GJAE 59 (2010), Number 3, Special Issue
Professional Interest, New Issues and Recent Methodological Developments in Agricultural and Resource Economics

Analysing the Effect of Decoupling on Agricultural Production: Evidence from Irish Dairy Farms using the Olley and Pakes Approach

Wirkungen der Entkopplung auf die landwirtschaftliche Produktion: eine empirische Analyse für irische Milchviehbetriebe mit dem Ansatz von Olley und Pakes

Andrius Kazukauskas and Carol Newman
Trinity College Dublin, Ireland

Fiona Thorne
Rural Economy Research Centre, Teagasc, Dublin, Ireland

Abstract

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

Key words

productivity; semiparametric estimation; dairy farming; decoupling; Ireland

Zusammenfassung

Die jüngsten Reformen der Gemeinsamen Agrarpolitik haben dazu geführt, dass Direktzahlungen an Landwirte von der Produktion entkoppelt wurden. Von diesem Politikwandel wird erwartet, dass sich die Produktionsentscheidungen der Landwirte zukünftig weniger an staatlichen Stützungsmaßnahmen und mehr am Ziel der Gewinnmaximierung auf freien Märkten orientieren. In diesem Beitrag untersuchen wir Auswirkungen der Entkopplung auf die Produktivität von irischen Milchviehbetrieben und verwenden dabei eine modifizierte Fassung des Ansatzes von Olley und Pakes zur Schätzung der Produktivitäten. Bei der Wirkungsanalyse zur Entkoppelung wird im Modellansatz berücksichtigt, dass auch noch andere Politikänderungen neben der Entkopplung der Direktzahlungen stattgefunden haben. Im Zusammenhang mit der zunehmenden Preisvolatilität auf Agrarmärkten werden zudem Auswirkungen von Unsicherheit auf die Produktionsentscheidungen der Landwirte in der Nach-Entkoppelungs-Phase herausgearbeitet.

Schlüsselwörter

Produktivität; semiparametrische Schätzung; Milchproduktion; Entkoppelung; Irland

1 Introduction

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

Stochastic Frontier Approach. Using the former allows us to explain, in part, why previous studies may have failed to find a significant effect of decoupling on productivity.

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

There are a number of possible reasons why empirical studies to date have struggled to find a significant relationship between the decoupling policy and productivity/efficiency in the dairy sector. First, the introduction of the decoupling policy coincided with increased uncertainty due to greater price volatility in international dairy product markets. HENNESSY (1998) shows that support policies that are decoupled affect the decisions of risk-averse producers when there is uncertainty (ex-ante analysis). Faced with such uncertainty farmers may react differently to decoupling than would otherwise be the case. Second, the decrease in dairy product market support (such as the market intervention price) and the increase in milk quotas that have been introduced alongside the decoupling of payments make it difficult to disentangle the effects of the different policy changes. Third, lucrative capital grants given to farmers post-decoupling may have encouraged unprofitable farmers to make bad capital investment decisions made possible by the buffer of the SFP to subsidize production activities.[1] Fourth, most empirical investigations relying on the Stochastic Frontier Approach fail to explicitly control for simultaneity and selection biases in estimating production function parameters and resultant productivity or efficiency estimates (MATTHEWS et al., 2006; NEWMAN and MATTHEWS, 2006; ABDULAI and TIETJE, 2007; MATTHEWS et al., 2007; NEWMAN and MATTHEWS, 2007; CARROLL et al., 2008; HASSINE and KANDIL, 2009; CARROLL et al., 2010).

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

This paper is structured as follows. Section 2 provides the methodologies used for estimating productivity. Section 3 presents data related issues and the descriptive statistics for inputs and output. Section 4 discusses the main results and section 5 concludes.

2 Empirical Approach

In order to obtain estimates of farm level productivity changes we employ two methods which differ in the way in which they deal with simultaneity and selection bias. The simultaneity problem affects the coefficients on the inputs in the production function. Productivity is unobservable to the econometrician but is known by the farmer and so will affect his choices in relation to input usage. This correlation between unobserved productivity and inputs causes simultaneity bias when we use simple econometric techniques for estimating the production function parameters. Selec-

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

tion bias arises due to the correlation between farm exit decisions and productivity. The estimates of productivity depend on the estimates of the input coefficients. Therefore, consistent estimation of the input coefficients is crucial for consistent productivity estimates. Both potential biases must therefore be carefully addressed.

We start by assuming a Cobb-Douglas production function:

$$(1) \quad \ln y_i = \beta_0 + \sum_{k=1}^{K} \beta_k \ln x_{ki} + e_i$$

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

There is a second endogeneity problem present when using OLS to estimate the parameters of equation (1). If farms have knowledge of their productivity level (e_i) prior to exiting the sector, farms that continue to produce will be a selected group that will be partially determined by fixed inputs such as capital. The farms with a higher capital stock are expected to have a smaller probability of exiting the sector. This endogeneity problem can cause a downward bias in the coefficients on fixed inputs such as capital (ACKERBERG et al., 2007).[2]

The Stochastic Frontier Approach, originally proposed by AIGNER et al. (1977) and MEEUSEN and VAN DEN BROECK (1977), deals with the simultaneity problem by imposing a structure on the distribution of the part of the error term that captures technical efficiency. To demonstrate we use the PITT and LEE (PL) (1981) and the BATTESE and COELLI (BC) (1992) models. Using this approach, Equation (1) is simply extended to a general panel data specification by adding the subscript *t* to output, inputs and the error term. We first assume a time-invariant inefficiency term (PITT and LEE, 1981):

$$(2) \quad \ln y_{it} = \beta_0 + \sum_{k=1}^{K} \beta_k \ln x_{kit} + v_{it} - u_i$$

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

$$(3) \quad u_{it} = u_i \times \exp[-\eta(t-T)]$$

where $t=1,2,....,T$ is time and η is a parameter to be estimated. In the Stochastic Frontier Approach simultaneity bias is eliminated by assuming that the inefficiency term is independent and identically distributed. This assumption may be wrong for a number of reasons. For example, it could be that the inefficiency term is a function of farm specific variables (such as farm size in terms of capital, land, etc) or/and the last period farm productivity or efficiency level. Furthermore, selection bias is ignored. However, using such an approach, or any of its many extensions, to measure the productivity of agricultural enterprises is attractive given the homogeneity of the technology employed and, at least within EU countries, the artificial incentives to remain in production even if unprofitable, thus reducing the possibility of selection bias. However, as the sector moves in a more market-oriented direction, the need to explicitly control for simultaneity and selection bias becomes necessary. Previous studies which have used this approach may not be appropriate for linking policy changes to TFP in the future.

To address these issues we consider the semi-parametric approach to estimating productivity proposed by OLLEY and PAKES (1996). The outline of the OP procedure presented here closely follows the expositions by VAN BIESEBROECK (2003), PAVCNIK (2002) and RIZOV and WALSH (2008). The production function to be estimated is given by:

$$(4) \quad \begin{aligned} \ln y_{it} &= \beta_0 + \beta_l \ln l_{it} + \beta_d \ln d_{it} + \\ &+ \beta_h \ln h_{it} + \beta_k \ln k_{it} + \beta_a \ln a_{it} + w_{it} + v_{it} \end{aligned}$$

where y_{it} is the farm's output level, l_{it}, d_{it} and h_{it} are labour, direct costs and herd inputs respectively, which are adjustable over one time period; k_{it} and a_{it} are capital and land variables which are quasi-fixed

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

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

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

$$V(k_{it}, a_{it}, l_{it}, h_{it}, d_{it}, w_{it}) = \max \begin{Bmatrix} L_{it}, \Pi(k_{it}, a_{it}, l_{it}, h_{it}, d_{it}, w_{it}) - \\ -c(i_{it}) + \rho E\left[V_{it+1}(.) \middle| \Omega_{it}\right] \end{Bmatrix} \quad (5)$$

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

$$X_{it} = \begin{cases} 1, if\ w_{it} \geq \varpi_{it}(k_{it}, a_{it}) \\ 0, \quad otherwise \end{cases} \quad (6)$$

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

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

The productivity/investment relationship can be inverted by expressing productivity as an unknown function of investment, capital, land and farm-specific characteristics, $w_{it} = i_{it}^{-1}(k_{it}, i_{it}, a_{it}, z_{it})$, relying on the assumption that there is only one unobserved farm specific variable (w_{it}) and that investment is increasing in w_{it}. Substituting this expression into the production function given in Equation (4) gives the estimating equation for the first step.

$$\begin{aligned} \ln y_{it} &= \beta_0 + \beta_l \ln l_{it} + \beta_d \ln d_{it} + \\ &+ \beta_h \ln h_{it} + \phi_t(k_{it}, a_{it}, i_{it}, z_{it}) + v_{it} \end{aligned} \quad (7)$$

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

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

$$\begin{aligned} w_{it} &= E\left[w_{it} \mid \Omega_{it-1}\right] + \xi_{it} \\ w_{it} &= E\left[w_{it} \mid w_{it-1}\right] + \xi_{it} \\ w_{it} &= g\left(w_{it-1}\right) + \xi_{it} \end{aligned} \quad (8)$$

ξ_{it} is not correlated with the state variables at time *t* as these variables are only functions of the information available at time *t-1*. Substituting Equation (8) into Equation (4) yields:

$$\begin{aligned}(9)\quad &\ln y_{it} = \beta_0 + \beta_l \ln l_{it} + \beta_d \ln d_{it} + \beta_h \ln h_{it} + \\ &+ \beta_k \ln k_{it} + \beta_a \ln a_{it} + g(w_{it-1}) + \xi_{it} + v_{it}\end{aligned}$$

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

$$\begin{aligned}(10)\quad &\ln y_{it} - \hat{\beta}_0 - \hat{\beta}_l \ln l_{it} - \hat{\beta}_d \ln d_{it} - \hat{\beta}_h \ln h_{it} = \\ &= \beta_k \ln k_{it} + \beta_a \ln a_{it} + g(i_{it-1}^{-1}(.)) + \kappa_{it}\end{aligned}$$

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

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

$$\begin{aligned}&w_{it} = E\left[w_{it} \mid \Omega_{it-1}, X_{it} = 1\right] + \xi_{it} \\ (11)\quad &w_{it} = E\left[w_{it} \mid w_{it-1}, X_{it} = 1\right] + \xi_{it} \\ &w_{it} = \gamma\left(w_{it-1}, \varpi_{it}\right) + \xi_{it}\end{aligned}$$

This leads us to the following production function in place of equation (10):

$$\begin{aligned}(12)\quad &\ln y_{it} - \hat{\beta}_0 - \hat{\beta}_l \ln l_{it} - \hat{\beta}_d \ln d_{it} - \hat{\beta}_h \ln h_{it} = \\ &= \beta_k \ln k_{it} + \beta_a \ln a_{it} + \gamma(i_{it-1}^{-1}(.), \varpi_{it}) + \kappa_{it}\end{aligned}$$

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

It is widely assumed in the market exit literature that efficient firms are more likely to survive. TSIONAS and PAPADOGONAS (2006) explicitly link stochastic measures of technical efficiency to the likelyhood of market exit. DIMARA (2008) find that high levels of technical efficiency increase median survival times and lower the hazard rate of exit in general. We assume that the probability of staying in business is not only a function of ϖ_{it} but also of farm-specific characteristics z_{it}. We predict the probability of survival using a Tobit model[3]:

$$\begin{aligned}&e_{it} = \sum \theta_z z_{it} + \overline{w}_{it} + \varsigma_{it} \\ (13)\quad &e_{it} = \sum \theta_z z_{it} + \Gamma_{it}(k_{it}, a_{it}, i_{it}) + \varsigma_{it}\end{aligned}$$

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

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

$$\begin{aligned}(14)\quad &\ln y_{it} - \hat{\beta}_l \ln l_{it} - \hat{\beta}_d \ln d_{it} - \hat{\beta}_h \ln h_{it} = \\ &= \beta_k \ln k_{it} + \beta_a \ln a_{it} + \\ &+ \gamma(\hat{\phi}_{t-1} - \beta_k \ln k_{it-1} - \beta_a \ln a_{it-1}, \hat{P}_{it-1}) + v_{it}\end{aligned}$$

The capital and land coefficients can be estimated in the last step using NLLS. Similar to the first stage, γ (.) is approximated nonparametrically by a fourth-order polynomial.[4] The estimated coefficients are used to calculate the productivity term:

$$\begin{aligned}(15)\quad &tfp_{it} = \exp(\ln y_{it} - \hat{\beta}_l \ln l_{it} - \hat{\beta}_d \ln d_{it} - \\ &- \hat{\beta}_h \ln h_{it} - \hat{\beta}_k \ln k_{it} - \hat{\beta}_a \ln a_{it})\end{aligned}$$

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

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

3 Data

The data used for estimating the productivity of Irish dairy farms are taken from the National Farm Survey (NFS). The NFS is conducted annually by Teagasc, the Irish Agricultural and Food Authority. The sample is based on a stratified random sample, representing farm size and system of production. In this paper, we focus on the production function for the main output of dairy farms, i.e. milk production. Inputs, which are not directly assigned to milk production, are allocated proportionally to a share of milk output in total farm output. A balanced panel dataset comprising 101 farms and a full unbalanced sample with 507 farms are used (see table 1 for two sample descriptive statistics). The balanced sample is used as a robustness check.

Output is measured using total milk sales deflated according to the Irish Central Statistics Office (CSO) milk price index. A value figure is chosen over quantity due to the fact that milk differs in quality across farms. The deflated value takes into account quality differences (CARROLL et al., 2010).

Labour, capital, herd size, direct costs and land are used as the production inputs. Allocated values of family, casual and hired labour to dairy farming are used as the labour input. The value input was chosen over a labour unit variable for similar reasons to the output variable. The quality of casual and hired labour is quite different across farms. These labour quality differences are reflected in different wage rates. The herd input is calculated as average herd size (cow numbers). The direct cost input includes expenses on concentrates, feeds, fuels, electricity, vet services/ medicines and other miscellaneous direct costs. The capital input includes the estimated value (by farmer) of machines and buildings. Acres devoted for the feed area are used as the land input. When inputs are not explicitly assigned to dairy farm activity in the data, they are allocated according to the proportion of dairy gross output in total gross output. This allocation approach was also used by THORNE and FINGLETON (2005) and by CARROLL et al. (2010) for NFS data. All variables are deflated using price indices which are available from EUROSTAT except for the labour input variable which is deflated by the agricultural average wage rate (AAWR). Table 1 presents descriptive statistics of all variables used in our analysis.

Table 2 provides an indication of the possible importance of accounting for selection bias in the

Table 1. Descriptive Statistics for Farms in the NFS Representative Sample 2001-2007*

Variable	balanced		full	
	Obs	Mean	Obs	Mean
Output, EUR	707	107 010	1 959	89 995
Capital, EUR	707	78 887	1 959	65 696
Land, acres	707	83.94	1 959	74.95
Labour, units	707	1.37	1 959	1.28
Herd size, cow No.	707	67.05	1 959	58.20
Direct costs, EUR	707	35 392	1 959	30 725
Soil type 1, D	707	0.56	1 959	0.56
Soil type 2, D	707	0.38	1 959	0.37
Soil type 3, D	707	0.06	1 959	0.07
Children, D	707	0.56	1 959	0.54
Off-farm job, D	707	0.09	1 959	0.10

* The 2001-2007 period is selected since we are interested in exploring the most recent developments in the dairy sector and we want to compare farm productivity dynamics in the post-1999 CAP reform era with the productivity dynamics in the decoupled payment environment after 2005. D stands for a dummy variable. Soil type 1 represents the best quality land.
Source: own computations

Table 2. Possible Selection Bias: Capital Intensity and How Often Farms Appeared in the NFS Representative Sample 2001-2007

	>=6		<6		>=3		<3	
Variable	**Obs**	**Mean**	**Obs**	**Mean**	**Obs**	**Mean**	**Obs**	**Mean**
Output, EUR	1 073	103 233	886	73 963	1 695	93 234	264	69 203
Capital in 10 000 EUR	1 073	7.56	886	5.37	1 695	6.81	264	5.06
Labour, Units	1 073	13 209	886	11 032	1 695	12 491	264	10 511
Herd, Cow no.	1 073	64	886	51	1 695	60	264	48
Direct Costs, EUR	1 073	34 920	886	25 644	1 695	31 757	264	24 096
Land, Acres	1 073	81	886	67	1 695	76	264	66
SOIL1, D	1 073	0.59	886	0.52	1 695	0.57	264	0.52
SOIL3, D	1 073	0.06	886	0.07	1 695	0.07	264	0.06
CHILD, D	1 073	0.57	886	0.51	1 695	0.54	264	0.54
OFFFARM, D	1 073	0.1	886	0.11	1 695	0.1	264	0.11
Capital/Labour	**5.47**		**4.62**		**5.2**		**4.49**	

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

Table 3. Input Elasticities

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

Note: The negative land elasticity result may be caused by the large quantity of under-resourced land in Irish agriculture(see CARROLL (2008) for more discussion). The bootstrapped standard errors are presented for the capital and labour elasticities in the modified OP models. Standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1).
Source: own computations

representative NFS sample. To demonstrate the importance of farm exit, we divide the 2001-2007 NFS dairy farm sample into four subsamples according to how many times the farms appeared in the NFS.[5] First, we divide the sample into two subsamples: one subsample consisting of farms which appeared in the NFS six or more times and the other less than six times. On average, the former subsample consists of farms which are 40 percent bigger in terms of capital. These farms are also more capital intensive. When we compare the two NFS subsamples that contain farms which appear three or more times and less than three times in the survey, respectively, the average size difference is similar. The farms which are in the sample for more time periods are more than 34 percent bigger in terms of capital and tend to be more capital intensive in their milk production.

4 Results

4.1 Production Function Results

Table 3 presents the estimates of the input coefficients (elasticities) from the production function estimations as described in section 2.[6] The production function elasticities are estimated using the full unbalanced panel data sample.

There are two reasons why we should worry about coefficients estimated using OLS. First, there is a simultaneity problem associated with input choices. The positive correlation between the productivity term and the variable inputs could lead to an upward bias in the OLS estimates. In our OP model we assume that herd, labour and direct costs are the variable inputs which can be adjusted in the same period that productivity is realized. Herd size can be adjusted to some extent in one year by transferring heifers, buying cows or selling them. Labour inputs are also assumed to be adjustable in one year since farmers usually hire casual workers for seasonal jobs, i.e. farmers can hire and lay off casual workers without high contractual costs. The direct costs such as concentrates, feed and fuel can be even more easily and faster adjusted to changing farm needs. The more severe the upward bias the easier it is to adjust the input to current realizations of productivity (OLLEY and PAKES, 1996). Comparing OLS and OP elasticity estimates of the variable inputs, it is clear that the direct cost coefficient is reduced by OP estimation. It seems that the labour and herd inputs are not very easily adjusted as their coefficients are similar to the OLS estimates. The labour, herd and direct cost coefficients estimated using SFA are somewhat smaller or similar to the OLS estimates. The direct cost coefficient drops by roughly 20 percent – much more than the coefficients on the other variable inputs. These results could suggest that SFA goes some way to addressing the simultaneity problem. Since simultaneity bias and omitted variable bias are very similar problems (endogeneity bias), they have the same solution. The simultaneity problem can be constructed as an omitted variable

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

[6] See appendix 1 for the full set of production function estimates.

problem. The inefficiency term in SFA could be seen as the omitted variable which could capture the causes of the simultaneity problem in the production function. The coefficients on capital and land are also affected by simultaneity. After correcting for selection bias the modified OP produces a much higher capital coefficient, although the coefficient is insignificant. The insignificant capital and land coefficients can be explained by the economic environment during the 2001-2007 period where higher asset values on farms meant that the sale of assets and farms was common. Thus, the more land and capital (buildings) farmers had the bigger incentives they had to sell their assets for property development regardless of productivity levels.

4.2 Probability of Exit

Next we introduce the possibility of selection bias. OP controls for selection bias using actual data on observed exits. Unfortunately, our sample has no such data. However, since we suspect possible selection bias in our sample[7], we proxy the actual exit variable using an efficiency term which we estimate using SFA for the full sample. The empirical literature suggests that technical efficiency is a good predictor for market exit (TSIONAS and PAPADOGONAS, 2006; DIMARA et al., 2008).

The probability of exit is obtained by estimating the Tobit model given in equation (10), where $\Gamma_{it}(.)$ is a fourth-order polynomial in k_{it}, a_{it} and i_{it}. The farm-specific characteristics included are soil quality, the presence of children and whether the farmer has an off-farm job. Soil quality can have a significant effect on grass yields. Larger grass mass might reduce the need to buy feed from other farms. Thus, higher quality soil can reduce direct costs and increase the farm's productivity. Having children can have a positive effect on the survival decision as having children can increase a farmer's motivation to stay in business and keep the farm business for future generations. Having an off-farm job can reduce the time the farmer can dedicate to farming activity. The less attention devoted exclusively to farming, the greater the potential for lower productivity levels and a higher probability of exit. The results of the Tobit models are presented in table 4.

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

The second problem with the estimation of the production function is that there may be a bias in the fixed variables. The estimated probability of farm survival can help us deal with the selection bias problem which can be an issue in OLS and SFA estimation. In our paper, we treat capital and land as quasi-fixed production factors. Since farms with a larger capital stock have a higher probability of staying in the dairy business, even with lower productivity levels, it is expected that this relationship can lead to a downward bias in the capital coefficient. After adjusting the OP capital coefficient estimates for this selection bias by using our estimated predicted probability of survival, we get a higher capital coefficient as expected (see table 3). The capital coefficient increases to 0.21 while the OLS estimate is 0.06 and the SFA estimate is 0.05. The fact that SFA capital elasticities are even smaller than the OLS elasticities casts doubt on the robustness of SFA in estimating capital elasticities where selection bias may be an issue.[8]

4.3 Comparison of SFA and OP Productivity Estimates

OP and SFA production function elasticity estimates are used to calculate farm productivity levels. Individual farm level productivity and a productivity index are constructed using equation (11). An aggregated Irish dairy farming productivity measure is calculated annually using the NFS weights so the results are representative of the whole Irish dairy farming population.

Figure 1 presents the estimated cumulative productivity indices using SFA and OP productivity estimation techniques, with a Cobb-Douglas (CD) production function specification. Both productivity estimation techniques, SFA and OP, produce quite similar TFP trends. BATTESE and COELLI's (1992) time-variant inefficiency model with a Cobb-Douglas

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

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

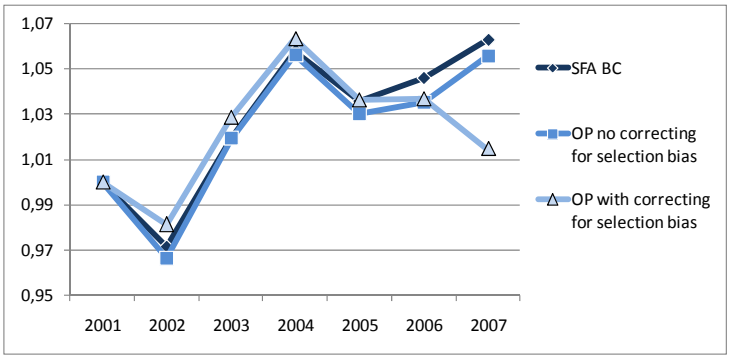
Table 4. Tobit Models of Farm Survival

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

Note: The Tobit_BC model uses a technical efficiency term estimated by BC model as the dependent variable and the Tobit_PL uses a PL efficiency term as the dependent variable. Standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1).
Source: own computations

specification shows the highest overall increase in dairy farm productivity from 2001 to 2007, i.e. 6.3 percent or a compound annual growth rate (CAGR) of 1.02 percent. Productivity, as estimated using OP before correcting for selection bias, increases by 5.6 percent (0.91 CAGR). After adjusting for selection bias there is just a 1.5 percent (0.24 CAGR) increase in productivity levels over the 2001-2007 period. The dairy sector productivity growth results using SFA and OP before correcting for selection bias are in line with the findings of NEWMAN and MATTHEWS (2006) and CARROLL (2008). Both papers use SFA for estimating the Irish dairy sector productivity growth. NEWMAN and MATTHEWS (2006) estimated 1.2 percent growth per annum over the 1984-2000 period while CARROLL (2008) estimated 1.4 percent growth over the 1996-2006 period.

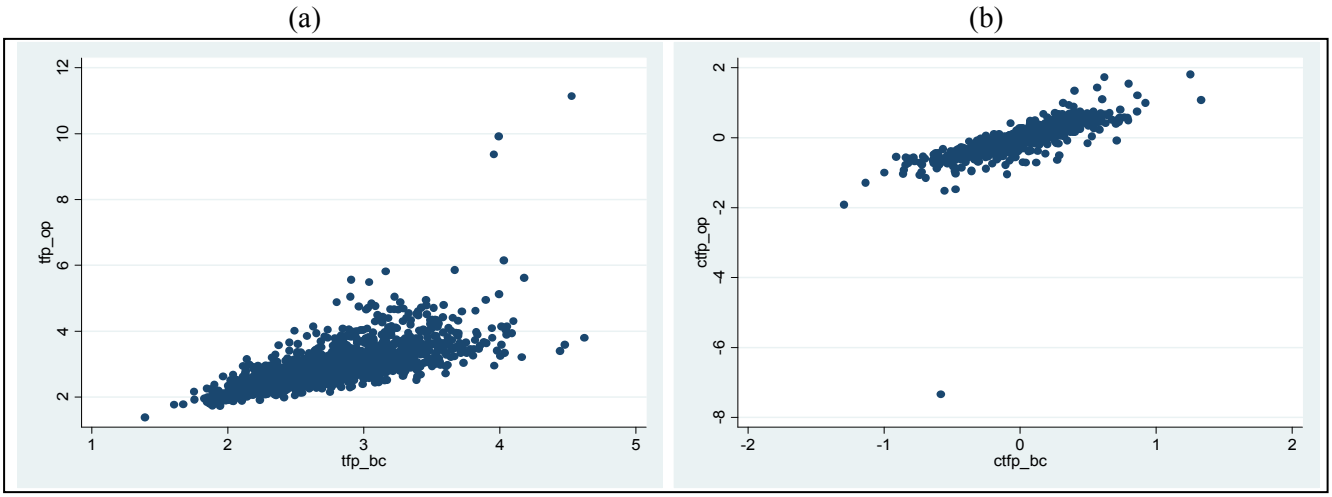
Figure 1. Productivity Indices: OP vs. SFA using the Balanced Panel



Source: own presentation

Figure 2 shows the correlation of TFP estimates using the modified OP procedure and using SFA with Battese and Coelli's time-variant inefficiency term specification. The correlation of TFP levels using different methodologies is obvious (0.71 correlation). When we compare the changes in TFP using the modified OP with the changes in TFP using SFA, we find an even stronger correlation (0.77). This result shows that both methods produce similar results in levels and in the changes in TFP. This indicates that productivity trends in figure 1 are not just similar on

Figure 2. OP after Correcting for Selection Bias vs. Battese and Coelli's Time Variant Inefficiency SFA Model with a Cobb-Douglas Specification



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

aggregate but the productivity levels and changes are also similar for individual farmers across both models.

4.4 Analysis of Productivity Trends

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

The divergence in TFP trends can largely be explained by the different capital coefficients in the estimated production functions. In 2007, the capital stock of our analyzed farms increased by more than 30 percent on average (compared with 2005), mostly encouraged by the availability of capital good grants (see appendix 2 for more details) and higher output prices. Since the models estimated using SFA produce smaller capital coefficients due to the possible selection bias problem, capital as an input is not considered to be as important as it is where OP estimation with the correction for selection bias is applied. The huge increase in capital and small increase in output therefore leads to a decrease in TFP levels using the OP approach with the correction for selection bias. Meanwhile SFA models weight capital with less importance in the production process, and the increase in output accompanied by a relatively smaller increase in other inputs (except capital) yields an increase in the level of TFP.[9]

4.5 Analysis of Variation in Farm-level Productivity

Before analysing the decoupling effect on dairy farmers' productivity, it is important to understand the environment in which the dairy farmers operated during the 2005-2007 period. Uncertainty about the SFP scheme in 2005 and increased milk price volatility potentially had an influence on farmers' confidence/motivation. This uncertainty possibly encouraged many dairy farmers to postpone capital investment (investment in new buildings dropped by 3 percent in 2005). In 2006, capital investment in new buildings jumped to almost 5,560 euros from 3,850 euros per farm as farmers' confidence in business prospects and the reformed agricultural policy improved (see appendix 2). 2007 was unprecedented for dairy farmers as milk prices increased dramatically, boosting confidence even further. Investment in new buildings jumped to 18,800 euros per farm.[10] Mean-

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

[10] In 2007 investment in new buildings increased fivefold and grants in relation to new farm buildings increased by 18 times compared to 2005 (see appendix 2). All

while, output increased just marginally. It could be that the huge fluctuations in capital investment during the 2005-2007 period led to negative productivity changes, which dominated possible productivity increases due to the introduction of decoupling in 2005. Possible channels for these productivity improvements due to decoupling include reductions in production costs due to the increased competition in the milk product market, increased specialization in more profitable products, more profitable product introduction in farm production or ceasing production of less profitable farm products.

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

$$(16)\quad pr_{it} = \alpha_0 + \alpha_t Time_t + \alpha_{dd} DD_t + \alpha_p \ln P_t + \alpha_i \ln I_{i,t-1} + \alpha_t \ln INT_t + \alpha_{wd} WD_t + \alpha_z Z_{it} + \zeta_{it}$$

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

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

The first column of table 5 presents the results of the productivity model given in Equation (16), excluding the intervention price and lagged investment. We find that during the decoupling period productivity is lower as indicated by the negative and significant coefficient on the decoupling dummy. However, after controlling for the increased price uncertainty using the intervention prices, we find a positive and signifi-

Table 5. Analysis of the Effect of Decoupling on Productivity

	1	2	3	4	5	6
COEFFICIENT	**Full Sample**			**Balanced Sample**		
lnP	-0.2104***	-0.2025***	-0.0863	0.0031	0.0191	0.0519
	0.0492	0.0548	0.0537	0.0424	0.0455	0.0487
Time	0.0113***	0.0038	0.0224***	0.0036	-0.0015	0.0038
	0.0042	0.0043	0.0079	0.0042	0.0046	0.0065
DD	-0.0290*	0.0054	0.0722**	-0.0069	0.0100	0.0293
	0.0164	0.0175	0.0302	0.0151	0.0162	0.0227
SOIL1	0.0377**	0.0424**	0.0422**	0.0446	0.0460*	0.0460*
	0.0181	0.019	0.0189	0.0277	0.0262	0.0262
SOIL3	-0.0278	-0.0302	-0.0303	-0.0720	-0.0685	-0.0686
	0.0289	0.0303	0.0303	0.0478	0.0487	0.0487
CHILD	0.0322**	0.0318**	0.0325**	0.0017	0.0013	0.0015
	0.0149	0.0157	0.0158	0.0233	0.0221	0.0221
OFFFARM	-0.0156	-0.0279	-0.0284	-0.0622	-0.0559	-0.0556
	0.0235	0.0241	0.024	0.0392	0.0388	0.0389
WD	-0.0177*	-0.0208*	-0.0377**	-0.0094	-0.0142	-0.0190
	0.01	0.0118	0.0154	0.0085	0.0089	0.0096
$lnI_{i,t-1}$	-	-0.0225***	-0.0226***	-	-0.0200***	-0.0200***
	-	0.0047	0.0047	-	0.0059	0.0059
lnINT	-	-	0.6367***	-	-	0.1823
	-	-	0.2204	-	-	0.1552
Constant	-22.0505***	-6.7947	-49.5712***	-7.2123	3.1849	-9.0428
	8.4918	8.553	17.525	8.4234	9.2682	14.0406
Observations	1959	1519	1519	707	687	687

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

cant decoupling policy effect on productivity. The coefficient on the decoupling indicator in column 3 of table 5 suggests that decoupling increased dairy farm productivity by 7.2 percent, on average. The coefficient on lagged investment indicates that the actual investment had a negative impact on farm productivity. The 1 percent increase in investment is associated with 0.02 percent decrease in productivity. This finding supports the idea that the generous capital investment grants and small capital cost for farmers, associated with these capital investment schemes, encouraged dairy farmers to overinvest in capital stock, making farms less productive, i.e. allocatively inefficient. The coefficient on the intervention price associated with market uncertainty indicates that price uncertainty matters. The 1 percent decrease in the butter intervention price decreases dairy farm productivity by 0.6 percent.

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

The results are very similar using the balanced sample (columns 4 to 6 of table 5). After controlling for the increased price uncertainty, we again find that the decoupling dummy is positive but not significant. This result not only gives us confidence in the previous results using the full sample, but also shows that the source of the positive decoupling policy effect is not just the selection process (when the less productive farms exit), but also the production decision adjustment of the remaining farmers, making farms more market-orientated and, consequently, more productive.

5 Conclusions

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

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

References

ABDULAI, A. and H. TIETJE (2007): Estimating Technical Efficiency under Unobserved Heterogeneity with Stochastic Frontier Models: Application to Northern German Dairy Farms. In: European Review of Agricultural Economics 34 (3): 393-416.

ACKERBERG, D., L.C. BENKARD, S. BERRY and A. PAKES (2007): Econometric Tools for Analyzing Market Outcomes. In: Heckman, J.J. and E.E. Leamer (eds.): Handbook of Econometrics. Elsevier, Amsterdam: 4171-4276.

AIGNER, D., C.A.K. LOVELL and P. SCHMIDT (1977): Formulation and Estimation of Stochastic Frontier Production Function Models. In: Journal of Econometrics 6 (1): 21-37.

BATTESE, G.E. and T.J. COELLI (1992): Frontier Production Functions, Technical Efficiency and Panel Data: With an Application to Paddy Farmers in India. In: Journal of Productivity Analysis 3 (1): 153-169.

BOUAMRA-MECHEMACHE, Z., R. JONGENEEL and V. REQUILLART (2008): Impact of a Gradual Increase in Milk Quotas on the EU Dairy Sector. In: European Review of Agricultural Economics 35 (4): 461-491.

CARROLL, J. (2008). Productivity of Irish Agriculture. MLit Thesis, Trinity College Dublin.

CARROLL, J., C. NEWMAN and F. THORNE (2010). A Comparison of Stochastic Frontier Approaches to Estimating Inefficiency and Total Factor Productivity: An Application to Irish Dairy Farming. In: Applied Economics (Forthcoming).

CARROLL, J., F. THORNE and C. NEWMAN (2008). An Examination of the Productivity of Irish Agriculture in a Decoupled Policy Environment. Teagasc End of Project Report Number 5507, Carlow, Ireland.

DIMARA, E., D. SKURAS, K. TSEKOURAS and D. TZELEPIS (2008): Productive Efficiency and Firm Exit in the Food Sector. In: Food Policy 33 (2): 185-196.

HASSINE, N.B. and M. KANDIL (2009): Trade Liberalisation, Agricultural Productivity and Poverty in the Mediterranean Region. In: European Review of Agricultural Economics 36 (1): 1-29.

HENNESSY, D. (1998): Production Effects of Income Support under Uncertainty. In: American Journal of Agricultural Economics 80 (1): 46-57.

HOWLEY, P., T. DONNELLAN and K. HANRAHAN (2009). The 2003 CAP Reform: Do Decoupled Payments Affect Agricultural Production? RERC Working Papers, Teagasc, Dublin, Ireland.

MATTHEWS, A., C. NEWMAN and F. THORNE (2006). Productivity in Irish Agriculture. 06-WP-RE-14, Rural Economy Research Centre, Teagasc, Dublin, Ireland.

MATTHEWS, A., C. NEWMAN and F. THORNE (2007): Productivity in the Irish Agriculture Sector. In: Aylward, C. and R. O'Toole: Perspectives on Irish Productivity. Dublin, Forfás**:** 116-129.

MEEUSEN, W. and J.V.D. BROECK (1977): Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error. In: Quarterly Journal of Economics 18 (2): 435-444.

NEWMAN, C. and A. MATTHEWS (2006): The Productivity Performance of Irish Dairy Farms 19842000: a Multiple Output Distance Function Approach. In: Journal of Productivity Analysis 26 (2): 191-205.

– (2007): Evaluating the Productivity Performance of Agricultural Enterprises in Ireland Using a Multiple Output Distance Function Approach. In: Journal of Agricultural Economics 58 (1): 128-151.

OLLEY, G.S. and A. PAKES (1996): The Dynamics of Productivity in the Telecommunications Equipment Industry. In: Econometrica 64 (6): 1263-1297.

PAVCNIK, N. (2002): Trade Liberalization, Exit, and Productivity Improvements: Evidence from Chilean Plants. In: The Review of Economic Studies 69 (1): 245-276.

PITT, M.M. and L.F. LEE (1981): Measurement and Sources of Technical Efficiency in the Indonesian Weaving Industry. In: Journal of Development Economics 9 (1): 43-64.

RIZOV, M. and P.P. WALSH (2008). Productivity and Trade Orientation in UK Manufacturing No. 2808. IZA Discussion Paper, Bonn.

THORNE, F. and W. FINGLETON (2005). Examining the Relative Competitiveness of Milk Production: An Irish Case Study (1996 – 2004). Rural Economy Research Centre Working Paper, Teagasc, Dublin, Ireland.

TSIONAS, E. and T. PAPADOGONAS (2006): Firm Exit and Technical Inefficiency. In: Empirical Economics 31 (2): 535-548.

VAN BIESEBROECK, J. (2003). Revisiting Some Productivity Debates. National Bureau of Economic Research, Inc., Cambridge.

Acknowledgement

The authors are grateful to the Irish Department of Agriculture, Fisheries and Food for providing financial support through the Research Stimulus Fund and to the National Farm Survey, Teagasc for permitting the use of the data. Our thanks also to Alan Matthews and Johannes Sauer for valuable comments.

Corresponding author:
ANDRIUS KAZUKAUSKAS
Department of Economics, Arts Building, Trinity College
Dublin 2, Ireland
e-mail: kazukaua@tcd.ie

Appendix

Appendix 1

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

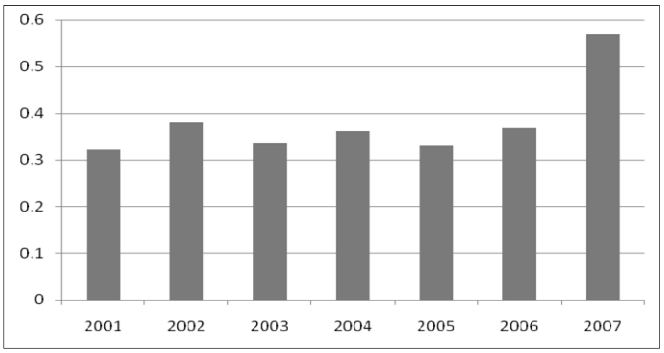
	OLS_CD	SFA_PL	SFA_BC	OP no corr	OP with corr
LCLCD1	-	-	-	0.0025	0.0025
	-	-	-	0.0076	0.0076
LCLCD2	-	-	-	-0.0002	-0.0002
	-	-	-	0.0003	0.0003
LCLCD3	-	-	-	0.0000	0.0000
	-	-	-	0.0000	0.0000
lnA1	-	-	-	-0.1356	-0.1356
	-	-	-	0.1023	0.1023
lnA2	-	-	-	-0.1725***	-0.1725***
	-	-	-	0.0653	0.0653
lnA3	-	-	-	0.0047	0.0047
	-	-	-	0.0431	0.0431
lnA4	-	-	-	0.0548***	0.0548***
	-	-	-	0.0190	0.0190
LALCD1	-	-	-	0.0112	0.0112
	-	-	-	0.0111	0.0111
LALCD2	-	-	-	0.0003	0.0003
	-	-	-	0.0006	0.0006
LALCD3	-	-	-	0.0000	0.0000
	-	-	-	0.0001	0.0001
LALC1	-	-	-	-0.0222	-0.0222
	-	-	-	0.0214	0.0214
LALC2	-	-	-	0.0027	0.0027
	-	-	-	0.0188	0.0188
LALC3	-	-	-	-0.0034	-0.0034
	-	-	-	0.0050	0.0050
CHILD	-	-	-	0.0188***	0.0188***
	-	-	-	0.0070	0.0070
OFFFARM	-	-	-	-0.0040	-0.0040
	-	-	-	0.0114	0.0114
SOIL1	-	-	-	0.0475***	0.0475***
	-	-	-	0.0076	1.0076
SOIL3	-	-	-	-0.0310**	-0.0310**
	-	-	-	0.0145	0.0145
Constant	-0.0325***	0.1695***	0.1695***	1.4366	1.4366
	0.0088	0.1695	0.0074	0.9044	0.9044
Observations	1959	1959	1959	1959	1959

The production function estimates using the balanced panel data. Standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1).
Source: own computations

Appendix 2

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

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



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

Source: own computations