of crop farms in Germany (Zhu and Lansink, 2010) have been uncovered too.

Coupled support has been linked to negative impacts on farm technical efficiency (Kazukauskas et al., 2014), arising from production induced distortions that prevented farmers from adapting their production decisions and resource allocation according to economic signals. Under the new decoupled system, agricultural production is no longer required in order to be a recipient of direct payments, therefore they are designed to support agricultural incomes while eliminating certain distortions believed to be associated with coupled income support. However, it has been argued that decoupled payments have indirect effects on farmers’ production decisions and overall farm economic performance (Bhaskar and Beghin, 2009; Rizov et al., 2013). A handful of recent comparative studies have addressed the effect of the introduction of decoupling on farm technical efficiency (Latruffe et al., 2012; Zhu et al., 2012; Latruffe et al., 2016) and on productivity (Rizov et al., 2013; Kazukauskas et al., 2014). Latruffe et al., (2012) explored the effect of the decoupling on technical efficiency of dairy farms in eleven EU countries. In all countries, total subsidy dependence had a negative and significant effect on farm efficiency. However, the impact of decoupling was significant for only six countries, with the effect being positive for five of them (France, Germany, Italy, Spain and the UK). Zhu et al., (2012) explored the coupling, insurance and wealth effects of several subsidies on farm technical efficiency of dairy farms in the Netherlands, Sweden and Germany between 1995 and 2004. They found only evidence of negative effects of subsidies on technical efficiency in all countries. Regarding how they captured the effects of decoupling some limitations of these two studies can be noted. First, Latruffe et al. (2012) relied on a dummy variable to capture the effects, however the use of dummies to capture policy reform impacts may create identification problems since other institutional/economic changes might be captured by the dummy variables in addition to/instead of the effects of decoupling (Carroll et al., 2008). Second, Zhu et al. (2012) used data between 1995 and 2004, therefore their analysis relied on the use of proxies to explore the effects of decoupling (i.e. three policy variables were included in the inefficiency effects model, two policy variables capturing the coupling effects of output and input related subsidies, and a third one capturing the effect of total subsidy dependence). More recently, Latruffe et al. (2016) explored the relation between subsidies and technical efficiency while accounting for possible endogeneity of inputs in the production function estimated. Their analysis was again made in a comparative framework, using FADN data for dairy farms for nine EU countries. Mixed affects were again found. For several countries, the effect of subsidies remained unchanged after the implementation of decoupling (negative in Belgium and the UK; positive in Spain and Portugal). However, in Italy the negative effect of subsidies on efficiency prior to decoupling turned to a positive effect after the implementation of decoupling. In Denmark, Ireland, France and Germany, the effect of subsidies, both before and after decoupling, was not significant. As opposed to the three previous analyses, Rizov et al. (2013) focused on the effects of decoupling in TFP levels and change in EU-15 farms. They found that, until the implementation of the MTR, CAP subsides appeared to have a negative impact on productivity for most of the EU-15 countries. In the period post-decoupling however, the negative effect of subsidies became less severe and it turned positive for some countries (Finland, Austria and Sweden). Despite the improvement, the magnitude of the effect was rather small in all cases. Kazukauskas et al. (2014) also addressed the effect of decoupled payments on productivity growth in Ireland, Denmark and the Netherlands in the dairy, cattle and crop systems. A reduction in the negative impact associated with the previous coupled payments was expected, however it was found that productivity post-decoupling only improved significantly on Irish cattle farms and on Danish dairy farms, but not on the rest of the enterprises in the three countries.

In light of this review, no clear evidence regarding the direction of the impact of decoupled payments has been found. In addition, to our best knowledge, there seems to be a lack of empirical research post-decoupling focused on the effects on efficiency of the different implementations on the MTR across countries, especially regarding the retention of different levels of partial coupling. We aim to contribute to this previous literature analysing the effects of the MTR subsidies in several ways. First, by using data between 2005 and 2012, several number of year post-implementation of the Mid-Term Review are considered. Second, we include detailed subsidy information, in order to explore the effects of different types of payments separately, rather than the aggregated effect of all farm payments. Third, no previous analyses have focused on the effects of the Mid-Term Review in the beef sector. This way, the analysis performed provides further empirical evidence on the effects of the MTR.

4. Efficiency estimation using distance functions

Stochastic Frontier Analysis (SFA) is the methodology implemented in order to obtain technical efficiency scores. For this analysis, it is preferred to the deterministic Data Envelopment Analysis (DEA) methodology, since agricultural production is very likely to be affected by stochastic factors (Irz and Thirtle, 2004) that otherwise would be subsumed in the technical efficiency score computed. In line with previous EU comparative analysis using SFA (Brümmer et al., 2002; Zhu and Lansink, 2010; Latruffe et al., 2012; Zhu et al., 2012), a distance function is estimated here[7]. Distance functions provide a characterisation of production technology when multiple inputs are used to produce multiple outputs (Shepard, 1970). Here we chose an output orientation for the distance function on the basis that the inputs used by most EU farmers are quasi-fixed, especially for the case of land and capital, and therefore they have more flexibility adapting output levels (Newman and Matthews, 2007). The definition of output distance functions is based on the concept of the output set (Färe and Primont, 1995), $P_t(\mathbf{x_t})$ in equation (1), which describes the set of all outputs, represented by vector $\mathbf{y_t}$, that can be produced using the input vector $\mathbf{x_t}$:

$$P_t(x_t) = \{y_t : x_t \text{ can produce } y_t\} \quad (1)$$

Modelling the output set $P_t(\mathbf{x_t})$ using an output distance function requires the assumption of weak disposability of outputs (O'Donnell and Coelli, 2005). Based on the relation expressed in equation (1), an output oriented distance function is defined as:

$$D_t^o(y,x) = min\{\delta : y_t/\delta \in P_t(x_t)\} \quad (2)$$

It describes the minimum amount by which an output vector $\mathbf{y_t}$ can be expanded and still remain producible with input vector $\mathbf{x_t}$. In other words, the output distance function describes the maximum radial expansion of the output vector that can be achieved for a given input

[7] Alternative approaches to incorporate more than one output are available, such as profit or cost functions. However, FADN does not have any information regarding farm specific prices, which precludes their estimation. Distance functions offer the additional advantage that they do not require any behavioural assumptions such as cost minimisation or profit maximisation.

vector (Coelli and Perelman, 1999). In order for this definition to hold, the output distance function is assumed to be homogenous of degree one in outputs, non-decreasing and convex in outputs, and non-increasing and quasi-convex in inputs (Färe and Primont, 1995; O'Donnell and Coelli, 2005). Output distance functions defined this way are related to the Farrell (1957) output oriented measure of technical efficiency, as this measure is equivalent to the maximum radial expansion of the output vector to the boundary of the production set $P_t(\mathbf{x_t})$, for a given input vector (Kumbhakar and Lovell, 2000). The distance function $D^o_t(x,y)$ will take a value which is less than or equal to one if the output vector $\mathbf{y_t}$ is an element of the feasible production set while $D^o_t(x,y)$ will take a value of one if $\mathbf{y_t}$ is located on the outer boundary of the production possibility set (Coelli and Perelman, 1999).

It is common in empirical applications to assume a translog functional form for output distance functions, due to its well know flexibility of the representation of technology, resulting in the expression described in equation (3). A time trend, together with its interactions with outputs and inputs, is also added to account for the effects of technical change.

$$\begin{aligned}\ln D^o_{it}(y,x,t) = \alpha_0 &+ \sum_{m=1}^{M} \alpha_m \ln Y_{itm} + \sum_{k=1}^{K} \beta_k \ln X_{itk} + \frac{1}{2}\sum_{m=1}^{M}\sum_{n=1}^{N} \alpha_{mn} \ln Y_{itm} \ln Y_{itn} \\ &+ \frac{1}{2}\sum_{k=1}^{K}\sum_{g=1}^{G} \beta_{gk} \ln X_{itk} \ln X_{itg} + \sum_{m=1}^{M}\sum_{k=1}^{K} \omega_{mk} \ln Y_{itm} \ln X_{itk} \\ &+ \tau_t\, t + \tau_{tt}\, t^2 + \sum_{m=1}^{M} \tau_{mt}\, t \ln Y_{itm} + \sum_{k=1}^{K} \tau_{tk}\, t \ln X_{itk}\end{aligned} \quad (3)$$

This functional form also has the advantage that the imposition of homogeneity is quite straightforward (Coelli and Perelman, 2000), by normalizing the function by one of the outputs[8] (Brümmer et al, 2002; Newman and Matthews, 2007; Zhu et al., 2012). However equation (3) cannot be estimated econometrically since $\ln D^o_{it}$ is unobservable. Using the homogeneity transformation allows to obtain an observable dependent variable, and substituting $\ln D^o_{it}(y,x,t)$ with $-u_{it}$ and adding a random error term (v_{it}) the estimable expression in equation (4) is obtained, where TL(.) denotes the translog functional form assumed.

[8] This approach has been criticised by some authors, as endogeneity might arise because the right hand side variables are built as a function of the left hand side variable. However, Brümmer et al. (2002) and Kumbhakar and Lovell (2000) have suggested that the output ratios create an output mix vector that is likely to be exogenous.

$$-lny_{itM} = TL(^{y_{it}}/_{y_{itM}}, x_{it}, t) + u_{it} + v_{it} \quad (4)$$

In equation (4) v_{it} is a producer specific two-sided error term that captures effects of random shocks, while u_{it} is the inefficiency term. The assumed distribution for v_{it} is $iidN(0,\sigma^2_v)$. Multiple distributions have been proposed in the past decades for the inefficiency term u_{it}. We implement a time variant model, where inefficiency is allowed to vary systematically as a function of time (Battese and Coelli, 1992).

$$u_{it} = u_i * exp(-\eta(t-T)) \quad (5)$$

$$u_i \sim iidN^{+}(\delta_j z_{itj}, \alpha_u^2)$$

The mean of the variance of the inefficiency component is expressed as a function of a vector of exogenous variables ($\mathbf{z_{it}}$) that are likely to affect farm technical inefficiency, as shown in equation (5). Finally, $\boldsymbol{\delta}$ is a vector of parameters to be estimated. Previous implementations of this specification includes Newman and Matthews (2007), who model the mean of the inefficiency component as constant; and Rasmussen (2010), who also modelled the mean as a function of a set of variables. Under the mentioned assumptions for the distribution of the errors, the inefficiency effects model and the output distance function parameters and technical efficiency scores can be estimated in one step using Maximum Likelihood.

5. Data and samples selected

Data taken from FADN is used for the estimation of the model described. This dataset which is maintained by the European Commission provides harmonised farm level yearly financial data for all EU member states. Even though the data is recorded and compiled by each member state individually, they implement a unified methodology for the definitions of the variables, therefore it allows to perform comparative analysis in a consistent way. For the purpose of this analysis, only farms classified as specialist cattle producers are selected[9].

Beef production is of great importance for the wider EU agricultural sector. Despite being the fourth most important agricultural product after milk, cereals and pig meat (Eurostat, 2015b), the EU produces about 7.6 million tonnes of beef per year (Eurostat, 2016a). Four EU member states, Ireland, France, Germany and UK, are compared. These countries were

[9] These farms correspond to group 49 in the TF14 classification, according to the current Standard Output classification. This classification replaced the previous Standard Gross Margin (SGM) classification in order to take into account the decoupling of direct income support.

chosen on the basis of the importance of beef production for the overall agricultural output. France, Germany and the UK are the largest producers, representing almost 50% of the EU total production together. Ireland is the fifth largest beef producer (representing 7.4 % of the total) (Eurostat, 2015b). In terms of the total number of animals, the top three member states are also France, Germany and the UK, followed by Ireland in fourth place (Eurostat, 2015b). These countries also represent a wide variety of implementation models allowed in the MTR, especially regarding the different levels of retention of coupled payments and additional support for the beef sector

Due to differing production systems employed in different countries, it is very likely that farms located in each of them do not share the same production technology. For this reason, we estimate separated frontiers for each sample included. The UK dataset was disaggregated to NUTS1[10] regions, since different implementations of the MTR were allowed for England, Wales, Scotland and Northern Ireland. Due to the low number of observations for Wales, the samples for England and Wales are merged in one, while the Northern Ireland sample was not used due to the low number of observations and the very high rotation of the panel. For each country, an unbalanced panel for the years 2005 to 2012 is built.

In FADN, total farm output includes three main components: total crops output, total livestock output (plus livestock products) and 'other' outputs. Table 1 shows farm output composition for each country, defined as the share of each of the different outputs on farm total output (excluding subsidies).

Table 1 – Farm total output composition

	Livestock and livestock products			Crop output	Other output
	All	Beef/veal	Other livestock		
Ireland	0.863	0.760	0.103	0.112	0.026
Germany	0.717	0.489	0.228	0.190	0.093
France	0.867	0.690	0.177	0.103	0.030
England/Wales	0.735	0.549	0.186	0.201	0.065
Scotland	0.782	0.623	0.160	0.174	0.043

Source: Own calculations based on FADN data.

On average, farms in all countries obtain over 70% of their total output from livestock production (which includes equines sheep, goats, pigs, poultry and other animals in addition

[10] NUTS stands for Nomenclature of Territorial Units for Statistics, which is a hierarchical system designed by the EU (and established by Eurostat) in order to divide the territory of the member states for regional statistical purposes. Three different levels of NUTS (1, 2 and 3) exist, progressing from larger (level 1) to smaller (level 3) regional units.

to cattle), with Ireland and France obtaining the highest share (over 86% in both cases). Larger differences can be observed for the share of beef/veal output on total farm output. With the exception of Germany (48.9%), all countries obtain over 50% of their total output form beef production. Irish cattle farmers obtain the highest share of their total output from beef production.

6. Econometric model and variables

The output distance function estimated in this analysis is described in equation (6). Given the differences in output composition outlined in the previous section, the choice of a multi-output representation of the technology seems justified.

$$
\begin{aligned}
-lnY_{itM} = {} & \alpha_0 + \sum_{m=1}^{M} \alpha_m ln(\frac{Y_{itm}}{Y_{itM}}) + \sum_{k=1}^{K} \beta_k \ln X_{itk} + \frac{1}{2}\sum_{m=1}^{M}\sum_{n=1}^{M} \alpha_{mn} \ln(\frac{Y_{itm}}{Y_{itM}}) \ln(\frac{Y_{itn}}{Y_{itM}}) \\
& + \frac{1}{2}\sum_{k=1}^{K}\sum_{g=1}^{G} \beta_{gk} \ln X_{itk} \ln X_{itg} + \sum_{m=1}^{M}\sum_{k=1}^{K} \omega_{mk} ln(\frac{Y_{itm}}{Y_{itM}}) lnX_{itk} + \tau_t\, t + \tau_{tt}\, t^2 \qquad (6) \\
& + \sum_{m=1}^{M} \tau_{mt}\, t ln(\frac{Y_{itm}}{Y_{itM}}) + \sum_{k=1}^{K} \tau_{tk}\, t \ln X_{itk} + \sum_{w=1}^{W} \theta_w dLFA_{itw} + u_{it} + v_{it}
\end{aligned}
$$

We distinguish two outputs, beef and veal and another aggregated category that includes all other outputs produced on the farm (i.e. crop output, milk and milk products, sheep output and other outputs). FADN does not collect information on physical farm outputs, only the value in euros. Beef and veal output is deflated using the Eurostat price index for cattle output. The implicit volume methodology is used to obtain volume measures for the aggregated other farm output category (Zhu et al., 2012). It is obtained by dividing the sum of the value of farm outputs other than beef (expressed in 2005 prices) by a farm specific aggregated Tornqvist price index computed using Eurostat annual price indices series for agricultural outputs. Beef output is used as the normalising output to estimate the distance function described in equation (6).

Inputs are also grouped into four categories, land, labour, capital and other costs. Land input, measured in hectares, includes the total utilised agricultural area of the farm (including land in owner occupation, rented land and land temporarily not under cultivation). In order to control for land quality, dummy variables capturing whether the farm is located in an area classified as less favoured are also included in the distance function[11]. Labour input is expressed in annual working units (with one AWU being equivalent to one person working full-time on the holding) and includes both paid and unpaid labour. Capital aggregates the value (in euros) of machinery, buildings and breeding livestock. The value of machinery and buildings is calculated as the value of assets at the end of the accounting year (closing valuation), calculated on the basis of the replacement value minus accumulated depreciation (European Commission, 2012). Breeding livestock includes the value at closing valuation of breeding heifers and other types of breeding livestock. Other costs input category includes the value in euros of livestock (total livestock feeds and other livestock costs) and crop (costs of seeds, plant protection, fertilisers and other costs) costs, energy and water, contract work and other farm costs. The implicit volume methodology is also used to aggregate capital and other costs inputs (Zhu et al., 2012). Again annual Eurostat price indices series for agricultural means of production are used to build farm specific aggregated Tornqvist price index (with 2005 as base year).

The variables included in the inefficiency effects model estimated represent the characteristics of the farm, together with a series of variables capturing the effects of CAP subsidies. Variables capturing effects of different farmers' characteristics are commonly included in the $\mathbf{z_{it}}$ vector too however this information is limited in FADN. We attempt to capture the effects of different policy implementations by including a series of policy variables. Two variables built as the amount of SFP (in 100 euros) and environmental payments (in 100 euros) received per hectare are included in the inefficiency effects model of all countries analysed. Environmental payments are included as a separated variable in order to disentangle possible confounding effects with decoupled payments. In countries that implemented additional specific beef support under article 68 Regulation (EC) No. 73/2009 (France, Ireland and Scotland) a policy variable built as the amount of these payments (also in 100 euros) per hectare is also included. Finally, for the case of France an additional variable built once again as the amount of coupled beef support (in 100 euros) maintained per hectare is also included to capture the effects of partial coupling. Other variables included in the inefficiency effects model in all the countries are the shares of long and short term debt in total farm assets, the share of rented land in total farm utilised agricultural area and the share

[11] FADN includes a variable that indicates whether the majority of the area of a farm is situated in an area classified as less favoured (code 2 for less-favoured not mountain areas; and code 3 for less-favoured mountain areas) or not (code 1). LFA1 is used as the reference category for the dummy variables included.

of hired labour in total labour. Additionally, for France and Germany, regional dummies (built using NUTS1 regions in both cases) are included[12].

7. Results

Elasticities, returns to scale and technical change by country

The full set of estimated[13] coefficients of the production distance functions in each country is provided in Appendix II. The coefficients have no direct interpretation, but since the outputs and inputs were expressed in natural logarithms and were divided by their arithmetic means before estimation, it is possible to compute elasticities by partially differentiating the distance function with respect to each input. These are computed for each observation and the averages for each sample between 2005 and 2012 are provided in Table 2.

Table 2 – Distance elasticities and technical change

	Ireland	France	Germany	Scotland	England/Wales
Beef output	0.721	0.745	0.554	0.584	0.533
Other outputs	0.279***	0.255***	0.446***	0.416***	0.467***
	(0.005)	(0.002)	(0.005)	(0. 013)	(0.007)
Area	-0.278***	-0.194***	-0.045***	-0.293***	-0.145***
	(0.020)	(0.013)	(0.015)	(0.037)	(0.021)
Labour	-0.114***	-0.146***	-0.142***	-0.178***	-0.180***
	(0.022)	(0.012)	(0.017)	(0.039)	(0.024)
Capital	-0.140***	-0.179***	-0.107***	-0.123***	-0.139***
	(0.012)	(0.010)	(0.010)	(0.034)	(0.018)
Other costs	-0.621***	-0.544***	-0.782***	-0.469***	-0.623***
	(0.016)	(0.011)	(0.012)	(0.039)	(0.022)
Returns to scale	1.153***	1.063***	1.077***	1.063***	1.087***
	(0.021)	(0.013)	(0.015)	(0.035)	(0.023)

Notes: Standard errors are in parentheses (calculated using the delta method at the mean values). ***Significant at 1%.

All elasticities have the expected positive and negative signs respectively at the means. The elasticities with respect to output reflect changes in output composition. Beef output elasticity is obtained using the homogeneity property (Brümmer et al., 2002). In all countries, and especially in Ireland and France, the main beef output dominates production as would be expected, since the sample is constituted by specialist beef farms in each country. The importance of beef output is also coherent with the descriptive statistics provided in table 1,

[12] For the rest of the countries the regional variables were not statistically significant and were rejected by a likelihood ratio test at the 1% level in all cases.
[13] Limdep 9.0 software was used in the estimation.

which shows the share of beef output on total farm output is the highest in France and Ireland. Some common patterns in input importance can be observed in Table 2. Other costs have the highest importance in output production in all countries. Area is very high in Ireland and Scotland probably due to the higher reliance on grazing and use of grassland that characterise beef production there. On the other hand, Germany obtained an extremely low contribution of land input to output production, reflecting increased reliance on the use of concentrates to produce beef. By adding up the elasticities with respect of inputs, a measure of returns to scale is obtained. Increasing returns to scale are observed on average for farms in all countries.

Technical efficiency estimates and effects of exogenous variables

Before commenting on the efficiency scores obtained, it should be noted that this analysis is solely based on the estimation of a separated frontier for each of the countries included, therefore this approach precludes making any explicit comparisons regarding the economic performance among the different member states included. Table 3 provides the average technical efficiency levels for farms in each country between 2005 and 2012.

Table 3 - Technical efficiency scores by country

	Mean	Standard Deviation	Minimum	Maximum
Ireland	0.723	0.149	0.212	0.977
Germany	0.749	0.172	0.086	0.982
France	0.728	0.138	0.188	0.979
England/Wales	0.723	0.135	0.243	0.974
Scotland	0.661	0.144	0.212	0.980

Technical efficiency scores indicate how close farms in each country are operating on average with respect to their specific country frontier, and take values between 0 and 1. In general, farms in all countries appear to have scope to increase their output levels. The lower technical efficiency scores for Scotland could be due to substantial differences in the quality of land among farms (for example, hill versus lowland farms) that have not been fully accounted for through the use of the less favoured area dummy variable in the distance function estimated.

The estimates obtained in the inefficiency effects model are presented in Table 4. Note that the magnitude of the coefficients has no meaningful interpretation, and that the sign refers to the effect of each variable on technical inefficiency (i.e. a negative (positive) coefficient implies a positive (negative) effect on technical efficiency).

Table 4 – Effect of exogenous variables on technical inefficiency

	Ireland	France	Germany	Scotland	England/Wales
Constant	0.641*** (0.050)	0.275*** (0.051)	0.496*** (0.101)	0.823*** (0.081)	0.442*** (0.077)
SFP (100 €/ha)	-0.138*** (0.019)	-0.066*** (0.010)	-0.126*** (0.019)	-0.125*** (0.021)	-0.065*** (0.022)
Env. subs (100 €/ha)	0.051** (0.021)	0.118*** (0.029)	0.171*** (0.024)	-0.021 (0.085)	0.102*** (0.028)
Coupled subs (100 €/ha)	-	0.052*** (0.013)	-	-	-
Additional beef support (100 €/ha)	-0.523** (0.238)	0.089 (0.347)	-	-0.167 (0.213)	-
Short term debt ratio	-3.656 (3.268)	0.382*** (0.098)	0.209 (0.167)	0.165 (0.313)	0.044 (0.256)
Long term debt ratio	0.605 (0.462)	0.208*** (0.072)	0.359*** (0.114)	-0.207 (0.470)	0.134 (0.152)
Rented land share	-0.291*** (0.100)	-0.108*** (0.041)	-0.057 (0.076)	0.022 (0.055)	-0.118** (0.055)
Hired labour share	-0.437 (0.338)	-0.149* (0.084)	-0.345*** (0.113)	-0.140 (0.127)	-0.237** (0.116)

Notes: Standard errors are in parentheses. *Significant at 10%; **Significant at 5%; ***Significant at 1%.

The main variables of interest for this analysis are the ones capturing the effects of decoupling and the maintenance of different levels of coupled support. Since subsidy variables are built as the amount of each type of subsidy per hectare, possible size effects are removed and they capture the effect of subsidy intensity (Latruffe et al., 2016). The effect of receiving higher SFP per hectare is positive and significant for all countries included in this study. The literature in this area has suggested that the positive effect of income support is likely to be arising from the relaxation of farmers' credit and financial constraints (Rizov et al., 2013). It has also been suggested that a positive effect might be caused by a reduction in farmers risk aversion as a result of the income certainty associated with decoupled payments (Zhu et al., 2012; Rizov et al., 2013). As opposed to the case of decoupled support, obtaining higher levels of coupled support per hectare for French farms appears to have negative effects on technical efficiency. The effect of receiving higher additional beef support per hectare has a significant and positive effect only for Irish farms, while the effect is insignificant for Scotland and France. The differing effects that these payments have depending on the country considered are not surprising given differences in farm types targeted and the differences in the amount of years they were granted in each country (see Appendix I). The additional payments granted to Irish beef farmers were designed differently to those in Scotland and France. In France and Scotland these payments aimed to address specific disadvantages affecting beef farmers in economically vulnerable types of farming (EUR-Lex., 2009), while in Ireland they aimed to enhance animal welfare and improve farming skills of farmers by establishing certain guidelines that needed to be followed in order to receive the payment (such as farmer training or participation in discussion groups as well as improvement of certain farm practices). These results seem to suggest that the payments implemented in Ireland are more effective at improving farm efficiency than the ones implemented in Scotland and France. However, it should also be noted that a possible issue with self-selection of participants in this scheme might be present, since the Irish scheme was voluntary and tended to attract better managers who are more willing to participate in discussion groups, recording, etc. Finally, receiving higher environmental subsidies per hectare has a negative and significant effect on efficiency in all countries except in Scotland, although in this case the effect is not statistically significant.

Moving on the rest of variables included in the inefficiency effects model, the short and long term ratios capture farm financial viability. In line with some previous literature (Iraizoz et al., 2005; Hadley, 2006), the effect of debt to total farm assets appears to have a general negative relationship with technical efficiency of beef farms, although in most cases the effects of the debt ratios are statistically insignificant. Negative effects are likely to be arising from high indebted farmers incurring in higher costs (Latruffe, 2010). These negative effects have also been linked to limited capacity to adopt new technologies, since access to credit might be more difficult for farmers with higher debts (Zhu et al., 2012). Both short and long term debt ratios have a negative and statistically significant negative effect for French farms. Considering that they are also the ones with highest debt levels among the countries analysed, this result suggests that higher borrowing is an important factor eroding technical efficiency of French beef production. Higher share of long term debt also has a negative significant effect for German beef farms. Since higher debt is usually associated with higher capital input, for the case of German beef farms, this result might reflect the low response to capital input (i.e. lowest capital elasticity). Higher shares of rented land have a positive impact on technical efficiency of beef farms in Ireland, France and England and Wales. It has been pointed out in the literature that the need to pay rent may induce efficiency improvements in order to keep up with payments (Latruffe et al., 2012). Finally, the effect of higher shares of paid labour into total labour is also positive for French, German and English and Welsh beef farms. Some reasons behind this effect could be better educated and trained workers (Latruffe, 2010) or the possibility for more specific and fewer tasks for all farm workers as a result of increase in the work force on farm (Latruffe et al., 2012).

8. Conclusions

The analysis performed consists of a comparative assessment of the effects of different implementations allowed for in the 2003 MTR on economic performance in the beef sector in Ireland, France, Germany, Scotland and England and Wales. Besides introducing decoupled payments, the MTR also allowed member states to maintain limited coupled supports that have been focused on the beef sector. As a result, there are significant differences in subsidies granted in each Member State. However, only a handful of comparative analyses have looked at the effect of different types of CAP subsidies on farm economic performance, and even less have performed this type of analysis after the MTR was implemented and including several years post-implementation of decoupling. Moreover, empirical analyses exploring the effect of subsidies on technical efficiency of beef production in Europe are also scarce. Therefore this analysis contributes to fill these gaps in the literature. For his purpose, several output distance functions (one per country included) have been estimated, together with an inefficiency effects model to explore he effects of subsidies and other variables on farm efficiency.

Estimates for the distance elasticities show different patterns of input importance, with other costs having the highest importance in output production regardless of the country. Results also show that beef farms in all countries analysed operate under average increasing returns to scale during the period analysed. In addition, technical efficiency scores indicate that on average there is scope for improved output production for beef farms in all countries. Since these scores are measured with respect to a country specific frontier, no inter country comparisons can be made from the estimates obtained here. However, an interesting area for further research would be the increasingly popular estimation of a meta-frontier (see for example Battese et al., 2004, O'Donnell et al., 2008 or Huang et al., 2014), in order to explore in more detail performance differences between these countries.

The results obtained in the inefficiency effects model estimated for each country show that receiving higher SFP per hectare is related with improved technical efficiency levels. However, the maintenance of coupled support allowed for in the MTR seems to be compromising technical efficiency of French beef producers. These findings have important implications in practice. For example, disparities in effects on efficiency (i.e. it deteriorated in some countries, while it improved in some others) of different implementations of the MTR might induce distortions in important areas such as intra-EU trade of agricultural goods (Renwick et al., 2011; Prehn et al., 2015). In addition, under the new regulations in place following the 2013 CAP reform, Member States are still allowed to maintain voluntary coupled support for specific farming sectors. According to European Commission (2015b), the beef and veal sector still is the most highly supported with these types of payments. More specifically, France and Scotland have maintained coupled support, with France maintaining the highest level allowed.

Finally, some limitations can be highlighted. Possible issues with rotation of the sample might be present due to the unbalanced nature of the panel, which seems to be more severe for some countries than for others[14]. Another limitation that needs to be highlighted is that FADN only includes farms considered to be commercial, based on a given economic size threshold, which varies by country[15]. Minviel and Latruffe (2016) found that the direction and statistical significance of the effect of subsidies on technical efficiency can be sensitive to the empirical specification chosen for the variables and the model. Despite these notes of caution, this research contributes to the very thin evidence regarding the effects of the MTR on farm performance, particularly for beef producers, suggesting a rather robust positive effect of the implementation of full decoupling on efficiency in this sector, as opposed to the implementation of partial coupling. Such findings have high policy relevance considering that coupled support has been maintained in the 2013 CAP reform.

References

ARFINI, F. & DONATI, M. 2008. Health check and farm efficiency: a comparative assessment of four European agricultural regions. 109th Seminar of the EAAE “The CAP after Fischler Reform: national implementations, impact assessment and the agenda for future reforms”, November 20-21, Viterbo, Italy.

[14] The attrition rate is defined as the percentage of farms that abandon the farm from one year to the next. For the samples considered in this analysis, between 2005 and 2011, the rates are as follows: 21.86% for Ireland, 17.29% for France, 25.42% for Germany, 9.84% for Scotland and 32.68% for England/Wales.

[15] For the case of Ireland it is 8 and for Germany, France, England, Wales and Scotland it is 25, measured in 1000 euros (EUR-Lex., 2008).

BATTESE, G. E. & COELLI, T. J. 1992. Frontier production functions, technical efficiency and panel data: with application to paddy farmers in India. *Journal of Productivity Analysis*, 3, 153-169.

BATTESE, G. E., RAO, D. P. & O'DONNELL, C. J. 2004. A meta-frontier production function for estimation of technical efficiencies and technology gaps for firms operating under different technologies. *Journal of Productivity Analysis*, 21, 91-103.

BHASKAR, A. & BEGHIN, J. C. 2009. How coupled are decoupled farm payments? A review of the evidence. *Journal of Agricultural and Resource Economics*, 34, 130-153.

BRÜMMER, B., GLAUBEN, T. & THIJSSEN, G. 2002. Decomposition of productivity growth using distance functions: the case of dairy farms in three European countries. *American Journal of Agricultural Economics*, 84, 628-644.

CARROLL, J., THORNE, F. & NEWMAN, C. 2008. An Examination of the Productivity of Irish Agriculture in a Decoupled Policy Environment. *End of Project Report, RMIS: 5507*.

COELLI, T. & PERELMAN, S. 1999. A comparison of parametric and non-parametric distance functions: With application to European railways. *European Journal of Operational Research*, 117, 326-339.

COELLI, T. & PERELMAN, S. 2000. Technical efficiency of European railways: a distance function approach. *Applied Economics,* 32, 1967-1976.

EUR-LEX. 2003. Council Regulation (EC) No 1782/2003 of 29 September 2003 establishing common rules for direct support schemes under the common agricultural policy and establishing certain support schemes for farmers. *In:* COUNCIL, E. (ed.). Brussels: Official Journal of the European Union L 270.

EUR-LEX. 2008. Commission Regulation (EC) No 1242/2008 of 8 December 2008 establishing a Community typology for agricultural holdings. *In:* COUNCIL, E. (ed.). Brussels: Official Journal of the European Union L 335.

EUR-LEX. 2009. Council Regulation (EC) No 73/2009 of 19 January 2009 establishing common rules for direct support schemes for farmers under the common agricultural policy and establishing certain support schemes for farmers. *In:* COUNCIL, E. (ed.). Brussels: Official Journal of the European Union L 30.

EUROPEAN COMMISSION. 2012. Community Committee for the Farm Accountancy Data Network. Farm Return Data Definitions. Accounting year 2011. Brussels: European Commission.

EUROPEAN COMMISSION. 2015a. Evaluation of Article 68 measures. Agrosinergie EEIG (ed.). Brussels: European Commission.

EUROPEAN COMMISSION. 2015b. Voluntary coupled support – Sectors mostly supported. Notification of decisions taken by Member states by 1 August 2014. Brussels: European Commission.

EUROEPAN COMMISSION, 2016. Direct payments 2015-2020. Decisions taken by Member States: State of play as at June 2016. Brussels: European Commission.

EUROPEAN COURT OF AUDITORS. 2011. Single Payment Scheme (SPS): Issues to be Addressed to Improve its Sound Financial Management. Luxembourg: European Court of Auditors.

EUROPEAN COURT OF AUDITORS. 2012. Suckler cow and ewe and goat direct aids under partial implementation of SPS arrangements. Luxembourg: European Court of Auditors.

EUROPEAN COURT OF AUDITORS. 2013. Common Agricultural Policy: Is the specific support provided under article 68 of Council Regulation (EC) No 73/2009 well designed and implemented?. Luxembourg: European Court of Auditors.

EUROSTAT 2015a. Agricultural production - Animals [Online]. Eurostat. Available: http://ec.europa.eu/eurostat/statistics-explained/index.php/Agricultural_production_-_animals [Accessed 17/11/2016 2016].

EUROSTAT 2015b. Agriculture, forestry and fishery statistics. In: EUROSTAT (ed.) Eurostat Statistical Books. Luxembourg: Eurostat.

FÄRE, R. & PRIMONT, D. 1995. *Multi-Output Production and Duality: Theory and Applications*, Boston: Kluwer Academic Publishers.

FARRELL, M. J. 1957. The measurement of productive efficiency. *Journal of the Royal Statistical Society. Series A (General)*, 120, 253-290.

FOGARASI, J. & LATRUFFE, L. 2009. Farm performance and support in Central and Western Europe: A comparison of Hungary and France. Conference of the Agricultural Economics Society, Dublin, Ireland.

HADLEY, D. 2006. Patterns in Technical Efficiency and Technical Change at the Farm-level in England and Wales, 1982–2002. *Journal of Agricultural Economics*, 57, 81-100.

HILL, B. & DAVIDOVA, S. 2012. *Understanding the common agricultural policy*, Earthscan London.

HUANG, C. J., HUANG, T.-H. & LIU, N.-H. 2014. A new approach to estimating the meta-frontier production function based on a stochastic frontier framework. *Journal of Productivity Analysis*, 42, 241-254.

IRZ, X. & THIRTLE, C. 2004. Dual technological development in Botswana agriculture: a stochastic input distance function approach. *Journal of Agricultural Economics,* 55, 455-478.

KAZUKAUSKAS, A., NEWMAN, C. & SAUER, J. 2014. The impact of decoupled subsidies on productivity in agriculture: a cross-country analysis using microdata. *Agricultural Economics*, 45, 327-336.

KLEINHANß, W., MURILLO, C., SAN JUAN, C. & SPERLICH, S. 2007. Efficiency, subsidies, and environmental adaptation of animal farming under CAP. *Agricultural Economics,* 36, 49-65.

KUMBHAKAR, S. C. & KNOX LOVELL, C. A. 2000. *Stochastic frontier analysis*, Cambridge University Press.

LATRUFFE, L. 2010. Competitiveness, productivity and efficiency in the agricultural and agri-food sectors. OECD Publishing.

LATRUFFE, L., BRAVO-URETA, B. E., MOREIRA, V. H., DESJEUX, Y. & DUPRAZ, P. 2012. Productivity and subsidies in the european union: An analysis for dairy farms using input distance frontiers. International Association of Agricultural Economists 2012 Conference, August 18-24, Foz do Iguacu, Brazil.

LATRUFFE, L., BRAVO-URETA, B. E., CARPENTIER, A., DESJEUX, Y. & MOREIRA, V. H. 2016. Subsidies and Technical Efficiency in Agriculture: Evidence from European Dairy Farms. *American Journal of Agricultural Economics,* Advance access.

MCCLOUD, N. & KUMBHAKAR, S. C. 2008. Do subsidies drive productivity? A cross-country analysis of Nordic dairy farms. *Advances in Econometrics,* 23, 245-274.

MINVIEL, J. J. & LATRUFFE, L. 2016. Effect of public subsidies on farm technical efficiency: a meta-analysis of empirical results. *Applied Economics*, 49, 213-226.

NEWMAN, C. & MATTHEWS, A. 2007. Evaluating the productivity performance of agricultural enterprises in Ireland using a multiple output distance function approach. *Journal of Agricultural Economics*, 58, 128-151.

O'DONNELL, C. J. & COELLI, T. J. 2005. A Bayesian approach to imposing curvature on distance functions. *Journal of Econometrics,* 126, 493-523.

O'DONNELL, C. J., RAO, D. P. & BATTESE, G. E. 2008. Meta-frontier frameworks for the study of firm-level efficiencies and technology ratios. *Empirical Economics*, 34, 231-255.

PREHN, S., BRÜMMER, B. & THOMPSON, S. R. 2015. Payment decoupling and intra-european calf trade. *European Review of Agricultural Economics,* 42, 625–650.

RASMUSSEN, S. 2010. Scale efficiency in Danish agriculture: an input distance function approach. *European Review of Agricultural Economics*, 37, 335-36

RENWICK, A., JANSSON, T., THOMSON, S., REVOREDO-GIHA, C., BARNES, A. & SCHWARZ, G. 2011. The economic impact of allowing partial decoupling under the 2003 Common Agricultural Policy reforms. *In:* MOREDDU, C. (ed.) *Disaggregated Impacts of CAP Reforms.* OECD Publishing.

RIZOV, M., POKRIVCAK, J. & CIAIAN, P. 2013a. CAP Subsidies and Productivity of the EU Farms. *Journal of Agricultural Economics,* 64, 537-557.

THORNE, F., DILLON, E., DONNELLAN, T., HANRAHAN, K., HENNESSY, T., KINSELLA, A., LAEPPLE, D. & MCKEON, M. 2015. A Review of the Financial Status of Irish Farms and Future Investment Requirements. Ireland: Teagasc/Bank of Ireland.

VROLIJK, H. C. J., DE BONT, C. J. A. M., BLOKLAND, P. W. & SOBOH, R. A. M. E. 2010. Farm viability in the European Union. Assessment of the impact of changes in farm payments. The Hague: LEI-WAGENINGEN, UR.

ZHU, X., DEMETER, R. M. & LANSINK, A. O. 2012. Technical efficiency and productivity differentials of dairy farms in three EU countries: The role of CAP subsidies. *Agricultural Economics Review,* 13, 66-92.

ZHU, X. & LANSINK, A. O. 2010. Impact of CAP subsidies on technical efficiency of crop farms in Germany, the Netherlands and Sweden. *Journal of Agricultural Economics,* 61, 545-564.

APPENDIX I. Subsidy implementation by country.

	Implementation year	Implementation model	Decoupling	Coupled support		Optional specific support
Ireland	*2005*	Historical	Full	-		*2008-2012* Suckler Cow Herd Welfare and Quality Scheme
Germany	*2005*	Dynamic hybrid	Full	-		-
France	*2006*	Historical	Partial	*2006-2009* Suckler cow premium 100 %[a] Slaughter premium bovine adults 40%[a] Slaughter premium calves 100 %[a]	*2010-2012* Suckler cow premium 75 %[a]	*2010-2013* Aid for calves from suckling cows, for organic and labelled calves
UK(Scotland)	*2005*	Historical	Full	-		*2012-2013* Scottish Beef Scheme
UK(England and Wales)	*2005*	Dynamic hybrid (England)/Historical (Wales)	Full	-		-

[a] % of the component of national ceilings. Recall, each coupled payment maintained had a fixed ceiling, equal (i.e. 100%) to or less (i.e. 40%) than the component of each type of pre MTR direct payment used to calculate the national ceilings (see footnote 3 for definition).

APPENDIX II. Distance function parameters.

	Ireland	France	Germany	Scotland	England/Wales
Constant	-0.164*** (0.031)	-0.065*** (0.017)	-0.062*** (0.023)	-0.239*** (0.064)	-0.071** (0.035)
Land	-0.244*** (0.031)	-0.267*** (0.020)	-0.093*** (0.026)	-0.255*** (0.039)	-0.124*** (0.030)
Labour	-0.145*** (0.036)	-0.131*** (0.020)	-0.146*** (0.031)	-0.200*** (0.038)	-0.230*** (0.043)
Capital	-0.227*** (0.021)	-0.155*** (0.016)	-0.124*** (0.020)	-0.126*** (0.037)	-0.189*** (0.031)
Other costs	-0.627*** (0.028)	-0.449*** (0.017)	-0.701*** (0.019)	-0.484*** (0.043)	-0.556*** (0.038)
Other output	0.249*** (0.009)	0.308*** (0.002)	0.489*** (0.005)	0.422*** (0.016)	0.410*** (0.010)
Area^2	0.043 (0.055)	-0.105*** (0.035)	-0.011 (0.024)	0.052 (0.055)	-0.038 (0.044)
Area x Labour	-0.060 (0.040)	0.006 (0.029)	-0.006 (0.028)	0.061 (0.058)	0.071 (0.047)
Area x Capital	-0.033 (0.022)	-0.018 (0.020)	-0.040*** (0.014)	-0.039 (0.036)	-0.029 (0.031)
Area x Other costs	0.015 (0.035)	0.124*** (0.019)	0.072*** (0.013)	0.116** (0.049)	0.089** (0.038)
Labour^2	-0.090* (0.050)	-0.149** (0.058)	-0.019 (0.061)	-0.041 (0.130)	0.047 (0.080)
Labour x Capital	-0.050** (0.023)	-0.022 (0.023)	-0.011 (0.022)	0.013 (0.077)	-0.103** (0.042)
Labour x Other costs	0.122*** (0.038)	0.119*** (0.026)	0.050** (0.025)	-0.138* (0.083)	0.042 (0.052)
Capital^2	-0.038*** (0.013)	-0.088*** (0.005)	-0.034*** (0.006)	-0.063 (0.063)	-0.097** (0.042)
Capital x Other costs	0.057*** (0.020)	0.120*** (0.014)	0.071*** (0.011)	0.056 (0.055)	0.118*** (0.041)
Other costs^2	-0.197*** (0.037)	-0.300*** (0.023)	-0.158*** (0.015)	-0.174** (0.082)	-0.228*** (0.053)
Other output^2	0.080*** (0.002)	0.061*** (0.000)	0.118*** (0.001)	0.109*** (0.006)	0.132*** (0.002)
Area x Other output	0.028*** (0.006)	-0.008*** (0.003)	-	0.015 (0.022)	0.042*** (0.010)
Labour x Other output	-0.003 (0.008)	0.020*** (0.004)	-	-0.081** (0.038)	-0.068*** (0.016)
Capital x Other output	-0.020*** (0.004)	-0.014*** (0.003)	-	0.052** (0.022)	-0.052*** (0.010)
Other costs x Other output	-0.027*** (0.006)	0.013*** (0.003)	-	-0.100*** (0.025)	0.048*** (0.013)
Time	-0.004 (0.010)	-0.056*** (0.005)	-0.060*** (0.009)	-0.101*** (0.015)	-0.074*** (0.012)
Time^2	0.000 (0.001)	0.004*** (0.001)	0.003*** (0.001)	0.009*** (0.001)	0.006*** (0.001)
Time x Area	-0.004	0.017***	0.013***	-	0.001

	(0.005)	(0.003)	(0.003)		(0.006)
Time x Labour	0.007	0.002	0.003	-	0.009
	(0.006)	(0.004)	(0.005)		(0.008)
Time x Capital	0.015***	-0.008***	0.002	-	0.006
	(0.003)	(0.002)	(0.003)		(0.006)
Time x Other costs	-0.010**	-0.021***	-0.016***	-	-0.014*
	(0.005)	(0.003)	(0.003)		(0.008)
Time x Other output	0.018***	0.001***	0.002*	-	0.019***
	(0.002)	(0.000)	(0.001)		(0.003)
LFA 2 (D)	0.111***	-	0.055***	0.081	0.080***
	(0.020)		(0.012)	(0.050)	(0.019)
LFA 3 (D)	-	0.192***	-	-	-
		(0.017)			
λ	1.408***	1.576***	1.679***	1.489***	1.685***
	(0.031)	(0.014)	(0.020)	(0.038)	(0.029)
σ_u	0.360***	0.283***	0.355***	0.243***	0.311***
	(0.004)	(0.001)	(0.003)	(0.002)	(0.003)
η	-0.030***	-0.014***	-0.016***	-0.009	-0.014*
	(0.005)	(0.002)	(0.005)	(0.006)	(0.008)

Notes: Standard errors are in parentheses. *Significant at 10%; **Significant at 5%; ***Significant at 1%. (D) Indicates a dummy variable. Separability of outputs was rejected by a likelihood ratio test at the 1% level for the case of Germany, while and non-neutral technical change was rejected at the 1% level for Scotland.