Supply Response in France, Germany, and the UK: Technology and Price

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by

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Abstract: *We extend the methodology of a two-step profit function to obtain area and yield elasticities. We then estimate the effects of price and technology on crop output of France, Germany, and the UK. Area elasticities were obtained by adding area shadow price equations to the standard dual model of output and input equations. Change in output is dominated by technology in the UK and mixed in France and Germany. The results indicate policies affecting price will have diverse responses across countries and crops*.

Introduction

The numerous agricultural programs under the Common Agricultural Policy (CAP), the costs of the CAP, WTO constraints, and world markets make it difficult to model EU agricultural production and trade because modelers must make judgements about the technical and political feasibility of the results (see Josling, et. al.). On top of this, the EU is composed of 15 sovereign nations with varying histories, languages, inheritance laws, climatic conditions, and soils that combine to create agricultural heterogeneity. Most likely, the technical parameters of agricultural supply are influenced by these varied conditions and the numerous, sometimes conflicting, EU policies which have proven difficult to model.

While models may not be able to represent EU agricultural policies in detail, statistical methods may be able to establish the relative importance of general factors such as prices and technology on agricultural output in specific countries. For example, policies mainly affect output prices and models can capture the effect of output prices on supply response. Furthermore, while agricultural policies complicate modeling EU agriculture, the prominence of these policies underscores the importance of subjecting EU agriculture to empirical investigation. EU agricultural support policies and export subsidies were key issues during the GATT negotiations of the Uruguay Round. Within the EU, the costs of agricultural support policies to consumers and taxpayers have been an issue. For these and other reasons, agricultural policymakers and economists around the world would like to know what might happen to agricultural output when EU reforms lower support prices.

For example, if technological change has been the major reason for European agricultural growth, then EU agricultural output may continue to grow even as the EU lowers support prices. It also would indicate that yields could play an even greater role in driving output growth since the level of technology tends to influence yields. If instead, prices are relatively more important in determining agricultural supply, lower support prices may quickly reduce output by influencing year-to-year acreage decisions and longer term yield response.

This paper summarizes a study of the agricultural sectors of France, Germany, and the UK, (countries that account for over 50 percent of agricultural production in the EU-15), which had two principal objectives:

1) Determine the relative influence of technology and price on the supply of various crops, and;
2) 2) Estimate the price elasticities of area and yields in a manner consistent with the standard assumptions of economic theory.

Using an extension of the Chambers and Just two-step profit maximization model, we estimated output supplies and input demands system in the three EU countries and report:

1) The price and technology elasticities of supply and input demand;
2) the price and technology contribution to supply changes, and;
3) the components of crop supply elasticities such as yield and acreage elasticities.

Other Studies

There are few recent models of EU agriculture that use accepted statistical techniques to consistently estimate the supply response of the principal crops. The more comprehensive models have focused on aggregate product categories rather than individual crops (Ball *et al*., Larson). Ball *et.al*., estimated supply elasticities for production categories such as grains, feedgrains, livestock, and oilseeds for most EU countries. Earlier, Larson *et. al*., estimated a profit function for Germany in much the same manner as Ball. Both models imposed all theoretical properties, including the convexity condition, of a profit function on model parameters. Guyomard *et.al*., estimated the supply response for France using a profit function and reported price elasticities for various crops (soft wheat, barley, maize, other coarse grains, rapeseed, sunflower, and soybeans) but did not account for pulses, sugarbeets, animal products, or fruits and vegetables.

Given the paucity of statistical work in the area, these models provide useful insights into EU agriculture. However, they do not address two issues of interest to many economists and policymakers. These issues include: 1) The role of technology relative to that of price in determining the level of agricultural output in the EU, and; 2) the importance of area response relative to yield response. We now turn to these issues.

Our Approach

Yield and acreage elasticities were commonly reported before duality-based methods became the standard technique for estimating agricultural supply models (Coyle). To calculate these elasticities, agricultural economists estimated separate area and yield models using what today would be considered *ad hoc* methods. Yet, for the past twenty-five years economists have emphasized that supply elasticities must be derived from, and be consistent with, economic theory (Chambers, 1988). This often creates a gap between matter-of-fact real world economists who calculate acreage and yield elasticities and economists who use more formal models.

Several papers have come partway in bridging this gap. Chambers and Just (1989) devised a dual framework for modeling producer's behavior when quasi-fixed inputs (i.e. acreage) are allocated across products. They introduced a test for jointness for this model but they did not pursue the possibility their model had opened up for estimating acreage elasticities. Antle (1983) depicted agricultural production as a series of sequential decisions that relied on updating of information. Recently, Antle (2000) exploited the dual properties of a sequential decision model for non-jointly produced products, but he did not focus on the acreage allocation decision. Coyle (1993) in contrast, developed an acreage allocation model to handle a more general technology and worked out the attendant properties of the dual function. However, Coyle's paper did not address the issue of yields.

In this paper we extend the Chambers and Just (C&J) model by showing that, under certain assumptions, the C&J profit function can be estimated and combined with shadow price equations which together make it possible to calculate the elasticity of acreage allocation with respect to output prices. This, in turn, makes it possible to calculate all of the terms contained in C&J's "uncompensated" or long run elasticity formula (See C&J 1989, eq. 13), that includes acreage response equations. From this methodology, we show that both yield and acreage response equations can be calculated from the parameters of an estimated profit function.

An Acreage Allocation Model

The Chambers and Just model is a two-step approach to profit maximization. First producers maximize profits subject to a predetermined allocation of their quasi-fixed inputs. Then, in the second step, producers choose optimal allocation levels. For the following discussion, we let land be the only allocable quasi-fixed input. Producer's maximize profits conditional on a fixed set of acreage allocations or:

$$\Pi(p, w, a^1, \ldots. a^n, z) = \max_{y.x} \; p'y - w'x : y : eY(x, a^1 .. a^n) \qquad (1)$$

where: p is a vector of output prices, w is a vector of input prices, a^i is allocation of acreage to crop i, for i=1...n., z is a vector of other fixed inputs, y a vector of outputs, and x a vector of inputs.

The set $yeY(,x\ a^1\ ..a^n\ )$ defines the technology set.

The properties of the profit function in (1) are consistent with the properties of a standard multioutput profit function . The acreage terms essentially behave like quasi-fixed factors in any profit function. Given the profit function in (1), the decision to optimally allocate acreage can be depicted as:

$$\begin{aligned} &\underset{a^1..a^n}{Max}\ \Pi\ (p\ ,w\ ,a^1\ ,....\ a^n\ , z) \\ &s.t.\ \sum_{i=1}^{n} a^i = Ld \end{aligned} \qquad (2)$$

with first order (F.O.C.) conditions of:

$$dp(P,W,a^1,....a^n,z)/d\,a^i = l = ws \quad for\ i = 1..n \qquad (3)$$

where: λ is the lagrange multiplier equal to ws, the shadow price of allocated land. The solution to the maximization problem in (2) is a standard profit function.[2]

In estimating the above profit function, Ball *et. al.*, and C&J,. ensured their model parameters were consistent with the 2nd stage F.O.C. conditions by imposing the following set of nonlinear restrictions: $\delta\pi/A_1=\delta\pi/A_j$ for j=2… n, (4)

Our alternative method for representing equation (3) is operationally simple. Set $\delta\pi/\delta A_j=ws$ where j=1..n and where ws is the shadow price of land. In an optimal world, ws is

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[2] The decision process by producers may not follow the same order as in the C&J model. However, given information *ex-post* to the production decisions, one can assume (or test) if producers behaved as if they followed the Chamber two-step decision process.

equivalent to the price of land. Then, using observed land prices as the dependent variable, estimate shadow price equations jointly with the system of output supply and input demand equations while imposing cross-equation restrictions on common parameters within the system of equations. These shadow price equations will represent a stochastic approximation to the 2nd stage F.O.C. conditions in equation (4).

The system of output supply, input demands, and shadow price equations can be solved together with a land summation constraint to obtain acreage equations, which will be a function of output prices, input prices, and fixed factors, including the total land area. Taking the derivative of each of the acreage equations with respect to output prices obtains the response of acreage with respect to the output prices. To illustrate, specify a profit function as:

$$\Pi = Z + \sum_{i} \sum_{j} g_{ij}\, p_i * A_j + \Sigma\, d_{jj} A_j^2 \qquad (5)$$

> where: Z represents the standard component of a profit function which includes, output prices, input prices, technology, and non-allocative quasi-fixed inputs. The *a* terms represent acreage allocations. The *i* subscript, represents the *n* output prices. By Hoteling's Lemma, the supply equations are:

$$
\begin{array}{c}
d\Pi(P,w,A)/d\, P_1 = Y_1 = d(Z)/d\, P_1 + g_{11} * a_1 + g_{12} * a_2 \ldots g_{15} * a_5 \\
. \\
. \\
. \\
d\Pi(P,w,A)/d\, P_1 = Y_n = d(Z)/d\, P_n + g_{n1} * a_1 + g_{n2} * a_2 \ldots g_{5} * a_5
\end{array}
\qquad (6)
$$

Input demands are similarly represented. The acreage shadow price equations are obtained by taking the derivative of the profit function with respect to each allocation. Taking that derivative and dividing through by the own price in each equation obtains:

$$
\begin{aligned}
\partial \Pi / \partial a_i &= ws/P_1 = g_{11} + g_{21} * (P_2/P_1) + \ldots ?_{n1} * (P_5/P_1) + 2\, d_{11} * (a_1/P_1) \\
&\;\;\vdots \\
\partial \Pi / \partial a_n &= ws/P_n = g_{1n} * (P_1/P_n) + g_{2n} * (P_2/P_n). + \ldots g_{nn} + 2\, d_{nn} * (a_n/P_n)
\end{aligned}
\tag{7}
$$

To calculate acreage response to prices, the shadow price equations are jointly solved along with the constraint sum of acres equals the total land area (Σa_i=Ld.). Jointly solving the shadow price equations and taking the derivative of the resulting acreage equation with respect to an output price, obtains a formula which calculates the acreage response to prices. It can be shown that, given the above specification, the change in acreage allocation, a_n with respect to output price P_i is:

$$
d\, A_n / d\, P_i = -\frac{\left[\sum_{1}^{J-1} (g_{in} - g_{ij}) / 2 * d_{jj}\right]}{\left(\sum_{1}^{j-1} d_{nn} / d_{jj} + 1\right)}
\tag{8}
$$

All the terms in equation (8) are contained in the parameters of the profit function. Thus, any parameter required to calculate the elasticity of acreage with respect to an output price can be obtained by jointly estimating a system of output supply, input demand, and acreage shadow price equations. It is important to emphasize that the acreage response equations do not have to be derived. By itself, the formula in equation (8), provides sufficient information on how to combine the estimated parameters to calculate the acreage response to a change in an output price.

In addition to the restrictions on common parameters between equations, the following restrictions can be imposed on the shadow price equations to insure a symmetric acreage response to changes in output prices:

1) Set each d_{ii} of each profit function to be equal.
2) Impose symmetry on the γ's so that $\gamma_{ij}=\gamma_{ji}$.
3) Impose the restriction that $\Sigma\gamma_{i1}= \Sigma\gamma_{i2} = \Sigma\gamma_{ij}$ for every j in each profit function.

Specific Crops

Assuming non-joint production between four categories of crops, we specified the four profit functions, which taken together, represent the output of each country's agricultural sector. The first profit function represented grains crops, the second, pulses and sugar beets, the third aggregate vegetables and aggregate fruits, and the final profit function represented aggregate animal production.

The grains and oilseed models focused on four crops- wheat, barley, other grains, and rapeseed. In addition, we modeled corn for France and oats for Germany. We also specified a roots and tubers equation as part of the pulses and sugar beets model for Germany and the UK. Following Larson, we represented sugar beets as a fixed output because of the nature of the EU sugar quota. We also specified demands for the total amount of fertilizer, labor, and pesticides used in each country's agriculture. Each input demand equation represented the sum amount of each input demand from each profit function (see Chambers and Just for modeling input demand for non-jointly produced goods). We did not include interaction terms between the input prices and acreage terms in our model because of degrees of freedom constraints.

Our data set consisted of annual data for France, Germany, and the UK for 25 years, from 1973 through 1997. The assumption of non-jointness among product categories (grains, animals, pulses and tubers, fruit and vegetables) saved degrees of freedom by reducing the number of exogenous variables in each supply equation. This also helped reduce the chance of multicollinearity among prices. We took further steps to reduce multicollinearity among prices within the grains' models.[3] In sum, we specified four profit functions, each of which has outputs from the following groups of products:

- grains, and rapeseed;
- pulses, roots, and sugar beets;
- fruits, vegetables, and;
- animal products.

Estimating the Model

No policies were incorporated in the models with the exception of the quota on sugar. We specified normalized quadratic profit functions for the previously mentioned four categories of agricultural products (see appendix)[4]. For each profit function output supplies and input demands were derived from Hoteling's Lemma. Shadow price equations were obtained by taking the derivative with respect to the acreage terms. For consistency purposes, we also estimated shadow price equations for the fixed tractor input and a shadow price equation for sugar beets that we had modeled as a fixed output. Output prices were lagged representing lagged relative price expectations.

We jointly estimated the supply equations from each profit function, the sum of the input demand equations across profit functions, and area shadow price equations. This was done for each country. We imposed all the various symmetry conditions among output supply, input demand, and shadow price equations. We did not impose convexity and thus allowed for the possibility of obtaining wrong sign elasticities. In each country model, the energy price was represented by the price of oil and is

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[3] Our technique is described in a methods paper by Arnade available on request.

[4] The focus is on crop acreage and yield choice. Livestock was modeled as an aggregate and is not discussed.

used as the numeraire.

Prior to estimating the model, a Data Envelopment Analysis (DEA) was applied to EU data for 15 countries to calculate a technological change index for each crop in each country (Leetmaa and Arnade (1999), Faire (1996), Trueblood (1996). We then used the technical change index for the country being modeled as the exogenous technology variable in both the output supply and input demand equations. This variable was lagged one period to prevent simultaneous equation bias.

In estimating shadow price equations, the left hand side shadow price and each of the exogenous variables was divided by it's own p_j. This reduced the likelihood of multi-collinearity in the VCV matrix of errors in these equations. Also, for consistency, we estimated a shadow price equation for sugar beets and for tractors.

The Interesting Results

Technology or Price.

We estimated parameters for the price and technology variables of each country model in each equation. These parameters were then multiplied by the average annual changes in prices and the technology indices in our database. The results presented in Table 1 compare own price and technology influences on outputs.[5]

Only in the UK is technology a more dominant factor than price in influencing output response. Technology has ten times the impact that prices have on UK wheat and "other grain" production and approximately five times the impact on barely and rapeseed production. In France and Germany, the relative impact of price and technology are more mixed. Technological change dominates the French wheat production but reduces the production of "other grains" which had a strong price

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[5] The models and complete set of elasticities can be provided on request.

response. The impacts of own price and technical change on maize and barley production are approximately the same in France, although when all cross-price effects are considered, price effects dominate the supply of these two crops.[6] In Germany, prices are more important than technology in increasing output of every grain crop except oats.

The large impact of technology in the UK may be a result of investment in grain crops that occurred when UK farmers anticipated high and *guaranteed* CAP support prices.[7] In addition, the physical stock of capital in the UK was considerably lower than in Germany or France (see Ball, 1993). Theory tells us that, with diminishing returns, the marginal product of capital is greater at lower levels . Thus, investment at this margin could have a greater impact.

Comprehensive Supply Elasticities

The output supply elasticities in tables 3-5 represent the complete impact of price on supply and include the price influences on yields, areas, as well as cross-area price effects. France's comprehensive supply elasticities have positive signs for all crops. Own-price elasticities for "other grains" and rapeseed are relatively high, barley has an elastic supply response, and wheat and maize have low own-price elasticities. Estimated cross-price elasticities of barley, maize, and rapeseed are high indicating they substitute for all crops. Most other crops are a mix of substitutes and complements for each other. Since barley is in crop rotation with rapeseed, it is not surprising that barley and rapeseed appear to be substitutes for other crops.

The Guyomard *et.al.*, study of French agriculture provides comparable estimates of own price elasticity for the grains crops. Their elasticity estimates were higher than ours for all comparable

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[6] Surprisingly, technical change reduces rapeseed and pulse production in France. This was probably the result of large-scale adoption of the double zero (double low) variety of rapeseed that continued throughout the 1980's. This variety had a lower yield than the traditional variety but was a preferred animal feed.

[7] Our technology index would measure capital not included in the tractor stock.

crops (wheat, barley, other maize, and rapeseed) and may reflect the sample period (1970-1992) of the study. That is, price reductions stemming from the 1992 reforms may have lowered our elasticities since price increases often elicit a larger ouput response than do price decreases (Tomek, Tweeten). [8]

The comprehensive supply elasticities for Germany tend to be higher than the elasticities for France. All own-price elasticities in the grain category have the right sign but the elasticities for vegetables and fruits have the wrong sign. The results for the other crops are mixed perhaps due to the large differences in farm structure in the different regions of Germany. The UK's comprehensive elasticities for grain crops are low with the exception of the "other grains" category. The comprehensive fruit price elasticity stands out as unusually large and in practical terms is almost equivalent to a flat supply curve. The cross-price elasticities present a mixed picture in terms of magnitude and sign.

Area Elasticities

Table 7 presents the elasticity of area with respect to output price. French own price elasticities have the right sign. Wheat and fruit area elasticities are close to zero while rapeseed has the highest area elasticity and is more than half the size of its comprehensive elasticity. Area also plays an important role in German supply elasticities. All grain crop area elasticities have the right sign and, as in France, only rapeseed has an elastic response to prices. However, all non-grain crop elasticities have the wrong sign or are small. All UK area elasticities have the right sign but all are close to zero except for fruit.

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[8] Asset fixity lowers producer response to downward falling prices. Additionally, an assymetric response to the direction of price changes would be a likely reaction to past price reductions in the CAP reform of 1992, which were compensated by direct payments to producers. Dairy and sugar quota allocations in previous reforms also provided incentives to farmers anticipating future reforms to maximize yield regardless of price in order to form a high historical base.

Yield Elasticities

Table 8 provides the estimates of the yield elasticities. Overall, French yield elasticities are quite low. However, most crops turn out to be area substitutes but yield complements. For example, while wheat substitutes for maize, barley, and rapeseed in acreage response, it complements other grains in the yield response. Wheat is a relatively more reliable crop in yield and has more uses than other grains and it is a natural substitute for them. Yet, when wheat yields increase, it could result from intensive input use that is jointly applied to other grains. And while "other grains" are a strong substitute for maize, barley, and rapeseed in terms of area, "other grain" is a complement to maize in yield.

German wheat and barley yield elasticities are unusually high. Perhaps this is due to the relative small farm size in Germany (prior to reunification). Area constraints would force German producers to rely on a yield response to price increases. However, German rapeseed has almost no yield response to price perhaps because of the introduction of the low-yielding double-zero variety that was widely adopted over the sample period. To a lesser extent than France, there are instances in Germany where crops are area complements but yield substitutes. The UK yield elasticities for "other grains" are larger than French or German elasticities but are in the same range for all other crops.

Overall, the signs on the price variables are correct and statistically significant for the major crops. The results highlight that there are large differences in supply response among the countries even though the three countries operate under the CAP. For example, UK farms tend to depend on technical change and yield response to price. In contrast, French farmers primarily rely on area allocation to respond to price. It is notable that the statistical results that are closest to being robust across countries are for wheat, barley, and other grains which are the three principal crops in the model.

Conclusion

This paper summarizes our estimation of agricultural supply response models for three European countries, compares the price and technical change contribution to supply, and reports the output supply elasticities. While our model could not account for many of the agricultural policy mechanisms applied by the EU over the 1993-1997 period, it could provide insights into which country and crop would be most influenced by a change in price support. For example, we found technical change to be the major factor influencing agricultural output in the UK while prices had a relatively more important role in France and Germany.

We also report the components of crop supply elasticities. In France, area elasticities turned out to be a critical component of supply response, whereas, in the UK, yields were more important. In Germany the situation was mixed. In the UK, the importance of yield response to prices was consistent with the finding that technical change dominates supply response. Yields are influenced by technology whereas acreage response is a more short-run phenomenon. For grains, our model results were fairly robust across all countries. It was noted that the rapid adoption of a new variety of rapeseed in combination with a new EU oilseed policy during this period affected the results.

This article also introduced a method for estimating acreage elasticities using an accepted dual model of agricultural production. That is, we extended the method for estimating the Chambers and Just two-step profit function by estimating equations which represent the shadow price equations of acreage allocation. We then solve these equations together with a land constraint term to obtain the acreage response to output price. This technique, together with the standard method for estimating output supplies and input demands, makes it possible to calculate the elasticities of yield and acreage with respect to output prices.

There are several possible ways to follow up on the results presented in this paper. For example, this study has compared the influence of price and technological change on annual production of specific crops. Following this study, it would be useful to examine the relation between technological change and long-term price trends.

Finally, it should be emphasized that estimated elasticities often are sensitive to the assumptions made about a particular model and the techniques used to estimate its parameters. The elasticities reported in this paper are no exception.

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Appendix A

We specified a normalized quadratic profit function. This functional form is conditional on the observed set of acreage allocations. The functional form was:

$$\Pi = g^{1}(p) + \sum_{i=1}^{n+3} \sum_{k=1}^{3} b_{ik} * p_{i} * z_{k}$$

$$\sum_{i=1}^{n+3} \sum_{j=1}^{n} g_{ij} p_{i} * a_{j} + \sum_{j=1}^{n} d_{jj} a_{j}^{2} +$$

$$\sum_{j=1}^{n} \sum_{k}^{3} a_{j} * z_{k} + Oth$$

where:

$$g^{1}(p) = (1/2) * \sum_{1=1}^{n+3} \sum_{j=1}^{n+3} C_{ij} \; p_{i} * p_{j} \qquad \text{where} \; : \mathrm{C}_{ij} = C_{ji}$$

$$\text{for} \; : \; 1 \leq i, \; j \leq N,$$

Where: p_i represents n output and 3 input prices normalized on the price of energy, the z's represent nonallocatable quasi-fixed inputs (tractors, and technology) and a quasi-fixed output (sugar beets), and Oth represents other variables. The a_j's represent the acreage allocation terms. Note that the normalized NQ can be viewed as a special case of the popular General Mcfadden functional form. By Hoteling's Lemma, output supplies are now defined as:

$$d\Pi(.)/d \; p_{i} = y_{i} = b_{i} + \sum_{2=1}^{n+3} c_{ij} * p_{j} + \sum_{k=1}^{3} a_{ik} z_{k} + \sum_{j=1}^{n} g_{ij} a_{j}$$

for each output i . And input demands are defined as:

$$d\Pi(.)/d \; p_{n} = - x_{n} = b_{n} + \sum_{j=1}^{n+3} c_{nj} * p_{j} + \sum_{k=1}^{3} a_{nk} * z_{k}$$

for each input n.

Conditions for homogeneity are imposed by the functional form. Symmetry of supply response to price changes is imposed by restricting the C_{ij} matrix to be symmetrical. The acreage shadow price equations are:

$$d\Pi(.)/d\, a_j = \mathbf{Ws} = \sum_{i=1}^{n} g_{ij} * p_i + \sum_{k=1}^{3} u_{kj} z_k + d_{jj} * a_j$$

In estimating the shadow price equations, the left-hand side shadow price and each of the exogenous variables were divided through by it's own p_j . This reduced the likelihood of multicollinearity in the VCV matrix of errors in these equations. Since we estimated shadow price equations for acreage, we also estimated shadow price equations for the fixed tractor input and a shadow price equation for the fixed sugar beet output.

Appendix B

When land is the only quasi-fixed input, the elasticity of supply can be written as: (see equation 13 in Chambers and Just)

$$(d\ y_i(p,w,Ld)/d\ p_l)(p_i\ /\ y_i) = \{d\ y_i(p,w,a^1 \ldots a^n)/d\ p_l + (d\ y_i/d\ a_i)*(d\ a_i/d\ p_l) + \sum_{j=2}^{n}\ (d\ y_i/d\ a_j)*(d\ a_j/d\ p_l)\}(p_l \tag{1a}$$

where: yd$_i$ is the yield of crop I; and a$_i$ is the acreage of crop i.

The first right-hand side term, can be rewritten as:

$$d\ y_i(p,w,Ld)/d\ p_l = d\ y_i(p,w,a^1 \ldots a^n)/d\ p_l + \sum_{j=2}^{n}\ (d\ y_i/d\ a_j)*(d\ a_j/d\ p_l) \tag{2a}$$

This is because acreages are held fixed for this term. Representing the first term in brackets in equation 1a by equation 2a, multiplying through by the term outside the brackets, dividing the middle term by a$_i$ /a$_i$ and each of the remaining k terms by each a$_k$ /a$_k$ respectively, equation (1a) becomes:

$$\varepsilon^{yp}_{11} = \varepsilon^{ydp}_{11} + \varepsilon^{a}_{11} * \varepsilon^{sa}_{11} + \Sigma\varepsilon^{a}_{k1} + \varepsilon^{sa}_{1k} \tag{3a}$$

The left-hand term is the comprehensive supply elasticity; the first right hand term is the yield elasticity; and the first middle term is the acreage elasticity multiplied by the elasticity of output with respect to its own acreage. The final terms represent cross-price acreage elasticities, multiplied by the elasticity of crop response with respect to changes in other crop acreages. When the change in supply with respect to acreage equals one, and either all cross-price acreage elasticities are zero, or the change in crop output with respect to the acreage of other products is zero, the elasticity formula reverts to a yield plus acreage elasticity or: $\varepsilon^{yp}_{11} = \varepsilon^{ydp}_{11} + \varepsilon^{a}_{11}$

Table 1. Countries and Commodities in the Profit Function

Commodities	France	Germany	UK
Grains and Oilseeds	Wheat, corn, barley, other grains, rapeseed	Wheat, barley, oats, other grains, rapeseed	Wheat, barley, other grains, rapeseed
Roots,Tubers, and Sugar	Indices for potatoes & other root crops, pulses, and sugar	Indices for potatoes, pulses, and sugar	Indices for potatoes, pulses, and sugar
Fruits and Vegetables	Indices for Fruits and Vegetables	Indices for Fruits and Vegetables	Indices for Fruits and Vegetables
Animal Products	Livestock output index	Livestock output index	Livestock output index

Table 2: Source of Output Changes

	France		Germany		UK	
	Tech	Own Price	Tech	Own Price	Tech	Own Price
Wheat	571.4	134.1	284.2	661.9	355.7	38.3
O-Grain	-116.6	2267.1	85.9	509.7	83.3	6.2
Maize	23.9	35.9				
Barley	145.3	156.5	169.2	239.7	176.4	49.0
Rapesd	-67.7	91.7	45.0	943.3	32.7	7.7
Oats			18.5	10.0		
Pulses	-15.0	8.4	1.9	0.0	10.8	0.0
Roots			297.3	122.4	271.9	106.6
Vegtbl	7.7	664.4	174.3	-122.2	-15.0	37.9
Fruits	32.5	24.6	76.3	-63.6	-53.6	268.7

1/ The number represents the average change in output, arising from the factor in the column title. For example, technology change had almost 4 times the as much influence on wheat as the own price of wheat.

France: Table 3: Comprehensive Elasticities 1/

Prices

Quantity	Wheat	Grain	Maize	Barley	Rapesd	Pulses	Veget	Fruits
Wheat	0.21	4.33	-0.84	-0.22	-0.13			
O-Grain	0.03	1.45	-0.04	-0.11	-0.09			
Maize	0.18	-0.88	0.10	-0.07	-0.22			
Barley	0.15	-3.00	-0.09	0.50	-0.07			
Rapesd	-0.37	-7.58	-0.95	-0.23	2.97			
Pulses						0.31		
Vegtbl							0.78	0.00
Fruits							-1.22	0.37

1/ For example the own price elasticity for wheat in France is .21

Germany: Table 4: Complete or Uncompensated Elasticities 1/

Prices

Quantity	Wheat	Grain	Barley	Rapesd	Oats	Pulse	Root Crops	Vegetbl	Fruits
Wheat	3.60	-1.49	-1.64	-0.07	-0.12				
O-grain	-3.42	2.66	1.54	-0.15	0.38				
Barley	-3.05	1.26	1.97	-0.08	0.05				
Rapesd	-0.10	-0.14	-0.09	1.19	-0.09				
Oats	-2.23	2.90	0.48	-0.74	0.52	0.01			
Pulse									
Roots							0.47	-0.22	-0.09
Vegetbl							0.08	-0.60	0.13
Fruit							-0.04	0.15	-0.38

1/ Similar format to table 3

UK: Table 5: Complete or Uncompensated Elasticities 1/

Prices

Quantity	Wheat	Grains	Barley	Rapeseed	Pulse	Crops	Vegtbl	Fruits
Wheat	0.14	0.25	-0.12	-0.06				
O-Grain	5.19	2.58	-0.65	-1.08				
Barl	-0.09	-0.05	0.20	-0.03				
Rapesd	-0.40	-0.41	-0.13	0.45				
Pulses					0.00			
Roots						0.09	-0.20	-0.76
Vegtbl						-1.19	0.26	0.21
Fruits						-2.13	1.06	15.97

1/ Similar format to table 3.

Table 6: Technology Elasticities

Table 7: Area Own Price Elasticities

	France	Germany	UK
Wheat	0.71	1.22	1.03
O-Grain	-0.11	1.93	10.58
Barley	0.44	-0.80	0.63
Maize	0.06		
Oats		4.69	
Rapesd	-1.36	0.82	1.30
Pulses	-0.30	0.81	0.72
Roots		-0.42	1.13
Vegetble	0.02	-0.23	-0.16
Fruit	0.55	0.44	-4.98

1/For example, French wheat output rises 7.1% if the French technology index rises 10%.

	France	Germany	UK
Wheat	0.038	0.49	0.00
O-Grain	0.614	0.40	0.02
Barley	0.202	0.08	0.00
Maize	0.216		
Oats		0.25	
Rapesd	1.584	1.43	0.03
Pulses	0.113	0.00	0.00
Roots		-0.23	0.06
Vegetble	0.512	-6.58	0.03
Fruit	0.078	0.00	2.36

Table 8: Yield Own Price Elasticities 1/

	France	Germany	UK
Wheat	0.175	2.21	0.12
O-Grain	0.088	0.65	2.47
Barley	0.048	1.77	0.21
Maize	-0.138		
Oats		-0.29	
Rapeseed	0.084	0.00	0.06
Pulse	0.100	0.42	-0.02
Roots		0.50	-0.02
Vegetabl	-0.270	0.16	0.03
Fruit	0.171	-0.38	-0.11

1/ acreage held fixed