Subsidies, Production Structure and Technical Change: A Cross-Country Comparison

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ABSTRACT

The effect of subsidies on production and technical change of crop farms in France and the United Kingdom (UK) during 1980-2006 is investigated. Subsidies were not neutral on production decisions, in terms of production intensity and type. Crop farms in both countries have experienced technical progress during the period studied, higher in France. Technical progress has favoured labour and chemicals in both countries, land in France, capital in the UK, while it has disfavoured land in the UK and capital in France. Technical change has been slowed down by crop area subsidies but increased by agri-environmental subsidies in both countries.

KEYWORDS: technical change, subsidies, input bias, crop farms

1. INTRODUCTION

Technical change in agriculture has received considerable attention from researchers, but studies investigating the impact of policies on it are rare. Some authors have investigated the effects of policy reforms on agricultural technical change, by comparing its rate across policy sub-period (e.g. Boyd, 1990: Brümmer et al., 2006). Other researchers have regressed the rate of farm-specific technical change over the level of subsidies received by farms (e.g. Guyomard et al., 2006; Sauer et al., 2006). While it is widely recognised that protectionist policies are a source of technical inefficiencies in agriculture (e.g. Latruffe, 2009), the effect on technical change is not straightforward. Subsidies may have a positive effect on technical change, by allowing farmers overcome financial constraints, but they can also have a negative effect via a softer budget constraint, less pressure to operate on the technological frontier or with the best available technology.

This paper aims to contribute to this debate, by investigating the role of public subsidies on technical change for two European Union (EU) countries which have pursued different agricultural policies in the past decades, and for which rural areas have a different meaning and importance: France and the United Kingdom (UK). The investigation is performed on farm-level data for the period 1980-2006. Moreover, the relationship between subsidies and production, and potential input biases in technical change are investigated.

The paper is structured as follows. The next section explains the model used, while section three introduced the data. Section four presents the econometric results and section five concludes.

2. THE TECHNOLOGICAL MODEL

For our purposes, a transformation function is desirable for modelling technological processes because multiple outputs are produced by the crop farms in the sample (crop, livestock, other). This precludes estimation of the production technology by a production function. Yet we wish to avoid the disadvantages of normalizing by one input or output as is required for a distance function.[1] We thus rely on a transformation function model representing the most producible output from a given input base and existing conditions, which also represents the feasible production set. This function can be written in general form as $0=F(\mathbf{Y},\mathbf{X},\mathbf{T})$, where **Y** is a vector of outputs, **X** is a vector of inputs, and **T** is a vector of (external) shift variables, which reflects the maximum amount of outputs producible from a given input vector and external conditions. By the implicit function theorem, if $F(\mathbf{Y},\mathbf{X},\mathbf{T})$ is continuously differentiable and has non-zero first derivatives with respect to one of its arguments, it may be specified (in explicit form) with that argument on the left hand side of the equation. Accordingly, we estimate the transformation function $Y_1= G(\mathbf{Y}_{-1},\mathbf{X},\mathbf{T})$, where Y_1 is the primary output of the crop farms and $\mathbf{Y}_{-1}$ the vector of other outputs, to represent the technological relationships for the crop farms in our data sample. Note that this specification does not reflect any endogeneity of output and input choices, but simply represents the most

[1] That is, imposing linear homogeneity on an input (output) distance function requires normalizing the inputs (outputs) by the input (output) appearing on the left hand side of the estimating equation. This raises issues not only about what variable should be chosen as the numeraire, but also about econometric endogeneity because the right hand side variables are expressed as ratios with respect to the left hand side variable. Although a common approach in input distance function-based agricultural studies is to normalize by land (e.g., Morrison-Paul and Nehring, 2005) to express the function in input-per-hectare terms, this is questionable when a key issue to be addressed is whether different kinds of farms with potentially different productivity use land more or less intensively.

Y_1 that can be technologically produced given the levels of the other arguments of the F(•) function (see also Morrison-Paul and Sauer, 2010).

We approximate the transformation function by a flexible functional form (second order approximation to the general function), to accommodate various interactions among the arguments of the function, including non-constant returns to scale and technical change biases. A flexible functional form can be expressed in terms of logarithms (translog), levels (quadratic), or square roots (generalized linear). We use the generalized linear functional form suggested by Diewert (1973) to avoid any mathematical transformations of the original data.[2] Our basic model is:

$$Y_{p,it} = F(\mathbf{Y}_{it}, \mathbf{X}_{it}, \boldsymbol{T}_{it}) = a_0 + 2a_{0s}Y_{s,it}^{0.5} + 2a_{0o}Y_{o,it}^{0.5} + \sum 2a_{0k}X_{k,it}^{0.5} + a_{ss}Y_{s,it} + a_{oo}Y_{o,it} + a_{kk}X_{k,it} + \sum a_{kl}X_{k,it}^{0.5}X_{l,it}^{0.5} + \sum a_{ks}X_{k,it}^{0.5}Y_{s,it}^{0.5} + \sum a_{ko}X_{k,it}^{0.5}Y_{o,it}^{0.5} + b_tT_{it} + b_{tt}T_{it}T_{it} + \sum b_{kt}X_{k,it}^{0.5}\,T_{it} + b_{st}Y_{s,it}^{0.5}T_{it} + b_{ot}Y_{o,it}^{0.5}T_{it} \qquad (1)$$

for farm i in time period t; where

Y_p = crop output, Y_s = livestock output, and Y_o = other output as the components of $\mathbf{Y}_{-1}$;

$\mathbf{X}$ is a vector of X_k inputs including X_{ld} = land, X_{lab} = labour, X_{cap} = capital, X_{chem} = chemicals, and X_{int} = intermediate inputs and a time trend t;

the following subsidies: S_a = crop area subsidies, S_h = headage subsidies, S_{ae} = agri-environmental subsidies, S_l = less favoured area (LFA) subsidies, S_i = investment subsidies, S_d = disaster subsidies, and S_o = other subsidies, as the components of the $\mathbf{T}$ vector.

To represent and evaluate the technological or production structure, the primary measures we wish to compute are first- and second-order elasticities of the transformation function. The first-order elasticities of the transformation function in terms of primary output Y_p represent the (proportional) shape of the production possibility frontier (given inputs) for outputs Y_s and Y_o, and the shape of the production function (given other inputs and Y_s and Y_o) for input X_k – or output trade-offs and input contributions to secondary and other output respectively. That is, the estimated primary output elasticities with respect to the other outputs, which are respectively

[2] E.g. taking logs of variables which would lead to modelling problems based on zero values (see Battese, 1997).

$$\varepsilon_{p,s} = \frac{\partial \ln Y_p}{\partial \ln Y_s} = \frac{\partial Y_p}{\partial Y_s} \frac{Y_s}{Y_p} \tag{2}$$

$$\varepsilon_{p,o} = \frac{\partial \ln Y_p}{\partial \ln Y_o} = \frac{\partial Y_p}{\partial Y_o} \frac{Y_o}{Y_p} \tag{3}$$

would be expected to be negative as they reflect the slope of the production possibility frontier, with its magnitude capturing the (proportional) marginal trade-off between different outputs produced.

The estimated primary output elasticity with respect to input k, which is

$$\varepsilon_{p,k} = \frac{\partial \ln Y_p}{\partial \ln X_k} = \frac{\partial Y_p}{\partial X_k} \frac{X_k}{Y_p} \tag{4}$$

would be expected to be positive, with its magnitude representing the (proportional) marginal productivity of X_k.

Second-order own-elasticities may also be computed to confirm that the curvature of these functions satisfies regularity conditions. The marginal productivity would be expected to be increasing at a decreasing rate, and the output trade-off decreasing at an increasing rate, so second derivatives with respect to Y_s, Y_o, and X_k would be negative (concavity with respect to both outputs and inputs).

Returns to scale may be computed as a combination of the Y_p elasticities with respect to the other outputs and inputs. For example, for a production function, returns to scale are defined as the sum of the input elasticities to reflect in a sense the distance between isoquants. Similarly for a transformation function, such a measure must control for the other outputs. Formally, returns to scale are defined for the transformation function similarly to the treatment for the distance function in Caves et al. (1982) – for our purposes as [3]

$$\varepsilon_{p,X_k} = \sum_k \frac{\varepsilon_{p,s}}{1 - \varepsilon_{p,s} - \varepsilon_{p,o}}. \tag{5}$$

Technical change is measured by shifts in the overall production frontier over time. As our technical change variable is the trend term t, productivity/technical change is estimated as the output elasticity with respect to t, namely

[3] See also Morrison-Paul and Sauer (2010).

$$\varepsilon_{p,t} = \frac{\partial \ln Y_p}{\partial t} = \frac{\partial Y_p}{\partial t}\frac{t}{Y_p}. \qquad (6)$$

This represents how much more primary output may be produced on an annual basis in proportional terms, given the levels of the inputs and other outputs.

Similarly, the elasticities of primary (crop) output with respect to the different subsidies *S*, are computed as

$$\varepsilon_{p,S} = \frac{\partial \ln Y_p}{\partial S} = \frac{\partial Y_p}{\partial S}\frac{S}{Y_p}. \qquad (6)$$

Hence, productivity changes due to the different subsidies' categories are estimated as output elasticities with respect to Y_P. This represents how much more/less primary output is produced in proportional terms due to marginal changes in subsidies, given the levels of the inputs and other outputs.

Second-order elasticities are computed to estimate input/output bias in technical change. They are as follows

$$\left[\frac{\partial Y_p}{\partial t}\frac{t}{Y_p}\right]\frac{1}{\partial X_k} \qquad (7)$$

$$\left[\frac{\partial Y_p}{\partial t}\frac{t}{Y_p}\right]\frac{1}{\partial Y_s} \qquad (8)$$

$$\left[\frac{\partial Y_p}{\partial t}\frac{t}{Y_p}\right]\frac{1}{\partial Y_o}. \qquad (9)$$

Similarly, bias in technical change due to subsidies is

$$\left[\frac{\partial Y_p}{\partial t}\frac{t}{Y_p}\right]\frac{1}{\partial S} \qquad (10)$$

And finally biases in productivity development (estimated by primary output elasticities) due to such subsidies are as follows

$$\left[\frac{\partial Y_p}{\partial X_k}\frac{X_k}{Y_p}\right]\frac{1}{\partial S}. \qquad (11)$$

$$\left[\frac{\partial Y_p}{\partial Y_s}\frac{Y_s}{Y_p}\right]\frac{1}{\partial S}. \tag{12}$$

$$\left[\frac{\partial Y_p}{\partial Y_o}\frac{Y_o}{Y_p}\right]\frac{1}{\partial S}. \tag{13}$$

These measures may be computed for each observation and presented as an average over a subset of observations (such as for the full sample, a specific farm, a specific time period or a particular group of spatially clustered farms), or may be computed for the average values of the data for a subset of observations.[4]

The econometric estimation of the above outlined generalized linear transformation function is done by a simple cross-sectional estimator. Alternatively, a random-effects specification has been estimated; however, it proved not to be significant at a reasonable statistical level. This is presumably due to the fact that the average farm is in the samples for only about 4-5 years.

3. DATA

Farm-level data are extracted from the Farm Accountancy Data Network (FADN) in France and from the Farm Business Survey (FBS) in the UK. Only fieldcrop farms, that is to say farms deriving more than 75 percent of their gross margin from field crops are considered[5]. The period studied is 1980-2006. As explained in the modelling section, the primary output is the value of output from crop production, while the two other outputs are the value of output from livestock production and the value of output from other production. Inputs are land as the agricultural utilised area (UAA) in hectares, labour as the number of (family and hired) full-time equivalent per year in Annual Working Units (AWU), the value of depreciation as the capital input, the cost of chemicals used and the cost of other intermediate inputs.

[4] The latter approach is called the delta method. It evaluates the elasticities at one point that represents the average value of the elasticity for a particular set of observations, allowing standard errors to be computed for inference even though the elasticity computation involves a combination of econometric estimates and data. The 'delta method' computes standard errors using a generalization of the Central Limit Theorem, derived using Taylor series approximations, which is useful when one is interested in some function of a random variable rather than the random variable itself (Gallant and Holly, 1980; Oehlert, 1992). For our application, this method uses the parameter estimates from our model and the corresponding variance covariance matrix to evaluate the elasticities at average values of the arguments of the function.

[5] Farms from the European standard classification Type of Farming 1.

Subsidies are categorised into the total value of direct payments provided per hectare of crop (crop area subsidies), the total value of direct payments provided per head of livestock (headage subsidies), the total value of agri-environmental subsidies, the total value of less favoured area (LFA) subsidies, the total value of subsidies to investment, the total value of subsidies provided to farms experiencing natural disaster, and other subsidies. Disaster subsidies are modelled as such for French farms only; they are included in other subsidies for UK farms due to convergence problems during the estimation. It should also be noted that the Single Farm Payments (SFP) introduced by the 2003 CAP reform are included in other subsidies for UK farms, but they are not yet available for French farms (the reform was implemented only in 2006 in France). All value data have been deflated with appropriate price indices.

Table 1 presents some descriptive statistics of both samples. UK farms are larger on average than French farms, both in terms of land and labour used. However, they produced slightly less than French farms on average. Regarding the subsidisation level, French farms received much more subsidies on average, in particular crop direct payments.

<< Table 1 >>

4. RESULTS

Table 2 presents first order elasticities, as well as returns to scale and technical change. As expected, the primary output elasticities with respect to both other outputs (equations (2) and (3) are negative, while the primary output elasticities with respect to all inputs (equation (4)) are positive. The primary output elasticities with respect to subsidies (equation (6)) indicate that crop output has been increased by crop area subsidies and other subsidies in both countries. No other subsidies had an effect in the UK, while in France headage subsidies and disaster subsidies have also been crop production increasing. Overall, first pillar subsidies have contributed to crop output increase. By contrast, second pillar subsidies, i.e. agri-environmental, LFA and investment subsidies, have slowed down the production of crop in France during the period studied.

Returns to scale (equation (5)) are estimated at 1.07 for French farms and 1.03 for UK farms (both estimates being significant at 1 percent), implying that crop farms in both countries were operating under increasing returns to scale. Technical change is on average 5.8 percent for the whole period for French farms, and 1.5 percent for UK farms: French crop farms experienced a much more pronounced technical progress than their UK counterparts.

<< Table 2 >>

Table 3 shows the changes in primary output elasticities with respect to both other outputs over time, as well as the part due to the various subsidies (equations (11), (12), (13)). Over time production shifted away from crop production towards livestock production and towards other production in France, while in the UK production shifted away from other output and from crop output towards livestock output. In other words, in both countries there is a reduction in crop specialisation, to the benefit of livestock production, and to a lesser extent for France, to diversification into other production. Intuitively, the shift from crop to livestock production was accelerated by headage payments in both countries, and also by LFA subsidies in France. By contrast, such subsidies had a slowing effect in the UK, as well as agri-environmental subsidies. Subsidies did not accelerate the shift from crop output to other production in France; by contrast, the shift was slowed down by crop area subsidies and LFA subsidies.

<< Table 3 >>

Table 4 presents estimates of input biases in technical change. Results indicate that, over the period, technical change has been neutral to none of the inputs. In both countries technical change has been labour and chemicals intensifying. However, the bias in other inputs differs across countries. Technical change has been land and other intermediate input saving in the UK but land and other intermediate input using in France. The opposite effect is observed for capital: technical change has been capital saving in France but capital intensifying in the UK. In other words, crop farms in France have substituted capital for all other inputs, while crop farms in the UK have substituted land and other intermediate inputs for labour, capital and chemicals.

<< Table 4 >>

Finally Table 5 shows estimates of the effect of subsidies on technical change. In both countries, technical change has been significantly slowed down by crop area subsidies, but significantly accelerated by agri-environmental subsidies and other subsidies. Also, headage subsidies have significantly accelerated technical change in France.

<< Table 5 >>

5. CONCLUSIONS

In this paper we have studied production changes and technical change in crop farms in France and in the UK during 1980-2006, as well as the relationship between subsidies and production and technical change.

Four main results emerge. Firstly, agricultural subsidies received by farms were not neutral on their production decisions, in terms of intensity and type of production. Regarding the intensity of production, first pillar subsidies have increased farms' primary output level (crop output) in both countries, while second pillar subsidies have decreased it in France but were neutral in the UK. Regarding the type of production, headage subsidies have contributed to moving from crop to livestock production on crop farms in both countries. Such findings reveal that, on average during 1980-2006, all kind of subsidies received by French and UK crop farms were not decoupled from production. In further research, it will be interesting to investigate whether the newly introduced SFP are decoupled as theoretically expected.

Secondly, on average crop farms in both countries have experienced technical progress during the period studied, much higher for French farms: 5.8 percent per year during 27 years, vs. 1.5 percent per year for UK farms.

Thirdly, technical change was not Hicks-neutral, that is to say the rates of substitution of the inputs did not remain unchanged. Technical progress have favoured labour and chemicals in both countries, land in France, and capital in the UK, while it has been in disfavour of land in the UK and in capital in France. This is in contrast to the widespread belief that technical change is labour saving and capital intensifying in developed countries. For example, using a Divisia Total Factor Productivity index, Bailey et al. (2004) find that technical change in UK agriculture during 1953-2000 has been capital variable inputs accumulating against labour and land. This effect is especially marked after 1975 for labour, but is reduced after 1981 for land.

Finally, agricultural subsidies have had an influence on technical change during the period studied. In both countries, while crop area subsidies have been a brake to technical change, agri-environmental subsidies have enhanced it. Using Malmquist indices calculated with Data Envelopment Analysis (DEA), Guyomard et al. (2006) also found that operational subsidies received by farms increased technical change for French crop farms during 1995-2002, but did not decompose the effect for various types of subsidies. Our results suggest that agri-environmental payments may have helped farms overcome financial difficulties to invest in new technologies, while crop area subsidies may have reduced farmers' incentives to improve their technology. Further research could investigate whether these subsidies induced input-bias technical change. For example Lachaal (1994) finds that subsidies received by dairy farms in the United States during 1972-1992 have been feed saving, capital using, and neutral with respect to labour. At the time of reflecting about the removal of agricultural subsidies, and about the role of public support in promoting farms survival and thus in preserving dynamic rural areas, this question is crucial. Would an all-at-once removal of subsidies allow more labour-using technical change and thus protect agricultural employment? Or, by contrast, would it encourage farms in pursuing labour-saving technical change in order to be able to respond to the market signals?

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Table 1: Descriptive statistics of the samples used (averages over the whole period 1980-2006)

	France	UK
Value of total output (euros)	215,202	172,352
Value of crop output (euros)	129,549	118,510
UAA (ha)	103.7	201.3
Labour (AWU)	1.68	3.99
Value of depreciation (euros)	14,439	14,091
Value of all intermediate inputs (euros)	25,077	58,139
Value of crop direct payments (euros)	34,103	5,176
Value of livestock direct payments (euros)	4,673	1,574
Value of agri-environmental subsidies (euros)	593	523
Value of LFA subsidies (euros)	152	13
Value of investment subsidies (euros)	236	17
Value of disaster subsidies (euros)	2062	-
Value of other subsidies (euros)	537	1,175
Total number of observations over the period	15,908	8,359

Source: French FADN and UK FBS.

Note: disaster subsidies are included in other subsidies for UK farms.

Table 2: First order crop output elasticities, returns to scale and technical change

	France	UK
Elasticity with respect to livestock output	-0.175 ***	-0.187 ***
Elasticity with respect to other output	-0.235 ***	-0.033 ***
Elasticity with respect to UAA	0.203 ***	0.206 ***
Elasticity with respect to labour	0.168 ***	0.187 ***
Elasticity with respect to depreciation	0.164 ***	0.180 ***
Elasticity with respect to chemicals	0.500 ***	0.361 ***
Elasticity with respect to other intermediate inputs	0.470 ***	0.330 ***
Elasticity with respect to crop area subsidies	0.785 E-03 ***	0.904 E-03 ***
Elasticity with respect to headage subsidies	0.128 E-03 ***	-0.042 E-03
Elasticity with respect to agri-environmental subsidies	-0.097 E-03 **	-0.114 E-03
Elasticity with respect to LFA subsidies	-0.228 E-03 ***	-0.571 E-03
Elasticity with respect to investment subsidies	-0.050 E-03 *	-0.266 E-03
Elasticity with respect to disaster subsidies	0.206 E-03 ***	-
Elasticity with respect to other subsidies	0.061 E-03 **	0.033 E-03 ***
Returns to scale	1.07 ***	1.03 ***
Technical change	0.058 ***	0.015 ***

Source: authors' own calculations

Note: ***, **, * represents significance at 1, 5, 10 percent. Disaster subsidies are included in other subsidies for UK farms.

Table 3: Change in primary output/other outputs elasticity over time and effect of subsidies

Change of crop/livestock elasticity due to	France	UK
time	-0.0016 ***	0.0019 ***
crop area subsidies	-0.438 E-08 ***	-0.583 E-08
headage subsidies	0.354 E-07 ***	0.978 E-07 *
agri-environmental subsidies	-0.722 E-08	-0.138 E-06 ***
LFA subsidies	0.356 E-05 ***	-0.356 E-04 **
investment subsidies	-0.525 E-07 ***	-0.103 E-06
disaster subsidies	-0.375 E-07 ***	-
other subsidies	-0.168 E-06 *	-0.656 E-07 **
Change of crop/other output elasticity due to		
time	-0.0037 ***	-0.0054 ***
crop area subsidies	-0.269 E-07 ***	-0.280 E-07 **
headage subsidies	-0.420 E-07 **	0.278 E-06 ***
agri-environmental subsidies	0.178 E-07	0.196 E-07
LFA subsidies	-0.206 E-05 **	-0.671 E-04 ***
investment subsidies	-0.276 E-06	-0.456 E-04
disaster subsidies	-0.126 E-06 ***	-
change due to other subsidies	-0.135 E-06	-0.248 E-06 ***

Source: authors' own calculations

Note: ***, **, * represents significance at 1, 5, 10 percent. Disaster subsidies are included in other subsidies for UK farms.

Table 4: Estimates of input biased technical change

	France	UK
Technical change due to UAA	1.083 ***	-0.448 ***
Technical change due to labour	81.111 ***	45.526 ***
Technical change due to depreciation	-0.005 ***	0.006 ***
Technical change due to chemicals	0.014 ***	0.002 ***
Technical change due to other intermediate inputs	0.022 ***	-0.0003 ***

Source: authors' own calculations

Note: ***, **, * represents significance at 1, 5, 10 percent.

Table 5: Impact of subsidies on technical change

	France	UK
Technical change due to crop area subsidies	-1.172 E-04 ***	-0.311 E-04 **
Technical change due to headage subsidies	0.340 E-04 ***	0.235 E-04
Technical change due to agri-environmental subsidies	0.0005 ***	0.001 ***
Technical change due to LFA subsidies	0.0005	-0.017
Technical change due to investment subsidies	0.0002	0.006
Technical change due to disaster subsidies	-0.248 E-04	-
Technical change due to other subsidies	0.0002 **	0.002 ***

Source: authors' own calculations

Note: ***, **, * represents significance at 1, 5, 10 percent. Disaster subsidies are included in other subsidies for UK farms.