Estimating the effects of single farm payments on multi-output agricultural production function

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Abstract

This study has evaluated impacts of the Single Farm Payment. It used a Computable General Equilibrium (CGE) model calibrated on Scottish data and focussed on a multi-output agricultural production function. Simulation results from a standard CGE were compared with those from an alternative optimisation framework proposed in this study. The latter yielded a policy effect that is likely to represent behaviour of a profit maximising farmer. A parameter sensitivity analysis was conducted for agricultural supply response. This revealed the importance of differences in supply conditions and a need to conduct further econometric studies to estimate supply parameters.

Key words: *Single farm payments; decoupling; multi-output farming; farm types; Constant Elasticity Transformation*

Introduction

One of the rationales for decoupling agricultural support is to reduce the interference of existing output related subsidy payments with production decisions (OECD, 2006). Clearly, output subsidies represent distortion of prices, serving as wedges between producer and market prices. Thus, the introduction of the Single Farm Payment (SFP) weakens the link between such payments and levels of agricultural outputs and inevitably results in redistribution effects with some farming activities expanding and others contracting (e.g. Acs et al., 2010). Consequently, decoupling and progressive reduction of SFPs are expected to encourage the agricultural and food production system to adapt themselves to a more market oriented environment, i.e., to be changed to a consumer driven mode (EU, 2010).

In this context, an important modeling issue would be to develop a policy simulation framework to explain how the SFP may cause changes in production decisions. This becomes particularly tricky in a multi-output farming setting where the policy shock would cause changes in the composition of farm output. Computable general equilibrium models have become popular tools to simulate such complex policy impacts; they provide flexible modeling options to trace feedbacks effects within and across sectors. Critically, however, in order to simulate policy effects within the multi-output farming system on the one hand and their relationship with the rest of the economy on the other, one would need to introduce significant modifications to a standard CGE model. The modeler may need to reconsider the conceptualization of the optimization procedure and

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specification of activity-commodity relationships. Some existing CGE models rely on a commodity-by-commodity relationship (e.g. GTAP model, see Keeney and Hertel, 2005) while others use a social accounting matrix with a one-to-one relationship between activities and commodities (see Swales, et al 2003). The structure of such models is considerably different from the kind one needs to simulate effects of the SFP.

Lofgren et al (2002) provides a modeling structure which is most suited for simulating policy effects on a multi-output farming sector; it permits that any commodity to be produced by one or more activities and any activity to produce one or more commodities. However, in this model, the optimisation problem is formulated in such as way that an aggregate commodity composite was derived using a Constant Elasticity Substitution (CES) functional form by considering output of a particular commodity by a certain activity as an “input”. For reasons we explain in detail in section 2 below, we found it appropriate to depart from this specification and introduce an alternative functional form, a CET functional form, whereby the optimisation problem is reformulated to obtain a composite activity output as a transformation of different commodities. In doing so, we followed Gohin and Gautier (2003) which applied a CET specification in relating an aggregate agricultural activity producing 19 agricultural outputs. In the present study, we model 7 separate agricultural sub-sectors (standard farm types in Scotland) producing 11 products, with each farm type producing more than one commodity type.

We formulate an economy-wide CGE model for Scotland and run four separate simulation experiments. In the first round we implement the CES specification (Lofgren et al 2002, henceforth Model 1). In the second round the CET specification (henceforth Model 2) that we have proposed is implemented. At this stage, we compare and contrast results from the two versions of the model. In the first two rounds we follow existing simulation models and assumed inelastic agricultural supply (OECD, 2001; OECD 2003; and Keeney and Hertel, 2005). In the third and fourth rounds of the simulation experiment, we confine our simulation experiments to Model 2 and assume elastic agricultural supply, i.e., by raising the CET elasticity parameters to more than 1 in two stages.

We proceed with the remaining part of this paper as follows. The Scottish CGE model and the baseline database are briefly described in the next two sections. We then present simulation results and finally provide concluding remarks.

Description of the CGE Model

We use a CGE model formulated to simulate impacts of SFP. The model is calibrated with Scottish data. It has evolved from earlier versions which are described in Gelan and Schwarz (2006) and Gelan and Schwarz (2008). The former was an initial version of the model with two-sectors (agriculture and non-agricultural sectors); in the latter, the agricultural sector of the Scottish economy was disaggregated into (5 standard farm types) and 10 commodity groups. The current model is a fully elaborated version with a detailed sectoral disaggregation: the agricultural sector into 7 standard Scottish farm types and 11 commodity groups; and the non-agricultural sector disaggregated into 33 activities and 33 commodities. Thus, the current model is based on a social accounting matrix which contains 40 producing sectors and 44 commodity groups.

Figure 1 displays the structure of the model with many nested functional forms representing economic linkages between different sectors of the economy: production relationships, activity-commodity links, and flows of marketed commodities. The complex inter-sectoral relationships are classified into three major blocks (see Panels 1, 2 and 3).[3] In Panel 1, starting from activity level (QA_A), the process of production is modelled as a nested multi-level structure. The first level of the nesting structure determines sectoral output (QA_A) as aggregation of intermediate inputs ($QINTA_A$) and value-added (QVA_A) using a Leontief functional form; this means substitution between these inputs is not allowed at this level (subscripts A and C denote activity and commodity respectively). At the second nest of the production function, the value-added and intermediate composites are split into their component parts. Using the Leontief functional form, the composite quantity of intermediate demand by each producing sector is disaggregated into demand for commodities from each farm type and the composite non-agricultural good ($QINT_{CA}$). The value-added composite is disaggregated into labour, land and capital using a Cobb-Douglass functional form.

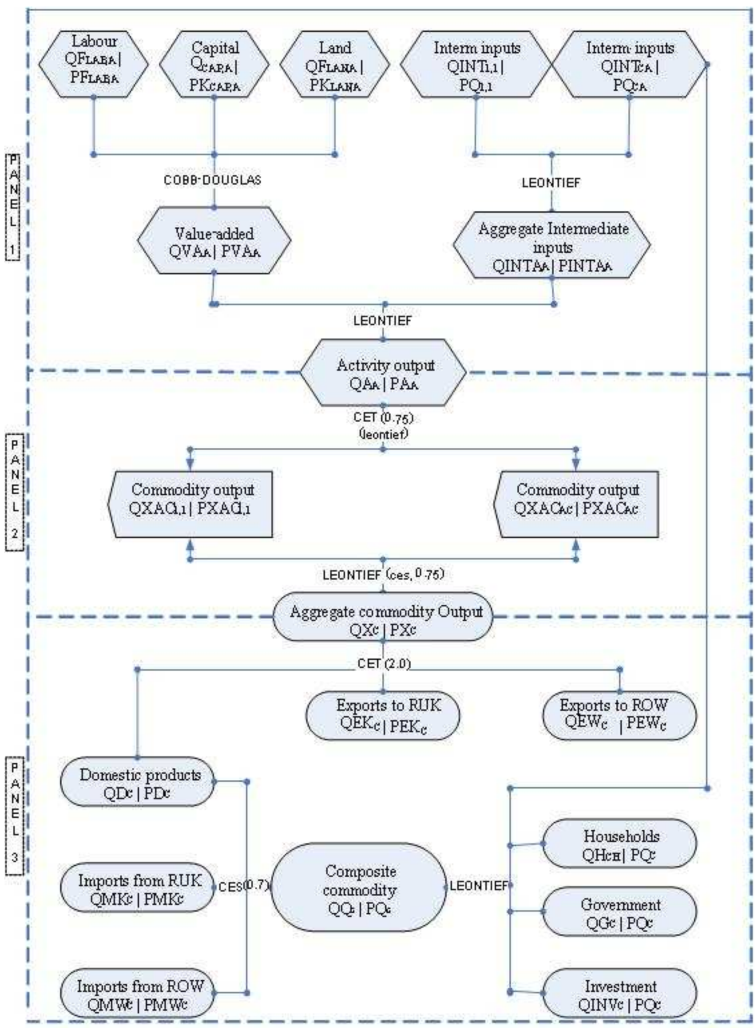

Figure 1: Structure of production and flow of marketed commodities

[3] Further details of the structural equations for the model with block by block illustration of institutional accounts are available in Gelan and Schwarz (2006).

Panel 3 displays flows of commodity supply. The upper part shows a CET function that allocates domestic commodity output (QX_C) to different geographical destinations: domestic sales (QD_C), exports to RUK (QEK_C), and exports to rest of the world (QEW_C). The lower part of the diagram shows determination of domestic demand for a commodity composite (QQ_C) from a two-way aggregation as a Leontief aggregation of demand by domestic institutions: intermediate demand by producing sectors, final consumption demand by households and government; and capital formation or investment demand. The Armington assumption is employed to disaggregate demand into commodities from different geographical origins (RUK and ROW, i.e., rest of the UK and rest of the World respectively) by using a Constant Elasticity of Substitution (CES) functional form. The Armington assumption implies that commodities from different geographical origins are treated as imperfect substitutes (Armington, 1969).

Panel 2 displays key relationships together with alternative functional forms which are most relevant to the purpose of this paper. The most important point is to recognise that each farm type produces a range of commodity outputs (see table 2 in the next section). In the context of Figure 1, the existence of variable the $QXAC_{AC}$ would mean that a one-to-one relationship between activity output (QA_A) and commodity output (QX_C) does not exist any more. This gives rise to an important modelling challenge related to model specification as to how policy shocks such as single farm payments affect different commodity groups separately and then get translated to effects on aggregate output by a particular farm type or farm unit. The current model is implemented using two alternative functional forms. For the first one, we follow Lofgren et al (2002) and implement a CES aggregation of $QXAC_{AC}$ to obtain total commodity output (QX_C) while the optimal farm product mix was assumed to be in fixed proportion (Leontief) using the base year database, i.e., $QXAC_{AC}$ is linked to QA_A in fixed proportion (see functional forms indicated in the brackets). The second specification is an alternative functional form we propose in this paper (shown outside the brackets). In the proposed specification, QA_A is determined as a CET aggregation of $QXAC_{AC}$ and QX_C is obtained as sum of the latter. The merit of the alternative specification lies in the importance of relating a policy shock such as the SFP to production decision making by the farmer. In our view, there seem to be some conceptual problem with obtaining optimal value of $QXAC_{AC}$ by relating this to QX_C with a CES functional form. The reason is that QX_C is a commodity composite which comes from different farm types, that is different decision making units. One does not encounter such conceptual problem with the functional form we proposed because QA_A is total output by similar decision-making units or farm types. In Figure 1, the default and exogenously given elasticity parameters values are shown next to the functional forms implemented.

The Social Accounting Matrix

The model was implemented with a social account matrix (SAM) constructed for Scotland with 2001 as a base year. It was essential to choose a base year which lies some years before the introduction of the policy change. Scottish input-output table constitutes a core of the database required to develop and implement the CGE model. The latest update to the Scottish input-output table before the policy change was done in 2001. Therefore, the rationale for choosing 2001 as a base year for this study lied in availability of data suitable for the purpose of the study and the necessity to time the base year before the policy change as well as the debates preceding it.

A condensed version of the SAM is presented below in Table 1, which contains ten aggregate accounts. For each account, total expenditure (given as a sum of row entries) is equal to the corresponding total for the receipts (given as sum of entries in the columns). For instance, while total receipts by activities from sales of commodities at basic prices was given as £154 billion, total expenditure by activities on intermediate purchases, factor payments and production taxes add up to £154 billion as well. The full SAM contains 107 individual accounts, given as the sum of numbers in the brackets for each sub-account. The factor accounts consist of family labour, wage labour, land and capital accounts. The household account consists of seven farming households (making a living with the seven farm types) and another account for households whose livelihood is based on non-agricultural activities.

Table 1: Condensed Social Accounting Matrix for Scotland (2001, £billions)

	Activities (40)	Commodities (44)	Factors (4)	Households (8)	Government (1)	Capital formation (1)	Rest of the UK (1)	Rest of the World (1)	Taxes (5)	Trade margins (3)	Totals receipts
Activities (40)	-	154	-	-	-	-	-	-	-	-	**154**
Commodities (44)	84	-	-	49	20	12	29	26	-	14	**234**
Factors (4)	68	-	-	-	-	-	-	-	-	-	**68**
Households (8)	-	-	68	-	4	-	14	-	-	-	**86**
Government (1)	-	-	-	-	-	-	4	-	22	-	**25**
Capital formation (1)	-	-	-	27	2	-	-10	-6	-	-	**12**
Rest of the UK (1)	-	36	-	0	-	-	-	-	-	-	**36**
Rest of the World (1)	-	20	-	-	-	-	-	-	-	-	**20**
Taxes (5)	1	11	-	10	-	-	-	-	-	-	**22**
Trade margins (3)	-	14	-	-	-	-	-	-	-	-	**14**
Totals payments	**154**	**234**	**68**	**86**	**25**	**12**	**36**	**20**	**22**	**14**	

Table 2: Activity-commodity mix in Scottish agriculture (2001, £m)

	Cereals	Oilseed rape	Potatoes	Other crops	Cattle	Milk	Sheep & wool	Pigs	Poultry & eggs	Misc. Livestock	Misc activities	Total activity output
LFA Sp. S.	0	0	0	1	10	0	58	0	0	10	12	**91**
LFA Sp. B.	11	0	0	3	235	1	34	82	0	0	26	**391**
LFA C & S.	10	0	1	4	139	10	82	0	60	4	20	**328**
Cereals	132	1	6	70	39	3	8	0	0	1	88	**349**
Gen. Crop.	142	30	161	63	55	0	6	0	33	11	52	**552**
Dairy	8	0	1	4	75	295	8	0	75	0	16	**483**
Mixed	56	1	5	12	129	10	31	0	3	0	22	**268**
Total Commodity output	**359**	**32**	**174**	**157**	**681**	**318**	**226**	**82**	**171**	**25**	**235**	**2460**
Subsidy	**-124**	**-13**	**-1**	**0**	**-268**	**-9**	**-59**	**0**	**0**	**0**	**0**	**-474**

The intersection of the "commodities" column with two row accounts would provide entries that are most relevant to the purpose of this paper. These are intersection with the "activities" (the make-matrix) and its intersection with one of the five accounts labelled as "taxes". The latter refers to indirect taxes on local outputs, which in the case of agricultural products have traditionally been (included) coupled subsidy payments. We have taken output these entries provided further details of these sub-accounts below (see Table 2).

According to the 2001 Scottish input-output database, which provided the bulk of data for constructing the SAM, total sales receipts from agricultural commodities at basic prices £2,460 million (see entry at the intersection of the last row and the last column in Table 2). This constitutes 1.6% of the corresponding entry (£154 billion at the activities-commodities intersection in the condensed SAM or Table 1). In the full SAM, farming activities (or farm types) are the only accounts in the make-matrix where an activity row intersects with more than one commodity accounts and vice versa. Therefore, the motivation behind presenting table 2 is to provide further details for the sub-matrix of the farming sector thereby facilitate the groundwork for the simulation experiments in the subsequent section. According to the Scottish input-output table, total output related subsidy payments during 2001 was £474 (see the last entry in the row headed as "subsidy" in Table 2).

Simulation Results

An important modelling task is to show how the activity-commodity mix would change in response to the SFP. Before we proceed to we provide one additional adjustment to data which is important for implementing the SAM-based model. This relates to the fact that there were some differences in the amounts of total subsidy payments reported in the Scottish input-output table and the sum of details provided in the agricultural census based Economic Reports on Scottish Agriculture. Consequently, we have established that the IO database seemed to have included some Pillar II payments such as LFA payments in the product subsidies. We have estimated that about 24% of the subsidy payments reported in the IO database was subject to decoupling. Accordingly, in the simulation experiments we conducted, only 76% of the total subsidy payments reported in Table 2 above was decoupled from production and paid to the corresponding household group as transfer payments by the government account.

However, less clear are the resource allocation effects of decoupled payments. Balkhausen et al. (2008) emphasise missing empirical evidence on resource allocation effects for various forms of direct payments due to the lack of historical precedents for these kinds of direct payments and follow Chantreuil et al. (2005) in their assessment that the complex nature of the impacts (including wealth, risk and dynamic effects) has become increasingly difficult to identify. Consequently, simulation studies still rely on ad hoc assumptions. While some studies such as Binfield et al. (2004) and OECD (2003) assume that the Single Farm Payment is only to a small extent less coupled than the Agenda 2000 area and headage payments, we follow, for example, Gohin and Latruffe (2006) in assuming that the Single Farm Payment is fully decoupled. The Scottish Executive has opted for full decoupling concerning the previously existing coupled direct payments. In order to reduce the redistribution effects of the CAP reform, the Scottish Executive opted for a SFP based on historic subsidy receipts from 2000 to 2002 rather than an area based flat rate payment system .The SFP replaced eight previously existing production based schemes in the crop and livestock sector (Scottish Government, 2011a).

In addition to fully decouple previously existing coupled payments the Scottish Executive made use of the National Envelope and implemented the Scottish Beef Calf Scheme (SBCS) for beef bred calves from suckler cows (Gelan and Schwarz, 2008). The SBCS uses just over 4% of the Scottish ceiling for the National Envelope and is funded by retaining approximately 10% of the decoupled beef payments (Scottish Executive, 2011b). However, Barnes (2007) finds that the SBCS only contributes to around 5% of overall public subsidies to producers in upland and hill areas and could not identify a distinct positive impact on cattle numbers in uplands. In this study, we focus on the implementation of the SFP, although we make references to the SBCS in general discussions in this paper.

We first run two separate simulation experiments in addition to replicating the initial database. These are intended to compare and contrast results from the alternative model specifications (Model 1 and Model 2). The simulation results reported below. In the second experiment, we turn our attention to variations in the size of the elasticity of commodity transformation. We discuss each of these in turn.

Impacts of the SFP agricultural output by farm type and commodity groups

We start by presenting the effect of SFP on farm commodity outputs (see Figure 2). In all cases, farm output will decline by no more than 10%. However, there are important differences in the proportionate changes for commodity groups and model specification.

As we expect, the rate of contractions in agricultural products was most directly related to the rate of coupled subsidy payments in the base year (see Figure 2). For instance, "cattle" attracted a relatively larger proportion of subsidy payments (see Table 2) and hence the contraction in this farm output was the largest. However, a comparison of Model 1 and Model 2 results shows important differences in the patterns of contractions in commodity groups. In general, the range between commodity output declines is higher with Model 2 than with Model 1. This implies that with Model 1 commodity outputs decline by more or less similar proportions regardless of the differential rates of subsidy payments in the base year. However, Model 2 allows for larger declines in subsidy dependent commodity groups and relatively smaller declines in commodity groups that were less dependent on subsidy. In other words, as we anticipated, Model 2 seems to represent more realistic producer behaviour.

The 9% reduction of cattle under Model 2 is close to the early FAPRI projections of the impacts of full decoupling for countries with similar agricultural sectors. Moss et al. (2002) predicted a decline of total cow numbers of just under 11% for Northern Ireland. The relatively small decline in sheep numbers is consistent with Scottish agricultural census data, which show a small decline since the introduction of the SFP (SAC, 2008). Compared to results of EU-wide studies (e.g. Balkhausen et al., 2008, Gohin, 2006 and Britz et al., 2006), our Scottish SFP simulations show bigger declines of agricultural commodity output, which can be explained by the bigger subsidy dependency of the Scottish agricultural sector.

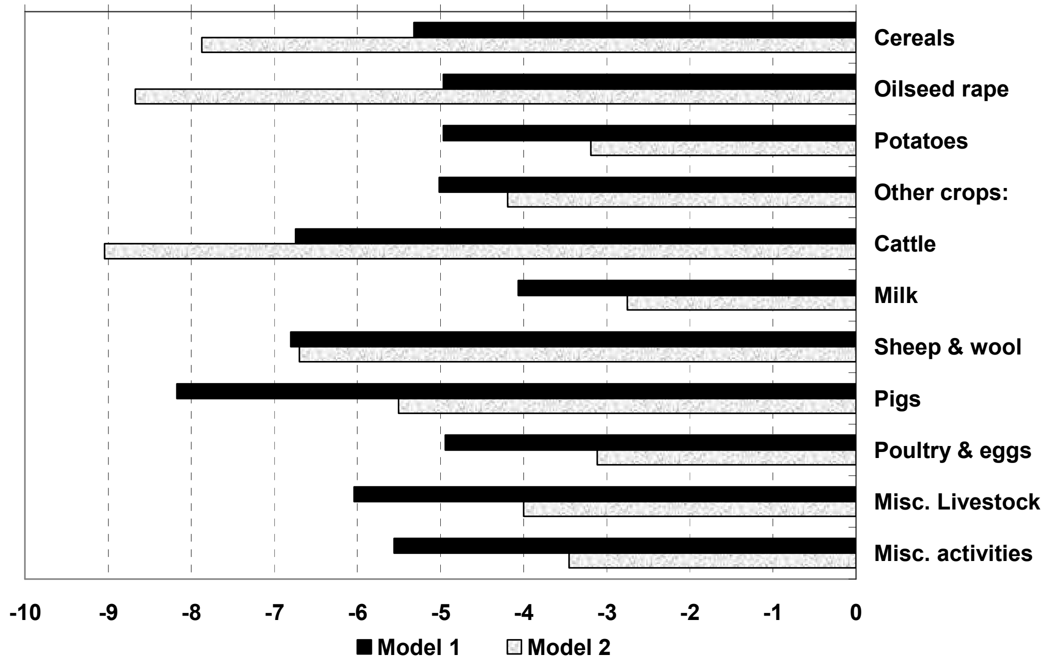

Figure 2: Impacts of SFP by farm outputs

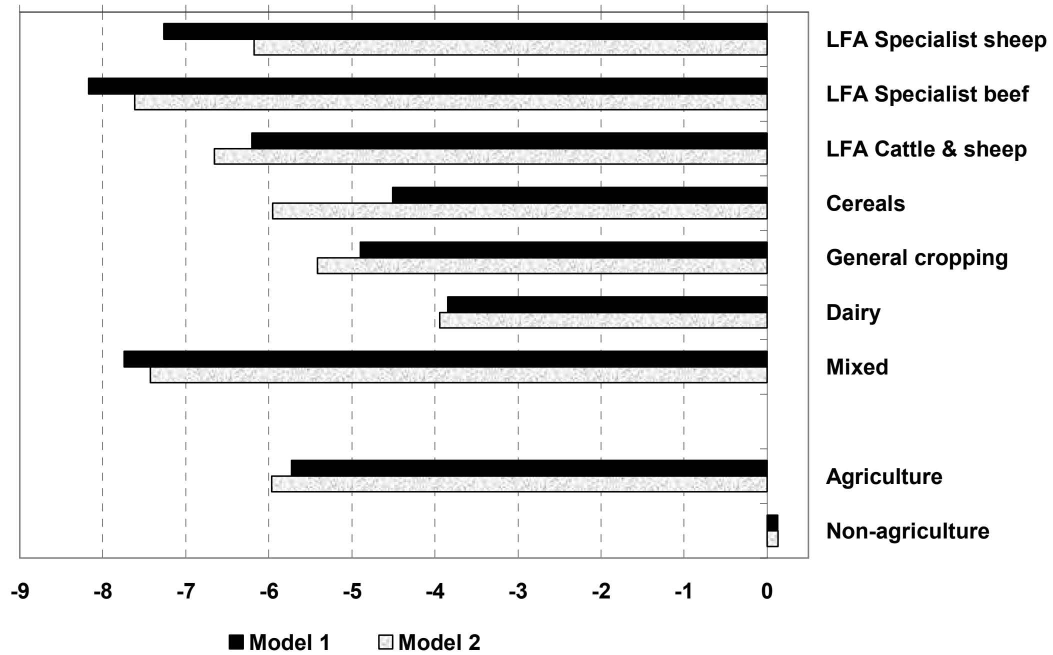

Figure 3: Impacts of SFP by standard Scottish farm types

Figure 3 displays aggregate output by farm types. The differences among farm types reflects the product mix in the base year as well as the extent to which each the activities were dependent on coupled subsidy payments. As far as comparison of model results is concerned, Model 2 shows relatively larger activity declines for farm types whose main output was dependent on subsidy. Additionally, we have reported total agricultural and non-agricultural sector effects of the SFP. The simulation results showed that total agricultural output would decline by 5% (with Model 1) and 6% (with Model 2) while the non-agricultural sector may experience a marginally positive effect; an increase by 0.13% and 0.14% respectively with Model 1 and Model 2. Similar aggregated effects on the agricultural and non-agricultural sectors have been reported for Ireland by Dixon and Matthews (2006) using a CGE model (IMAGE2 model) of the Irish economy. There are significant variations and differential impacts within the non-agricultural sectors. It is useful to note that non-agricultural sectors that have forward and backward linkages with agriculture suffer relatively large contractions.

Sensitivity of changes in farm output to the size of the CET parameter

The simulation results reported in the preceding section was based on the inelastic parameter value for the CET function, which is given as 0.75 in Figure 1. In doing so, we followed existing supply elasticity databases (e.g. FAPRI, 2011) and literature (e.g. FAO, 2003) on the subject of agricultural supply and relocation resources within different farm enterprises. However, there appear to be paucity of empirical evidence to suggest that agricultural supply or farm output transformation is really inelastic in most European countries. We leave empirical investigation into farm output transformation in Scotland to future research. For the purpose of this paper we limit ourselves to varying the parameter value and investigate sensitivity of farm output to the CET parameter values.

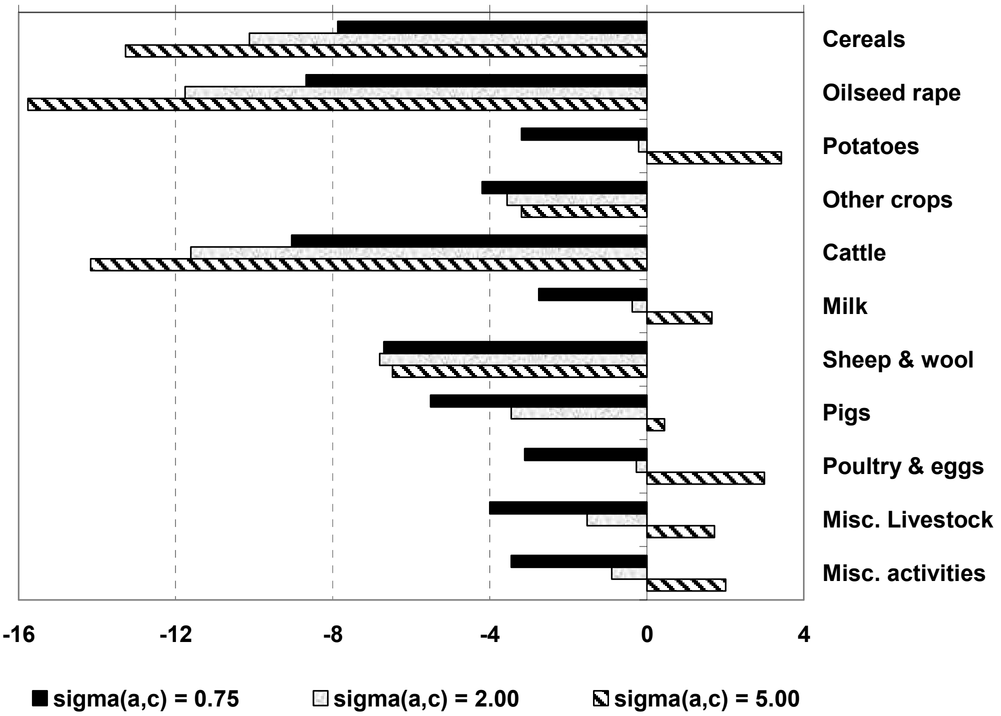

Figure 4: Sensitivity of impacts on products to variations in the size of CET parameter

Figure 4 compares three scenarios obtained using Model 2 and by fixing the CET elasticity parameters value at 0.75, 2, and 5. The case of 0.75 represents the default case reported in Figure 2. The other two cases provide simulation results for "what if" agricultural supply is moderately elastic or relatively highly elastic. This amounts to considering the possibility of farmers willing and able to adjusting production to market conditions.

As we expect, the larger the CET elasticity value the greater the decline in farm outputs which were relatively dependent on subsidy and the smaller the rate of decline farm output which were not subsidised in the base year. Given the current modelling framework, it is interesting to note that a sufficiently large CET parameter value would lead to a relatively large farm restructuring that farm outputs which were not coupled with subsidy in the base year would experience an increase from the base year level. This sensitivity analysis calls for further empirical research into parameterisation of supply functions in the conditions of multi-output farming in Europe.

Conclusions

The primary objective of introducing the SFP was to reduce the interference of output related subsidy payments with production decision by farmers. This raised an interesting modelling issue particularly in the context of a multi-output farming sector. The reason is that if decoupling subsidy payments would lead to production according to market demand, then one expects that a profit maximising farmer would relocate resources away from a farming activity that have existed historically due to subsidy toward another product that was produced even without any subsidy payment being coupled with it.

Using a CGE model calibrated on Scottish data, this paper has highlighted two interrelated issues. We started with a conceptual issue related to model specification using a standard CGE model. We then reconsidered the optimization rule applied in the standard CGE model and then formulated an alternative modelling framework. A comparison of results from the standard CGE model and the alternative specification we proposed provided a useful insight into differences in the impacts of the SFP on changes in farm output composition. More specifically, the alternative model proposed in this paper yielded results that reflected behaviour of a profit maximising farming enterprise.

This paper has also raised an important empirical issue related to agricultural supply response. Although main simulation runs were conducted by assuming inelastic agricultural supply, we have explored the extent of policy effects on farm output composition if we assume an elastic agricultural supply. The sensitivity analysis provided results that re-enforced policy effects previously explored by applying the alternative model specification proposed in this paper. However, empirical investigation into agricultural supply response is left to future research.

The results of the alternative model are in line with the assumption that previously supported commodities such as cattle and sheep experience bigger output declines than commodities such as pigs which did not receive direct payment in the past. The results also show that due to a shift of resources from the agricultural sector to other economic sectors all analysed commodities and the agricultural sector as a whole experience a decline in output.

Overall the results reflect a shift to greater market orientation following the introduction of decoupling and the often marginal agricultural conditions with poorer quality land in Scotland. However, the implementation of the SFP accelerates the already existing trend of cattle and sheep retreating from the hills and uplands. Upland livestock farms deliver lambs and calves to lowland farms for finishing and a reduction of supply for finishers has major knock-on effects for the supply chain and the rest of the sector (Schwarz et al., 2006). In addition, areas of High Nature Value farmland in Scotland coincide with the areas that are experiencing the greatest declines in livestock numbers. The reduction of grazing in systems that are already low intensity and extensive could lead to a decrease in biodiversity. (SAC, 2008).

To counteract the decline in cattle numbers the Scottish government made use of the National Envelope and implemented the Scottish Beef Calf Scheme (SBCS) in 2005. But despite some positive effects on the gross margin, Barnes (2007) shows that the SBCS alone does not support the long term viability of beef producers in uplands. Further recoupling of direct payments to upland livestock is unlikely to be politically acceptable.

The discussion underlines the need for a territorial policy approach combining spatially explicit agri-environmental and socio-economic policy support measures to promote a diversified income basis of farm households and rural communities and to maintain and enhance the provision of public goods and other ecosystem services through upland agricultural systems. This will be no easy process and requires stronger integration of sectoral and regional policies. In addition, while payments for ecosystem services have received increasing attention in the literature over the last decade, more research is needed on how to develop and implement spatially targeted payments for ecosystem services in the CAP and on the impacts of changes in the policy support system on local rural communities.

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