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Agriculture's inter-industry linkages, aggregation bias and rural policy reforms

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Abstract

As agricultural policy reform and its effects have become increasingly territorialised, analyses which attempt to explain or predict impacts need to be more localised but also identify spill-over effects. In addition to the predictions of policy shocks predicted by sectoral partial equilibrium models, local and regional general equilibrium approaches which establish the wider effects of such policy shocks have become popular. However, these neglect a major, underexplored difficulty: agriculture is usually described as a single sector in input-output accounts, whereas policy shocks with differential impacts have effects on other industries which are different to those implied by average input-output coefficients. Regionalisation of aggregated input-output tables adds further to these difficulties. The objective of this paper is to develop a relatively simple method for dealing with these problems. It establishes the theoretical basis for aggregation bias and shows how it can be measured, in two contrasting case study regions in the United Kingdom and Sweden. Having established that this is a significant problem, a simple but effective procedure is demonstrated, based on additional information on variable costs, which transforms policy shocks from a direct change in agricultural output to that transmitted to the suppliers of inputs. This method provides an impact close to that which could be calculated if the general equilibrium system had indeed been disaggregated, and supports use of this approach in impact studies where the researcher does not have the time or funding available for completely disaggregating the agricultural sector's regional accounts.

Keywords: agricultural and rural development policy evaluation, CAP, input-output analysis, aggregation bias

JEL classification:

1. INTRODUCTION

Agricultural policy reform in most developed countries has shifted emphasis away from commodity support and towards environmental contracts, diversified production practices and rural development (Diakosavvas, 2006). The delivery of policy and consequent associated economic shocks which might arise from its reform has become increasingly territorialised: impacts will differ according to local resources, the nature of regional economic structure, and the effectiveness of governance (Watts *et al*., 2009). Alongside (and partly related to) this, the economic importance of agriculture within the overall rural economy has diminished, with food manufacturing, tourism, and public service employment correspondingly increasing their contributions (Copus *et al*., 2006). This implies that analyses that attempt to explain or predict the impacts of policy reform need to be extended from sectoral microeconomic models to more localised multisectoral general equilibrium approaches which identify spill-over effects, both sectoral and spatial. Such impact multiplier effects are now required for the purposes of European rural policy evaluation (European Commission, 2006: 8).

Broadly, two types of general equilibrium approaches exist: fixed-price Leontief-style Input-output (IO) models (including Social Accounting Matrix (SAM) multiplier models, which expand the examination beyond productive institutions to households, government and income distributions); and Computable General Equilibrium (CGE) models, based on SAMs, which relax the assumption of fixed prices. Both of these approaches have been developed to explore various dimensions of rural economic change at local or regional level. Uses of the first type include, for example, assessment of impacts of an agri-environment scheme on incomes and employment using local IO models in Norfolk, Devon and Derbyshire in the UK (Harrison-Mayfield *et al.*, 1998); use of an IO framework to investigate long-term structural changes on the regional economy of East Macedonia and Thrace in Northeast Greece (Ciobanu *et al.*, 2004); and comparison of IO multiplier effects of the 2003 CAP reforms in six European regions (Mattas *et al.*, 2008).

Use of the standard Leontief model is questionable, particularly because of its reliance on linear, proportionate, constant returns to scale production functions (McGregor *et al.*, 1996) and assumptions regarding factor supply (Kilkenny and Partridge, 2009). SAM approaches allow for more detailed interaction between production sectors and other institutions, and, together with estimates of behavioural parameters, provide the basis for CGE models. Thus SAM multipliers, for example, have been used to demonstrate how a uniform increase in demand in agricultural production, agri-food processing, forestry production and processing, and tourism affected the distribution of household income in South-western counties of rural Wisconsin (Leatherman and Marcouiller, 1999). Roberts (2000) explored the interaction between rural areas and their urban pole in the Grampian region in Northeast Scotland, using a bi-regional SAM, which estimated inter- as well as intra-local economic interactions. Psaltopoulos *et al.* (2006) and Roberts *et al.* (2009) respectively, have also used a CGE approach to compare the effects of a reduction in CAP supports in bi-regional systems in Crete and Scotland; single region SAMs have also been used to determine the economic "footprint" of rural market towns in England (Courtney *et al.*, 2007).

However, a major, but largely unexplored, difficulty relates to the nature of the "shock" applied to these models. Usually, IO transactions matrices describe agriculture either as a single sector or, at best, two sectors. In the most recent UK matrix (for 1995: ONS, 2002) agriculture is consolidated into a single sector, along with hunting and related service activities. This means that policy shocks with differential impacts (which, say, affect crop production more directly than livestock activities) would transmit indirect effects to other industries which are different to those implied by the average IO coefficients calculated for the sector as a whole. Consequently, aggregation bias is introduced into estimates of economic impact.

Traditionally, the problem of aggregation bias resulted from computational difficulties in deriving inverse matrices from transactions tables, in order to determine multipliers. Today, with no substantive limit on computing power, problems of aggregation arise mainly from regionalisation and the need to link together IO models with different sectoral classifications. National IO tables are often aggregated to facilitate data collection and management, even though the underlying data would allow for a larger disaggregation. Further, regionalisation can be problematic if data available at the national level (such as output, value added, employment, consumption, imports and exports) are not available at the regional level in the same sector classification; and this often forces the regional analyst to aggregate.

More relevant, though, is the issue of accurately and appropriately predicting direct shocks that IO and other general equilibrium models are designed to evaluate. Linking up with partial equilibrium models used to assess policy reform impacts on the agricultural sector (for example, Jones *et al.*, 1995; Helming and Peerlings, 2003; Mattas *et al.*, 2008; Neuwahl *et al.*, 2008) can cause a serious loss of information. That is because normally, such models describe changes in terms of animal numbers, cropping and grassland areas. Applying this information in terms of the value of an overall final demand change to national or regional IO models, where agriculture is normally aggregated into a single sector is the source of aggregation bias. It can be shown, however, that with additional information on variable costs, such shocks can be transformed from a direct impact on agricultural output to that transmitted to the suppliers of inputs; yielding an impact close to that which could be calculated if the IO system had indeed been disaggregated.

The rest of this paper is divided into three substantive sections. First there is a review of the basic framework of the IO model, which provides a basis for explaining the notion of aggregation bias. Within this section two regional accounts are also introduced, compared and used to demonstrate that aggregation bias is sizable and warrants concern. Second, the method proposed for dealing with aggregation bias and for integrating partial and general equilibrium models in applied work is introduced and tested in two regions. This shows how the variable cost approach can be used to transfer partial equilibrium results for agriculture to an IO model, and at the same time move the shock away from the more aggregated, bias-prone part of the table. For analytic simplicity and convenience, we compare results for both aggregated and disaggregated models using standard demand-driven multipliers. It has been demonstrated that, as most of the output of contemporary agriculture is sold to processing and marketing activities, traditional multipliers showing total effects on output due to exogenous changes in final demand are less useful (Roberts, 1994; Papadas and Dahl, 1999). As the final section argues in more detail, the principle developed here is of wider application and attention is drawn to the contexts in which it can be most usefully deployed, and some of the practical issues involved in integrating exogenous changes into the IO framework are identified.

2. THE INPUT-OUTPUT MULTIPLIER AS A REGIONAL ANALYTICAL TOOL

The IO transactions matrix is an accounting identity which provides a static description of inter-sectoral linkages within an economy at a specified point in time, including consumption of intermediate goods and services by productive sectors, final consumption expenditures by households, government and other institutions including exports, and determines value added in each industry. It is the basis of a fixed-price general equilibrium model which utilises Leontief production functions, and assumes (i) fixed coefficients of production assuming a linear constant return to scale production function; (ii) homogeneity, such that each sector produces a product not produced by any other sector; and (iii) perfect supply elasticity, so that if demand changes the economy is assumed to immediately satisfy the need for extra production inputs. Technical coefficients, calculated from the transactions table, show each industry's purchasing patterns, as the ratio of each input to total output in each sector. This model has traditionally been used to study the potential final demand changes in one or more sectors to stimulate wider impacts in output throughout the economy.[1] In this section, the theoretical problem of the aggregation bias which arises where several distinct sectors are amalgamated is described and evaluated, after which measurement in practice demonstrates the extent of the obstacle that this presents to the calculation of accurate multiplier estimates.

2.1. Aggregation bias

The problem of aggregation bias in IO models has been comprehensively reviewed up to 1971 by Kymn (1990) (since then, for reasons outlined above, of this topic has been limited, but see Demesnard and Dietzenbacher, 1995; Murray, 1998). It is appropriate to start with Theil's (1957) quantification of the extent of aggregation bias, on which most subsequent authors draw heavily. Transactions between production, consumption and final demand sectors of an economy can be written in matrix form as

$$\mathbf{x} = \mathbf{W} + \mathbf{f}$$

where x is a vector of n gross outputs, **f** the vector of final demands, and **W** is a matrix of inter-industry transactions. Transformation into the familiar Leontief open IO model may be written as

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f}$$

where **A** is a matrix of IO coefficients, and is related to transactions as $\mathbf{A} = \mathbf{W}\hat{\mathbf{x}}^{-1}$, where $\hat{\mathbf{x}}$ denotes a diagonalised matrix with the elements of $\mathbf{x}$ on the leading diagonal. Aggregating certain sectors (imagining for example that different enterprises within the agricultural sector such as livestock, arable and horticulture could be separately identified), a new system with fewer sectors can be described as

$$\mathbf{x}^* = (\mathbf{I} - \mathbf{A}^*)^{-1}\mathbf{f}^* \qquad (3)$$

consisting of m aggregated sectors. The two systems are related to each other by the following equation:

$$\mathbf{f}^* = \mathbf{S}\mathbf{f} \qquad (4)$$

[1] Specific indicators have also been suggested for the demand-driven model, such as the measures of hypothetical extraction or shut-down of sectors (West, 1999), decomposition of output responses (Sharma *et al.*, 1999) and elasticities (Mattas and Shrestha, 1991).

where

$$\mathbf{S} = \begin{bmatrix} 1 \dots 1 & \dots & \dots & 0 \dots 0 \\ 0 \dots 0 & 1 \dots 1 & \dots & 0 \dots 0 \\ & & \ddots & \\ 0 \dots 0 & \dots & \dots & 1 \dots 1 \end{bmatrix} = \begin{bmatrix} \mathbf{e}'_1 & \dots & \dots & 0 \\ 0 \dots 0 & \mathbf{e}'_2 & \dots & 0 \\ & & \ddots & \\ 0 & \dots & & \mathbf{e}'_m \end{bmatrix}$$

in which the row vectors $\mathbf{e}'_j$ link the disaggregated sectors to the aggregated. Since the aggregated direct coefficients can be obtained by dividing each element by the column sum of inputs,

$$\mathbf{A}^* = \mathbf{W}^*\hat{\mathbf{x}}^{*-1} \qquad (5)$$

it follows that:

$$\mathbf{W}^* = \mathbf{S}\mathbf{W}\mathbf{S}' \qquad (6)$$

and

$$\mathbf{x}^* = \mathbf{S}\mathbf{x} \qquad (7)$$

As a result,

$$\mathbf{S}\mathbf{A}\hat{\mathbf{x}}\mathbf{S}' = \mathbf{A}^*\hat{\mathbf{x}}^*$$

and thus

$$\begin{aligned} \mathbf{A}^* &= \mathbf{S}\mathbf{A}\hat{\mathbf{x}}\mathbf{S}'\hat{\mathbf{x}}^{*-1} \\ &= \mathbf{S}\mathbf{A}\mathbf{Z} \end{aligned} \qquad (8)$$

Where $\mathbf{Z}$ is composed of column vectors $\mathbf{z}_j$ which represent the proportion of output contributed to the *j*th aggregated sector by its disaggregated constituents, such that,

$$\mathbf{Z} = \hat{\mathbf{x}}\mathbf{S}'\hat{\mathbf{x}}^{*-1} = \begin{bmatrix} \mathbf{z}'_1 & \dots & \dots & 0 \\ 0 & \mathbf{z}'_2 & \dots & 0 \\ & & \ddots & \\ 0 & \dots & & \mathbf{z}'_m \end{bmatrix}$$

From (6) and (7), the following relationship can be derived:

$$\mathbf{S}\mathbf{Z} = \mathbf{S}\hat{\mathbf{x}}\mathbf{S}'\hat{\mathbf{x}}^{*-1} = \hat{\mathbf{x}}^*\hat{\mathbf{x}}^{*-1} = \mathbf{I} \qquad (9)$$

Equation (9) merely reflects the fact that, as an accounting system, the outputs from disaggregated sectors should add up to that of their aggregation. However, if equation (3) rather than equation (2) is used to predict the effects of aggregated shocks to the system, loss of information on the precise distribution of consequent input demands will lead to a biased result. Specifically, aggregation bias is the difference between outputs predicted from the aggregated system and those derived from aggregation of relevant sectors of the disaggregated system. Suppose there is a forecast shock to final demand, $\Delta\mathbf{f}$;

$$\begin{aligned} \mathbf{bias} &= \Delta\mathbf{x}^* - \mathbf{S}\Delta\mathbf{x} \\ &= (\mathbf{I} - \mathbf{A}^*)^{-1}\Delta\mathbf{f}^* - \mathbf{S}(\mathbf{I} - \mathbf{A})^{-1}\Delta\mathbf{f} \\ &= [(\mathbf{I} - \mathbf{A}^*)^{-1}\mathbf{S} - \mathbf{S}(\mathbf{I} - \mathbf{A})^{-1}]\Delta\mathbf{f} \\ &= \mathbf{N}\Delta\mathbf{f} \end{aligned} \qquad (10)$$

where

$$\mathbf{N} = (\mathbf{I} - \mathbf{A}^*)^{-1}\mathbf{S} - \mathbf{S}(\mathbf{I} - \mathbf{A})^{-1}$$

In general, therefore, the larger the number of disaggregated sectors contained within the vectors $\mathbf{e}_j$, the greater aggregation bias will be. Theil's work led to a considerable literature on the most appropriate schemes of combining sectors in order to minimise aggregation bias: for example, Fisher, (1958, 1969) and Blin and Cohen, (1977). Fisher's (1958) discussion provided a means to identify sectors which could be combined with least aggregation bias, under two circumstances: special purpose prediction, and general purpose prediction. The former produces a minimum-bias aggregation scheme given that the interest resides in the impact of a specific sector, whereas the latter gives an aggregation scheme which minimises overall bias on the predictive power of the model.

Our concern in this paper, however, is with undoing the bias associated in IO accounts which results from the already integrated agricultural sector, and the consequent difficulty of accurately predicting effects of intra- and inter-sectoral changes which result from policy reforms. As Wolsky (1984) argued, disaggregation is a different problem to aggregation because – especially in regional or low-income country analysis – the starting point is often highly aggregated tables which preclude the possibility of a detailed analysis of intra-sectoral changes. Within the agricultural sector, of course, this presents some serious challenges. Farms often have diverse enterprises which are affected differently by policy shifts: for example the decoupling of subsidies effected by the 2003 CAP reform, as well as de-intensification, have been predicted to lead to alteration in the composition of agricultural output (Balkhausen *et al.*, 2008). In terms of the disaggregation required to account for the detail of sectoral commodity changes, identifying destinations of particular outputs from these enterprises is not so much of a problem. However, disentangling total input purchases from whole farm data, and accounting for intermediate transactions within agriculture, cause costly and time-consuming problems, in both methodological and practical terms (Midmore, 1990; Moxey and Tiffin, 1994; Léon *et al.*, 1999). The question which arises is whether the bias caused warrants concern and this can be responded to by examining two regional case-studies where rather different agricultural structures are found.

2.2. The size of aggregation bias

The extent of aggregation bias, *a priori*, should depend on the specific sectoral economic structure of a nation or a region. Fisher (1958), noted above, showed that such bias can be negligible with regard to the overall predictive power of an IO model, but it can be more important if a shock arises in one of the aggregated sectors, and it has long been apparent that impacts on agricultural sectors can be accurately modelled in a table where all other sectors are fairly aggregated (Fox, 1962). In contemporary circumstances, it is likely to be insufficient resources of data and time that form the most significant constraint, rather than a lack of computation capacity.

With specific respect to data availability, the regionalisation (and even localisation) of IO required to estimate the impacts of increasingly territorialised rural policy frameworks further complicates the picture. Lahr and Stevens (2002) note that regional analysts often lack detailed socio-economic data for regionalisation at regional level, compared with that which exists within the corresponding national table. Typically, to regionalise an IO table (whether industry interactions are adjusted by survey or non-survey methods) both national and regional data on output, value added, employment, wages and consumption are required. If this data is not available for the latter in the same detail as for the former, aggregation is required to produce conformity.

Lahr and Stevens describe possible sequences for aggregation and regionalisation, and these may have significant consequences for the size of aggregation bias. Their baseline involves the regionalisation of a disaggregated table, followed by aggregation of results of a hypothetical impact analysis. The results of this are then compared with three possible alternative approaches:

- Regionalisation of a disaggregated national table, and aggregating the resulting table using regional output weights;
- Aggregation of a disaggregated national table using regional output weights, and then regionalising the resulting table by aggregate sector classification;
- Aggregation of a disaggregated national table using national output weights, and then regionalising.

Their hypothesis was that aggregation using national rather than regional weights should induce more error in regional tables and, correspondingly, aggregation before regionalisation rather than after. This was confirmed empirically from experiments conducted for nine States of the USA, where the first approach produced the smallest forecast error compared with the baseline, and the third produced the largest.

The bearing of Lahr and Steven's work on this paper relates to the comparison between their baseline and its alternatives. The test is between two versions of regionalised national tables; the first based on a disaggregated agricultural sector and the second based on one with a single agricultural sector aggregated using regional output weights. The method of regionalisation relies on the Flegg-Weber location quotient (FLQ) approach (Flegg and Webber, 1997, 2000; Tohmo, 2004; Flegg and Tohmo, 2008), enhanced by the insertion of superior survey data in key sectors. Two case study regions have been chosen, Östergötland (in Sweden) and East Wales (in the United Kingdom), to explore the occurrence of aggregation bias across varying agro-economic systems embedded in different spatial-economic contexts. In terms of the Lahr and Stevens tests, regional IO tables corresponding to approaches ii and iii could have easily be constructed, but concern here is with the residual bias which exists even if best practice in regionalising and aggregating an IO table has been followed.

3. CASE STUDIES - ÖSTERGÖTLAND AND EAST WALES

Östergötland is an administrative county in the Southeast of Sweden. The plains in its central region are among the most productive agricultural areas in Sweden, and are responsible for the largest share in the value of the region's agricultural production, with crop production and pigs and poultry predominant. Östergötland is one of the leading Swedish regions for large-scale poultry and egg production and has the second largest average number of dairy cows per holding (Statistics Sweden, 2007). In 2005, more than 80% of its agricultural area was in arable production, but both North and South of the central plains, production is more oriented towards dairy and cattle. Agriculture, the food industry, forestry, and the pulp and paper industry together employ between 6% and 10% of the total workforce. In rural areas in the region, agriculture employs 13% of the workforce, although for Östergötland as a whole, the corresponding share is 2%.

East Wales is a NUTS2 amalgamation of unitary local authorities on the Western periphery of the United Kingdom, and is substantially larger in overall area, population and absolute economic size than Östergötland. It has a highly diverse agricultural structure, with pockets fertile soils of intensive arable cropping at elevations of 300 metres or less, predominantly used for forage, but with some cereals being grown in the drier areas. In general, though, its mountainous areas are characterised by high rainfall and large areas of the uplands are classified as Severely Disadvantaged Area or Less Favoured Area. Most of this land only supports extensive livestock production (sheep, and some beef cattle) (Welsh Assembly Government, 2005). Here also, 2% of the overall sub-regional population is employed in agriculture.

The disaggregated IO table for Östergötland in 2005 is a regionalised version of the disaggregated Swedish national table constructed by Lindberg and Hansson (2009). The original table described 50 sectors, and sufficient information was available to disaggregate agriculture into production of 11 separate commodities. The disaggregated table for East Wales in 2003 is derived from Bryan *et al.*, (2004) and Jones and Munday (2004). The original 81 sector table has been extended by disaggregating agricultural production into seven separate commodities. Both regional tables were then aggregated for analytical purposes, using regional output weights.

Based on equation (10), aggregation bias resulting from a unit change in output in each of the disaggregated production sectors can be described. Table 1 summarises these proportionate biases, by major sectoral groups, in each region. Bias can be positive or negative; therefore, the penultimate column of each table shows total absolute bias, whereas the final column shows the sum of positive and negative differences. This demonstrates that, in most cases, there are significant offsetting biases.

Table 1: Total Agricultural Aggregation Bias by Broad Sectoral Group, Case-Study Areas

	1	2	3	4	5	Total	Total (absolute)
Östergötland (Based on 2005 Regional Input-Output Table)							
Dairy	-0.01%	-0.89%	0.14%	0.16%	0.75%	0.14%	2.35%
Cattle	-0.63%	-1.51%	-0.29%	-0.62%	-0.06%	-3.11%	3.86%
Sheep	-0.71%	-0.10%	0.20%	-0.18%	0.52%	-0.27%	2.32%
Pigs	-1.12%	-1.24%	-0.08%	-0.14%	0.62%	-1.96%	3.40%
Poultry and egg production	-4.30%	-0.69%	1.59%	1.55%	2.33%	0.49%	10.65%
Other animals	-0.53%	-1.72%	-1.02%	-1.55%	-1.59%	-6.41%	6.67%
Cereal crops	0.61%	2.25%	-0.03%	0.57%	1.46%	4.85%	5.67%
Other crops	-0.13%	0.80%	-0.62%	-0.75%	0.05%	-0.65%	3.45%
Forage	0.01%	0.81%	-1.56%	-1.46%	-1.49%	-3.69%	6.06%
East Wales (Based on 2003 Regional Input-Output Table)							
Dairy	1.37%	0.11%	4.19%	1.03%	7.67%	14.36%	14.37%
Cattle	-0.79%	0.10%	1.23%	-0.15%	-1.42%	-1.04%	5.53%
Sheep	0.24%	-0.10%	0.49%	-0.44%	-3.56%	-3.38%	7.13%
Pigs and Poultry	7.35%	0.12%	4.96%	2.28%	15.32%	30.02%	30.02%
Main crops	-0.55%	0.10%	3.21%	-0.23%	-2.68%	-0.15%	9.18%
Forage	-0.46%	0.10%	2.66%	0.26%	0.75%	3.32%	5.22%
Misc. output	-0.22%	0.10%	1.31%	-0.04%	-1.67%	-0.53%	5.25%

Key: 1. Agriculture, 2. Other natural resources, 3. Manufacturing, 4. Utilities and construction, 5. Services

In Östergötland, the largest overall bias is exerted by the other animal production sector, where use of the aggregate multiplier would understate impact by a little over 6%. The largest masking of positive by negative biases is in the poultry and egg production sector, but it is clearly also a problem in the other crops, forage, dairy and sheep sectors. There is no clear pattern regarding the distribution of bias between the broadly defined industrial sectors, but use of an aggregate multiplier for cropping sectors appears to exert more bias on manufacturing than in the livestock economy. The results for East Wales reveal a more prevalent aggregation bias in this region. The largest bias occurs in the combined pigs and poultry sector. In absolute terms, these activities have absolutely small representation in the region's agriculture, and have low regional multipliers. Also, the bias is positive in relation to other non-farm sectors, which confirms that the intensive housed livestock sector has little or no interaction with input suppliers in the region. Nevertheless, even within the more prevalent forms of agricultural production in the region, such as sheep meat and dairying, have biases between -3.4% and 14.4%. Some other sectors, most prominently the cropping sectors, display large offsetting biases; use of an aggregate agricultural multiplier in the livestock sectors transmits a high level of bias to the broadly defined services sectors of the regional economy; using such a multiplier for cropping transmits to majority of bias to the manufacturing part of East Wales' economic activity.

In both regions, a strong indication is provided that, by applying an agricultural commodity demand shock to an aggregated IO model, considerable over- or understatement of the impact will occur, depending on which sector actually experiences the change. Further, since the results for East Wales and Östergötland diverge, it is unlikely that, *a priori*, the size and distribution of the aggregation bias can be known. Because of this, and because this residual bias is in some cases large, it is worthwhile exploring alternatives which produce results closer to that of the baseline itself.

4. AN APPROACH TO MODELLING AGRICULTURAL SECTOR REFORM SHOCKS

Normally, full disaggregation of agriculture (or any other sector of detailed interest) into its constituent sub-sectors is costly and time-consuming. Various attempts to overcome this problem for the purposes of more thorough policy analysis have been suggested: for example Wolsky (1984) provides an exact method for calculating an expression for a disaggregated Leontief inverse from an aggregated version. This requires two steps, i) a simple description of an augmented matrix, and then ii) correction by a distinguishing matrix that embodies supplementary data. This supplementary data, however, implies knowledge of parameters reflecting weighted differences of the unknown coefficients themselves, indicating the difference between disaggregated sectors for demand for inputs from supplying sectors, between supply of their outputs to purchasing sectors, and exchanges within the disaggregated sectors themselves. Thus, as Gillen and Guccione (1990) note, some of the expressions required to arrive at these parameters are so complex that it would be easier to directly estimate the missing coefficients of the matrix $\mathbf{A}$: and "As a rule of thumb, to be useful a disaggregation method should require data less costly to obtain than those needed for the direct estimation" (p. 40).

The method proposed here is more pragmatic than Wolsky's: it is cheaper and quicker than partitioning the entire sector and does not require gathering large amounts of data. Considering again the expression of equation (10), Morimoto (1970) has shown that it can be expanded into the sequence:

$$\begin{aligned}\mathbf{N\Delta f} &= [(\mathbf{I} + \mathbf{A}^{*} + \mathbf{A}^{*2} + \cdots)\mathbf{S} - \mathbf{S}(\mathbf{I} + \mathbf{A} + \mathbf{A}^{2} + \cdots)]\mathbf{\Delta f} \\ &= [(\mathbf{A}^{*}\mathbf{S} - \mathbf{SA}) + (\mathbf{A}^{*2}\mathbf{S} - \mathbf{SA}^{2}) + \cdots]\mathbf{\Delta f}\end{aligned} \quad (11)$$

The first, and largest, of the bracketed terms in the second line of (11) is described as "first-order" aggregation bias, or

$$\mathbf{N}^{(1)} = (\mathbf{A}^{*}\mathbf{S} - \mathbf{SA}) \quad (12)$$

Among other results, Morimoto was able to show that where a final demand shock applies to the unaggregated sectors, this first-order aggregation bias $\mathbf{N}^{(1)}$ is zero. This leads to the important insight that bias on the estimates of indirect and induced effects is transmitted, in successive rounds, through the structure of input coefficients; for instance, the impact of milk quota restrictions on input use would be in different proportion to that described by the average agricultural input coefficient column, and so on. Consequently, focusing on the input structure of the disaggregated element of the agricultural sector, national or regional data derived from farm accounts could provide a reasonable approximation of the magnitude of the first round of direct effect; in effect, it could represent the consequent demand change for the output of the sectors supplying inputs. This shortcut to full disaggregation can be described as a "variable cost approach", because most countries provide accounting data for different farm types, which can be used as the basis for gross margin budgets for specific commodities. Within the European Union at least, sufficient information for such purposes is collected by the farm accountancy data network (FADN).

The purpose of this variable cost approach is to move demand changes anticipated to occur in the agricultural sector away from the aggregated part of the IO table by using relevant information about the input structure for those parts of the sector that are affected.

Since unbiased results can be obtained where some sectors of the IO table are aggregated, provided that those affected by the first round effect are not, modelling the first round effect as accurately as possible in sectors supplying inputs to agriculture should reduce the bias. This also addresses the problem caused by applying traditional exogenous final demand driven shocks in the agricultural sector, whereas in fact most output is sold to marketing and processing sectors. Instead, the effect is modelled directly for the sectors initially affected, and the direct effect on the agricultural sector is determined by the partial equilibrium model. Indirect and induced effects can still also be estimated for the agricultural sector.

As noted in the introduction, partial equilibrium models are often linked to general equilibrium models to predict the indirect impacts of farm activities as they adapt to exogenous changes in policies. The effects of the 2003 CAP reforms provide a contemporary context for testing the variable cost approach against full disaggregation, and Arfini *et al*. (2007) have developed a positive mathematical programming (PMP) model of the farming sector in various EU regions (including both Östergötland and East Wales). The simulated shock predicted for each region between 2004 and 2006 by Arfini *et al*.'s model is expressed in terms of changes in crop areas and livestock numbers[2], which can be used to construct a disaggregated shock vector for each of the agricultural accounts that are affected.

For Östergötland, the PMP simulation suggested that, consequent on the 2003 reforms, a reduction would occur in numbers of both dairy cows and other cattle (in this region, sheep production in the region is negligible). Total cereals, oilseeds and other crops would decrease (mainly driven by a reduction in wheat, the most important crop in the region) whereas fodder crops will increase. For East Wales, the PMP simulation indicated an overall decline in livestock production, a shift from dairy and beef cattle into sheep production, and an accompanying shift from cereals to grassland with modest increases in fodder crop production. Table 2 provides a comparative summary of the main details of the predicted physical changes in Östergötland and East Wales: these form the first step in developing a demand shock, to examine the nature of contextual bias which would result from applying an aggregate agricultural multiplier and to assess the validity of the variable cost approach.

[2] The Arfini *et al*. study considered two policy scenarios: the first envisaged full decoupling at 2004 for all products benefiting from direct support, including milk, according to Annex VI of Reg. 1782/2003; the other, additionally, included the impacts of product price variations as predicted by the FAPRI model predictions produced at Iowa State University, USA. In this paper, for the sake of simplicity, only the first scenario is considered.

Table 2: Summary of Simulation Results, Östergötland and East Wales

	Östergötland			East Wales		
(1000 head or hectares)	*Baseline*	*Simulation*	*% change*	*Baseline*	*Simulation*	*% change*
Dairy breeding cows	40.2	36.4	-9.5	104.2	56.0	-46.3
Beef breeding cows	73.4	57.6	-21.5	112.5	45.7	-59.4
Breeding ewes	-	-	-	2079.7	1957.0	-5.9
Total cereals	102.8	75.4	-26.7	16.1	3.0	-81.1
Grassland and fodder crops	53.7	61.1	13.8	473.0	490.0	3.6
Oilseeds	7.1	6.6	-7.0	-	-	-
Other crops	8.4	7.6	-9.5	15.3	9.4	-38.5

Source: Arfini *et al*. (2007)

Such changes in output necessarily require changes in the use of variable inputs: thus, for example in the case of arable sectors, each unit change in area has an associated change in use of agrochemicals, fertilisers and seed; for changes in livestock numbers, there will be consequent changes in use of feed, forage costs and veterinary services. Each element of physical output change shown in Table 2 can be linked to the relevant variable costs described in the gross margin calculation per hectare of crop, or per livestock unit (see Appendix). This enables construction of a first round variable cost policy shock, which should show the effect as transmitted by the aggregated agricultural sector. However, to combine FADN-type gross margin data3 with predicted changes in different elements of farm sector output, two important modifications need to be made. First, gross margin budgets normally report transactions at farm gate prices, whereas flows in an IO table are in "basic prices"; that is, prices net of trade and transport margins, which appear in other relevant rows. Second, IO tables only record purchases from sources within the geographical boundaries of the region, with the remainder allocated to the import account, whereas gross margin budgets report all purchases regardless of origin. To address the former, it can be assumed that average trade margins are the same as those used to construct (and are commonly reported alongside) the base IO table itself. For the latter, the appropriate Flegg-Weber location quotient can be used (or, if available, superior survey-derived coefficients) to estimate the proportion of total purchases derived from regional sources. The modified regional gross margin, applied to the proportionate change in commodity output, then provides the alternative first round variable cost shock.

To compare the variable cost approach with the alternative of applying an aggregate shock to a single agricultural sector in each region, a predicted demand shock needs to be constructed for the agricultural sector overall and for the individual sectors which have been identified in the disaggregated IO tables for each region. It is assumed that the physical changes simulated by the Arfini *et al*. model are sufficiently accurate proxies of the changes in the value of output in each sector, which enables the proportionate change in outputs from the disaggregated sectors to be calculated easily. These changes, multiplied by the relevant

[3] Details of how different production activities use these inputs in the case study regions are provided in the appendix to this paper. Note that for Wales, no published gross margin calculation is available for arable crops, even though the data for construction could be made available. However, for the majority of arable crops in this region, costs from the neighbouring West of England region can be used as a realistic proxy.

disaggregated agricultural output multiplier, provide the baseline for comparison, and are shown in Table 3. The total predicted reduction in output in Östergötland is €25.85 million; in East Wales, it is €278.11 million. However, if a single aggregated agricultural multiplier (derived from an aggregate regional table as described above) were used, the predictions of reduced output would be €26.51 million and €288.08 million respectively; these are shown in the final row of Table 3.

Table 3: Disaggregated Shock and Impact, Millions Euros,[4] Östergötland and East Wales

	Östergötland			**East Wales**		
	Shock output value	Multiplier	Impact	Shock output value	Multiplier	Impact
			Disaggregated Shock			
Dairy	-6.04	1.179	-7.12	-76.71	1.258	-96.50
Beef	-4.65	1.210	-5.63	-60.74	1.412	-85.76
Sheep				-6.98	1.436	-10.03
Cereal crops	-9.00	1.090	-9.81	-20.76	1.403	-29.13
Grassland and fodder crops	0.29	1.216	0.35	0.22	1.369	0.30
Other crops	-3.07	1.186	-3.64	-40.51	1.407	-56.99
Total	-22.47		-25.85	-205.48		-278.11
			Aggregated Shock			
Total	-22.47	1.180	-26.51	-205.48	1.402	-288.08

Turning next to predictions derived from the variable cost approach, the changes in variable cost which result from the physical output changes can in nearly all instances be linked to the relevant non-farm sectors of the Östergötland and East Wales IO tables, and match conformably with the largest elements of the relevant columns of the IO coefficient matrix. There are a few allocations that are less compatible than others; for instance, in East Wales, changes in compound feed purchases must be allocated to the miscellaneous foods sector; in Östergötland, processed seed is supplied from the wholesale and commission trade sector, where farm cooperatives in Sweden are classified. The values of these changes, by sector, are shown in aggregated form in Table 4 (there are different sectoral classifications in the respective IO tables which mean that exact comparisons cannot be made: this does not, however, affect the underlying principle of the variable cost approach). Note that these *total* impacts (direct and indirect) of the transmitted shock, which amount to €3.45 million and €73.56 million respectively, need to be compared with the indirect impacts generated by the two earlier predictions. That is, the direct effect of the earlier approach needs to be added back to achieve a fair comparison.

[4] Calculated on the basis of average exchange rates in 2004, €1= SEK9.1243, €1= £0.67866

Table 4: Simulated Changes in Variable Input Use, Östergötland and East Wales (millions Euros)

Variable Cost (Input-Output Sector)	Simulated Shock	Multiplier effect	Impact
Östergötland			
Concentrate Feed (Food and beverages)	-1.14	1.243	-1.42
Veterinary (Health services)	-0.08	1.099	-0.09
Machinery and equipment (Trade, maintenance and repair services)	-0.79	1.146	-0.90
Fuels and lubricants (Refined petroleum products)	-0.67	1.147	-0.77
Electric power (Electrical energy)	-0.01	1.023	-0.01
Fertilizers, pesticides and agrochemicals (Chemicals)	-0.19	1.120	-0.22
Trade margin (Wholesale trade)	-0.03	1.124	-0.04
Total indirect impact			-3.45
East Wales			
Purchased bulk feed, stock keep, seeds (Agriculture and fishing)	-1.61	1.402	-2.25
Concentrate feed (Miscellaneous foods)	-30.91	1.444	-44.63
Fertilisers and sprays (Chemicals)	-10.73	1.250	-13.41
Veterinary and medicines (Health)	-5.84	1.547	-9.03
Trade margin (Wholesale trade)	-3.11	1.365	-4.24
Total indirect impact			-73.56

This is provided by Table 5, which summarises the foregoing discussion. The first line, for both regions, shows what might be considered the most accurate estimate, which would be available if regional agricultural sectors could be disaggregated easily into their constituent enterprises. The second line shows predictions derived from applying a first round shock to sectors supplying the farming industry, and the third shows the effect of assuming a single multiplier relationship between agriculture and the rest of the economy. Obviously, the direct effect is the same in each case, and adding the indirect effect provides an estimate of total impact. In Östergötland, the variable cost method produced an estimate which was a little over 2% of that of the most accurate estimate, contrasting with an overstatement by the aggregate multiplier of around 20%. In East Wales, variable cost method produced an estimate of 1.3% over the most accurate estimate whereas the aggregate multiplier overstated the impact by almost 14%.

Table 5: Comparison of Predicted Impacts. Millions Euros.

	Östergötland			*East Wales*		
	Direct impact	Indirect impact	Total impact	Direct impact	Indirect impact	Total impact
Disaggregated model	22.47	3.38	25.85	205.48	72.63	278.11
Variable cost model	22.47	3.45	25.92	205.48	73.56	279.04
Aggregated model	22.47	4.04	26.51	205.48	82.60	288.08

5. CONCLUSIONS

This paper was prompted by concern that, with increasing use of regional multiplier analyses to comprehend and predict the impacts of policy change, the bias associated with estimates based on a single aggregated agriculture IO sector could be a significant problem. In two separate and quite different case studies, this proved to be the case. Moreover, the simple and cheap alternative to disaggregation of the sector, using modified variable cost data to estimate first and subsequent round effects, was demonstrated to be effective in reducing overall error by an order of magnitude, when analysing the regional impact of the 2003 CAP reforms.

Using the traditional exogenous change in final demand is, of course, controversial, and the shock has sometimes been completely adapted to solve for exogenous variables other than final demand. Supply-driven IO models with the traditional Leontief multipliers modified to reflect output to output relations were suggested by Johnson and Kulshreshtha (1982) for analysis of (upstream) output, value added and income effects of changes in agricultural sectors in Saskatchewan, Canada; explained formally by Miller and Blair (2009); used practically by Roberts (1994) when analysing the upstream and downstream effects of milk quota restrictions on UK farming activities; and again by Eiser and Roberts (2002) to study forest activities in Scotland. However, while not reported in this paper, application of the variable cost method to their mixed variable approach produced only marginally different numerical results when compared, respectively, with disaggregated and aggregated multiplier predictions in our case studies. Likewise, it appears that the principle outlined here can be extended further to the CGE approach, which is not constrained by fixed prices. While the gross margin data used is drawn from primarily published averages, there is scope for further refinement using the more detailed underlying information contained within the FADN database.

An especially promising use for the variable cost approach would be in more specialised and marginal activities within the agricultural sector. Table 1 suggests that, where input coefficient structures diverge substantially from the average for the sector as a whole, biases become substantially larger. Applications which might benefit from more accurate indirect regional impact estimates could be in the sugar sector (see for example, University of Cambridge and Royal Agricultural College, 2004; Renwick *et al*., 2005); or the implications of shifts from conventional to organic or low-input agriculture (Faber *et al*., 2007). Beyond analyses of agriculture and its impact on the rest of the rural economy, there may be other applications where an alternative to disaggregation may be required: similar issues have arisen in analysing the economic repercussions of a carbon tax (Choi *et al*., 2010), and the economic impacts of different levels of construction pollution (Cheng *et al*., 2006). While the best remedy will always be full and detailed disaggregation of the constituents of the agricultural sector, the variable cost approach is both logically and economically coherent, and has the advantage of being much simpler and quicker.

APPENDIX: VARIABLE COSTS DATA

Livestock Variable Costs, Euros/head, Östergötland, 2004

	Dairy Cows	Beef Cows
Purchased concentrates	202.54	45.81
Veterinary and medicines	42.74	20.28
Agricultural requisites	111.46	100.17
Seeds	419.54	174.92
Machinery and equipment	9.43	5.37
Fuels and lubricants	38.03	10.52
Electric power	72.22	33.98

Source: Own calculations based on Agriwise, www.agriwise.org

- Crop Variable Costs, Euros/hectare, Östergötland, 2004

	Cereals	Fodder crops	Oilseed	Other crops
Agricultural requisites	56.77	19.40	37.04	125.71
Seeds	39.56	50.96	46.58	135.68
Machinery and equipment	52.94	53.81	54.14	83.84
Fuels and lubricants	51.07	23.45	21.04	42.85
Electric power	100.28	155.08	169.33	147.63
Fertilizers, pesticides and agrochemicals	90.97	111.68	120.56	172.62

Source: Own calculations based on Agriwise, www.agriwise.org

Livestock and Forage Variable Costs, Euros/head, Wales, 2003/4

	Dairy Cows	Beef Cows	Breeding Ewes
	Livestock Variable Costs		
Concentrates	409.54	173.03	12.97
Purchased bulk feed	9.27	9.56	0.47
Stock keep	0.00	2.99	3.08
Veterinary and medicines	61.81	44.78	3.99
Other livestock costs	146.44	69.06	5.02
	Forage Variable Costs		
Seeds	9.70	3.68	0.31
Fertilisers	57.23	60.88	4.35
Sprays	5.16	1.78	0.18
Other forage costs	77.06	69.81	4.79

Source: Own calculations based on Wales Farm Business Survey (2004)

Crop Variable Costs, Euros per hectare, West Region, 2004

	Winter Wheat	Winter Barley
Seed costs	51.72	48.92
Fertiliser	153.39	132.47
Crop sprays	183.60	154.27
Other variable costs	115.52	82.96

Source: Lang and Allin (2006).

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