Sources of Growth in French Agriculture: Short-Run Supply and Input Demand Responses and Effects of Technological Change

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Abstract: A disaggregated variable profit function model is estimated for French agriculture. Short-run results suggest price inelastic, positively sloped supply functions and that French agricultural production has benefited from important technological gains since the early 1960s. These gains are due both to domestic public agricultural research expenditures and international transfers of technology.

Introduction

Since the slowdown in the growth of world agricultural trade in 1980, the USA and the EC have engaged in a series of confrontations over their respective agricultural policies. High producer prices and the general absence of production controls in Europe have been of particular concern in the USA as world grain stocks have risen and the EC has emerged, with substantial subsidies, as a net cereals exporter. Levels of frustration have increased on both sides of the Atlantic as the USA has responded with its own export enhancement payments and other costly policies.

While the drought affecting US production in 1988 may lower budget costs temporarily, it will not lessen the long-run conflict about policy-induced excess supplies. With current adversarial positions difficult to sustain, the USA and some members of the EC continue to seek means to limit their conflict and obtain relief from the high costs of their agricultural programmes.

However, two fundamentally different views of the sources of growth in European agriculture remain. The US view emphasizes that growth has been created by artificially high prices. European agriculture is seen as cost noncompetitive, and some argue that rather dramatic price-support reductions to bring internal prices to world levels would have large effects on agricultural input use, investment, and output (Schmidt, Frohberg, and Maxwell, 1987). The European view emphasizes the political infeasibility of such large price reductions (Bergmann and Petit, 1987) and the effects on output growth of factors such as technological change, structural policies, investments in input supply, processing and marketing facilities, and substitution of capital for labour in the modernization process (Petit, 1987; and Stanton, 1986). From this perspective, reduced price supports can have only a limited impact on output, and European agriculture is becoming increasingly competitive over time.

This paper addresses the debate about sources of growth in European agriculture by evaluating the changes in French agriculture from 1960 to 1984. A multiproduct variable profit function model is used as the basis for the analysis.

Empirical Specification

French agricultural output, which accounts for almost 30 percent of the agricultural production within the EC, is disaggregated into four output categories. Quantities of French agricultural production of cereals (Q_C), noncereal crops (Q_V), milk (Q_M), and animal products (Q_N) were computed from output series published by the Institut National de la Statistique et des Études Économiques (INSEE, 1985).[2] Output price indices (P_C, P_M, P_V, *and* P_N) were derived from INSEE data provided by the French Ministry of Agriculture. One-year-lagged average market prices were used in the model as proxies for expected output prices.

On the input side, the variable inputs are feed, fertilizer-energy, and hired labour, while family labour and capital investments (buildings and machinery) are considered quasi-fixed, and cultivated acreage and pasture acreage are assumed to be fixed factors of production.[3] For the fertilizer-energy and feed inputs, INSEE quantity (I_F *and* I_D) and price (r_F *and* r_D) data are used. Employment of hired agricultural labour (I_H) and a series on family labour, adjusted for off-farm work, were obtained from the French Ministry of Planning. These series are the ones used in the Ministry of Agriculture's MAGALI short-run forecasting model (Albecker and Lefebvre, 1985) and are more complete than previously published agricultural labour series. INSEE also publishes data on the cost of hired labour (r_H), which includes wages and social charges paid by farm owners on behalf of farm workers. INSEE data are also available on the total value of farm buildings and machinery (*K*). Series on cultivated acreage (*CL*) and pasture acreage (*PL*) are published by the Ministry of Agriculture.

Sources of technological change are represented by two variables. First, French public expenditures on agricultural research (*RES*) enter the model with a lag structure (several structures were tested and the results are discussed). Public agricultural research expenditures by the Institut National de la Recherche Agronomique and three smaller research institutes were compiled from budgets of the Ministry of Agriculture. These budgets include total expenditures in six categories but not a breakdown of expenditures by commodity. Data on private agricultural research expenditure are not available, nor are consistent data series on expenditures for agricultural extension and the levels of education and training of French farmers. Omission of these variables may bias upwards the estimated coefficients of public agricultural research expenditures in the model, since private research may be complementary to public research and extension expenditures, and education and training levels of farmers are likely to be positively correlated with research expenditures.

The second technological change variable included in the model is the level of total agricultural productivity in the USA. This variable was used as a proxy for international availability of technology. In the choice of this proxy, the hypothesis is that the USA is a major source of new agricultural technologies applied in France (other sources of international technology transfer, such as among European countries, were not modelled) and changes in US agricultural productivity were assumed to reflect, to a large extent, the availability of these new technologies, whether produced by the public or private sector. A five-year moving average of US productivity was used to account for possible lags in technology transfers and to minimize the effect of random yearly fluctuations. Use of a productivity index rather than US research expenditures eliminated the need to measure the lag associated with the effects of US research on US productivity.

In terms of agricultural policies, three French policy variables related to structural change were also included in the model. These variables were the cumulative area of farmland consolidated under voluntary programmes (*REM*) (lagged one year), the annual value of farm sales handled by the SAFERs to accommodate farm consolidation (*SAF*), and the annual value of early and supplementary retirement payments made to exiting farmers (*IVD*). Each of these policies is designed to facilitate modernization of the agricultural sector through consolidation and enlargement of production units. A fourth policy variable (*CR*) measures credit subsidies by the ratio of the average loan rate given to farmers to the market rate. This variable was constructed from unpublished data on the amounts of loans given to farmers by the Crédit Agricole at market and preferred interest rates.[4]

Finally, the average yearly deviations from normal rainfall (*WEA*) were included in the model to control for weather variations. A dummy variable (*DUM*) with a value of one starting in 1976 and zero otherwise was also included. This variable proxied for the aftereffects of the world oil shock in the early 1970s and an extremely severe drought in France in 1976. These events caused enduring structural changes in the French agricultural production system (Bourgeois, 1983).

Short-Run Output Supplies and Input Demands

The short-run model includes the four output supply and three variable input demand equations derived from a restricted profit function specified as a normalized quadratic. Coefficients of these equations were estimated by normalizing on the feed price and treating the remaining six equations as seemingly unrelated regressions. The hypothesis that the six equations are derived from profit maximization implies fifteen cross-equation symmetry restrictions. These restrictions were tested jointly, and symmetry was not rejected at a 5-percent significance level. The cross-price coefficients in the missing (feed) equation were then obtained by imposing the symmetry conditions, and its own-price coefficient was derived by homogeneity. The remaining coefficients of the feed equation are not subject to theoretical constraints. After fixing the price terms, these remaining coefficients were estimated by OLS.

Estimated elasticities at the data sample means are reported in Table 1. The estimated own-price elasticities suggest upwards-sloping output supply functions and downwards-sloping variable input demand functions for French agriculture that are price inelastic in the short run. The estimated own-price elasticities for cereals, noncereal crops, milk, and animal products are 0.34, 0.66, 0.53, and -0.006, respectively. The estimated fertilizer-energy, hired labour, and feed own-price elasticities are -0.88, -0.68 and -1.90, respectively. The own-price elasticities are statistically significant at the 5-percent significance level, with the exception of the cereal price elasticity (p=0.22) and the animal products elasticity (p=0.95).

The estimated cross-price elasticities shown in Table 1 suggest complementarities between production of cereals and milk and cereals and animal products that are marginally significant (p=0.11 and 0.15, respectively) and substitutability between noncereal crops and milk (p=0.07). Substitutabilities between production of cereals and noncereal crops and milk and animal products that might be expected *a priori* are not statistically significant. Thus, cross-price elasticities among the outputs seem to be less well estimated than own-price elasticities. Among the variable inputs, hired labour and fertilizer-energy are estimated to be substitutes (p=0.0003), while feed does not show substitutability with the other inputs.

With respect to the quasi-fixed factors, family labour is estimated to have positive effects on production of cereals, milk, and animal products. The estimated elasticities are 1.40, 0.49, and 0.87, respectively, with p-values of 0.12, 0.09, and 0.04, respectively. Capital also has positive effects in the cereals, milk, and animal products equations, with elasticities of 0.72, 0.80, and 0.74, respectively. The statistical significance of the capital elasticity is low in the cereals equation (p=0.58) and higher in the equations for milk (p=0.09) and animal products (p=0.19). Capital has a positive and significant effect (p=0.07) on use of fertilizer-energy, while family labour has a positive and significant effect (p=0.003) on employment of hired labour.

The elasticities for public agricultural research expenditures reported in Table 1 are 1.27, 0.27, 0.10, and 0.12, respectively, in the cereals, noncereal crops, milk, and animal products equations. The associated p-values are 0.0001, 0.02, 0.07, and 0.09, respectively. In each case, research expenditures have a positive and significant impact on production, the estimated effect being particularly large for cereals. French public agricultural research expenditures are not significant in the short-run variable input demand equations.

Because of the importance of the research variable, some additional comments on its lag specification are warranted. The estimated effects of public agricultural research expenditures shown in Table 1 are based on inclusion of one lag of the research expenditures variable in each equation. Research expenditures were lagged five years in the cereals, milk, and fertilizer-energy equations and four years in the other equations.[5] These lag lengths were selected after a preliminary estimation in which current research expenditures and five years of lagged expenditures were included in each equation without constraints on the lag coefficients. Despite collinearity introduced by inclusion of multiple lags, one or more lagged research expenditure variables were statistically significant in three of the four output equations (the exception was noncereal crops). The final model was

Table 1—Estimated Elasticities of the Short-Run Output Supply and Variable Input Demand Functions for French Agriculture and Significance Levels of the Estimated Coefficients*

Explanatory Variable	Dependent Variable: Q_C	Q_V	Q_M	Q_A	I_F	I_H	I_D
P_C	**0.34**	**-0.05**	**0.16**	**0.11**	**0.18**	**0.17**	**0.58**
	0.22	0.62	0.11	0.15	0.44	0.25	0.30
P_V	**-0.16**	**0.66**	**-0.24**	**-0.13**	**0.03**	**0.02**	**0.86**
	0.63	0.02	0.07	0.32	0.93	0.87	0.30
P_M	**0.18**	**-0.09**	**0.53**	**-0.02**	**0.26**	**0.04**	**0.25**
	0.11	0.06	0.0008	0.56	0.06	0.65	0.30
P_A	**0.40**	**-0.16**	**-0.007**	**-0.006**	**-0.38**	**-0.19**	**0.19**
	0.12	0.27	0.54	0.95	0.21	0.19	0.70
r_F	**-0.12**	**-0.007**	**-0.15**	**0.07**	**-0.88**	**0.59**	**0.10**
	0.44	0.92	0.06	0.23	0.03	0.0003	0.90
r_H	**-0.15**	**-0.006**	**-0.03**	**0.04**	**0.73**	**-0.68**	**-0.05**
	0.29	0.88	0.68	0.26	0.001	0.005	0.70
r_D	**-0.42**	**-0.23**	**-0.16**	**-0.04**	**0.12**	**-0.06**	**-1.90**
	0.30	0.30	0.30	0.70	0.90	0.70	†
L	**1.40**	**0.73**	**0.49**	**0.87**	**1.47**	**0.18**	**-0.70**
	0.12	0.32	0.09	0.04	0.16	0.003	0.60
K	**0.72**	**-0.38**	**0.80**	**0.74**	**2.83**	**0.19**	**1.50**
	0.58	0.73	0.09	0.19	0.07	0.61	0.38
RES	**1.27**	**0.27**	**0.10**	**0.12**	**-0.02**	**0.16**	**-0.04**
	0.0001	0.02	0.07	0.09	0.88	0.11	0.92
USP	**0.31**	**1.92**	**0.99**	**0.20**	--	--	--
	0.65	0.004	0.02	0.66			
CR	**-0.32**	--	**-0.14**	**-0.05**	**0.48**	--	**0.66**
	0.05		0.05	0.45	0.02		0.08
REM	--	--	**-0.19**	**0.27**	--	--	--
			0.55	0.49			
CL	**2.27**	**-0.62**	--	--	**-0.87**	**1.28**	**2.04**
	0.04	0.43			0.54	0.03	0.02
PL	--	--	**0.75**	**0.37**	**-0.95**	**-0.52**	**1.19**
			0.002	0.12	0.13	0.07	0.21
R^2‡	0.9903	0.9279	0.9908	0.9865	0.9814	0.9988	0.9549

*Elasticities are given in bold typeface; significance levels (p-values) are reported below the respective elasticities. All variables are defined in the text.

†The p-value of the own-price coefficient of the feed input is not computed but is likely to be greater than 0.30 since the variances of the other coefficients in the feed input equation are high.

‡Obtained in first-stage of GLS estimation, except for I_D, which is obtained from separate OLS estimation fixing coefficients of output and input prices based on symmetry and homogeneity properties of the system of equations.

estimated with only one lag of research expenditures to reduce collinearity and save degrees of freedom.[6]

The second technological change measure, international technology transfers proxied by the five-year moving average of US agricultural productivity, is also estimated to have significant positive effects on French agricultural production. The estimated elasticities of noncereal crops and milk supplies with respect to this measure of international technology availability are 1.92 and 0.99, respectively, with p-values of .004 and .02, respectively. The international technology transfer variable is not significant in the cereals or animal products equations. It is not included in the variable input demand equations because of the limited number of degrees of freedom afforded by the data. When included, it is not statistically significant (the p-values of its coefficient in the fertilizer-energy, hired labour, and feed equations were 0.61, 0.98, and 0.36, respectively).

The limited degrees of freedom afforded by the data also explain why all the policy variables are not present in all the equations. Overall, the French policy variables related to structural change and credit policy are not very robust in the model. Collinearity among the policy variables led to a focus on the cumulative area of farmland consolidated (REM) and on the measure of credit subsidies (CR). These variables were dropped from the final equations when their p-values in initial models were greater than 0.3 unless their exclusion noticeably affected the estimates of other coefficients. With this procedure for model specification, the credit variable has statistically significant effects in four equations ($p \leq 0.08$), but its negative sign in the input demand equations is difficult to interpret.

Among the remaining fixed and exogenous factors, the allocation of land between crops and pasture has a significant effect on cereals ($p=0.04$) and milk ($p=0.002$) production. The estimated elasticity of cereal production with respect to crop acreage is 2.27, somewhat larger than expected and suggesting the possibility of measurement error with respect to changes in land quality over time. Yearly deviations from normal rainfall do not enter the final model. Coefficients of the rainfall variable were not statistically significant, and their inclusion caused rejection of the cross-price symmetry conditions. These problems are likely to be due to the inadequacy of total annual rainfall as a proxy for weather conditions affecting agricultural production. The coefficient of the dummy variable for structural changes induced by weather and other shocks in the mid-1970s was statistically significant in three of the output equations and one of the variable input demand equations ($p \leq 0.05$), and it was retained in these equations.

Conclusions

Conflicting US and European views about the sources of growth and competitiveness of European agriculture shape agricultural trade negotiating positions and will have much to do with accomplishments in discussions, such as the current GATT round, and with the character of international competition in agriculture that emerges.

This paper has presented short-run results from a variable profit function model in which French agriculture is aggregated into four outputs, three variable inputs, and two quasi-fixed inputs. Some of the estimated coefficients should be interpreted with caution due to lack of statistical significance and possible bias (especially in the long run). Nevertheless, various caveats are unlikely to change several of the major results of the analysis or their policy implications. On the issues at stake in the trade negotiations, the analysis of growth in French agriculture cuts in several directions.

Estimates of the short-run output supply functions for French agriculture suggest that agricultural output levels in France are price responsive. This provides support for the view that European price policies have been a source of high European output levels. Lower European prices for agricultural products would reduce European production.[7]

Moreover, the analysis suggests that French agricultural production has benefited from important technological gains since the early 1960s. Growth of French agricultural output can not be attributed solely or even primarily to high prices. Production has increased despite falling real output prices and rising labour costs.

The importance of technological change in French agriculture has several implications. First, gains from a one-time reduction in farm price levels are likely to prove illusory. If France continues to pursue a strong programme of public (and private) agricultural research and continues to adopt new technologies available internationally, then outward shifts of its agricultural supply functions will quickly offset any given downwards movement along these functions. The case for negotiating fixed lower prices is weak, from either the point of view of those who might anticipate large gains from such an agreement or from the point of view of those who would like to claim such an outcome would be a major concession.

A second implication of the importance of technological change is that France is achieving a favourable competitive position relative to other producers. If France finds itself in a situation of comparative advantage in agriculture, the French approach to trade negotiations should shift towards a freer market stance in which France's comparative advantage would reap the largest benefits. This may pave the way for unexpected progress in trade negotiations. A freer market also implies that competition will remain stiff.

The USA and the EC may compete for agricultural export markets in the future largely through the generation and adoption of new technology. On this issue, the results are, perhaps, the most interesting and the most preliminary, and additional research is needed. While the technology spillover variable used in the analysis is imprecise, the results suggest that international transfers of technology play an important role for some commodities but not others. Under these circumstances, competition in world markets will affect domestic perceptions of optimal allocations of research expenditures among commodities. From a global perspective, domestic allocation decisions of individual countries may not be optimal. Additional work on the allocation of public research expenditures in Europe by commodity, on appropriate proxies for international availability of technology, and on the mechanisms, incidence, and magnitude of international technology transfers are warranted. In the interim, the study suggests that development of a sensible international framework for agricultural research among industrial countries will become increasingly important as more explicit trade barriers fade.

Notes

[1]Fédération Nationale Porcine (Paris), Virginia Polytechnic Institute and State University, and Virginia Polytechnic Institute and State University, respectively. The authors gratefully acknowledge the International Agricultural Trade Research Consortium for partial financial support and thank Michel Petit, Maury Bredahl, Jean-Marc Boussard, Albert Hayem, and participants in seminars at OECD and the Economic Research Service, US Department of Agriculture, for constructive early suggestions and assistance.

[2]The data used in the study covers the 1959-84 period. Many statistical series were not reported prior to this period, and data quality is poor for those that are available. Cereals accounted for 17.4 percent and milk for 18.0 percent of the value of French agricultural production in 1980. Noncereal crops and animal products are aggregates among diverse products.

[3]In the short-run analysis, both quasi-fixed and fixed factors are held at historical levels. In the complete study, long-run output supply and variable input demand functions are estimated, assuming use of family labour and capital adjusted optimally to long-run equilibrium values. Only the short-run results are presented here. The long-run results and a comparative analysis of the short- and long-run models are reported in Bouchet (1987).

[4]See Bouchet (1987) for further discussion of each of the variables included in the model. Of 31 million hectares in agricultural use, over 12 million hectares have been consolidated under the voluntary programme (Tuppen, 1983). Funding levels have limited the effectiveness of the SAFERs and IVD (Chombart de Lauwe, 1979), while loans at preferential rates represent between 60 and 70 percent of the loans administered by the Crédit Agricole, which provides about 70 percent of all farm credit.

[5]The research expenditures data series was cast back to 1955-58 using a regression of the research series on a constant, a trend, and a dummy variable, capturing a faster rate of increase of expenditures before 1970. Lags of research expenditures of up to five years could then be included in the model without losing observations. Five years is a shorter lag length than reported in much of the research evaluation literature (Pardey and Craig, forthcoming). The sum of the coefficients is not likely to be affected too much by truncating the lag length, but individual coefficients are likely to be biased upwards due to specification error. Given the purpose of the current study (to assess sources of growth), the sum, not the individual coefficients, is important.

[6]Imposing specific lag distributions did not prove to be a satisfactory alternative. With an imposed linear distribution, the research expenditures coefficient was statistically significant only in the cereals equation, despite the significance of the coefficient of at least one unconstrained research lag in the cereals, milk, and animal products equations. The cross-price symmetry conditions on the output supply and input demand equations were also strongly rejected when the linear lag distribution was imposed on the research expenditures variables. Imposing a quadratic structure with five lags maintained acceptance of the symmetry conditions, but levels of significance of the coefficients of the research variables were poor (only one coefficient had an associated p-value smaller than 0.15). The number of lags (five) is probably not sufficient to impose a quadratic lag.

[7]The responses to price changes are estimated to be inelastic even in the long run when usage of quasi-fixed capital and family labour have fully adjusted to optimal levels (see Bouchet, 1987).

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DISCUSSION OPENING—*Robert Innes* (University of California, Davis)

The authors have sought to capture technological change with two variables: French government research expenditures and a measure of international technological progress. However, technological change in France could occur without either of these inducements. For example, over time, farmers may learn to make better use of a franc of capital stock or a unit input of another factor, even without government expenditures on research or international technology transfer. To test for this possibility, the authors might want to incorporate a time trend measure in their regression model.

In the short-run analysis, the authors include capital stock (measured with value of land and buildings) as a right-hand-side (exogenous) variable. This treatment gives rise to two problems: First, since capital stock changes are likely to be driven by both productivity and price indices, simultaneity exists that is not accounted for in the seemingly unrelated regressions approach employed in the paper. Secondly, the coefficient on capital stock is, to some extent, capturing output responses to price, which suggests that the "short-run" price elasticities understate medium-to-long run price effects.

In the long-run analysis, capital stock is assumed to be "chosen" optimally so that it can simply be excluded from the right-hand side. Here, the price variables would appear to pick up both their partial effects on output and their indirect effects via capital stock changes. And the own-price elasticities do increase as a result. Moreover, the model here can be viewed as a reduced form in which the simultaneity mentioned above is no longer a problem.

However, the authors' long-run treatment is subject to another criticism: capital stock choices follow a complex dynamic process. They are not simply a function of last period's prices, as is implicitly assumed in the regression model constructed here. Rather, they are likely to depend on a more extensive history of both prices and productivity changes. These dynamics, I believe, should be explicitly modelled.

Why might these dynamics be important to the results? The reason is that other variables in the model, such as government research expenditures and/or the US productivity index may be picking up the longer run effects of price changes, leading to overstatement of research effects on output and understatement of price effects.

A government's choice of research expenditures is likely to be related to the economic performance of affected agricultural markets. For example, rapid improvements in productivity may well spur a government on to invest more in research, perhaps because of the impression conveyed by agricultural economists that research has generated these terrific benefits! In any event, an important simultaneity problem may exist here.

To measure the effects of international technological developments on French agricultural productivity, the authors included a measure of total US agricultural productivity as a right-hand variable. Like French agricultural output, US agricultural output responds to prices, capital stock changes, etc.

This variable therefore picks up output expansion that results from economic as well as technological phenomena. This observation suggests that, at face value, the US productivity variable may be a poor proxy for international technology transfer. But, more importantly, it suggests a reinterpretation of the paper's results. Specifically, farmer prices received in the USA are correlated with farmer prices received in France. This variable is a good proxy for the dynamic capital stock adjustment mechanism discussed earlier. As a result, the large effects of this variable in the authors' long-run analysis may be price driven.

Suppose we believe that some asset fixity exists in the French agricultural sector. We would then expect to see an output supply function (in own price) that is increasingly inelastic as price rises. Given this expectation, how should we interpret the paper's price elasticity estimates in an effort to deduce the effects of EC removal of its agricultural support policies?

In recent times, EC supported cereals prices have been as much as two to three times world levels. Variation in real farmer prices received (over the past 20 years) has been relatively little vis-à-vis the decline that would be experienced with the removal of supports. These observations suggest that the price elasticity estimates emerging from this paper are associated with points high up the supply curvey vis-à-vis world prices. Therefore, if we are performing the thought experiment of eliminating supports (and thus reducing farmer prices received by a large amount), the price elasticity we should use is considerably higher than estimated here.

One of the main questions motivating this analysis is: if government price supports were removed, would the EC switch back from being a net exporter to being a net importer of cereals? As concluding food for thought, consider a little back-of-the-envelope calculation in answer to this question. The authors estimate a long-run cereal own-price supply elasticity of 0.45. Adjusting this estimate to, say, 0.5-0.8 for the reasons mentioned above, a 50-percent reduction in price would reduce output by 25-40 percent. If technological change is as important as the authors suggest, then this medium-to-long-run reduction would be accompanied and probably overshadowed by the effects of technological progress. However, if the technological change variables are picking up longer run capital stock responses to price change—and I do not believe that this possibility can be ruled out at this point—then this reduction is likely to return the EC to self-sufficiency in cereals.

GENERAL DISCUSSION—*Winfried Manig, Rapporteur* (Universität Göttingen)

This paper was discussed with regard to the general impact of research or of the generation of new technologies on labour input in general and hired labour input in particular; especially the long-run effects were questioned. In this respect, time as a variable becomes important. Other discussion points were the effects of research expenditures and the treatment of capital stock in the model used.

Participants in the discussion included G. Escobar, R. Evenson, F. Jarrett, T.P. Phillips, S. Setboonsarng, and S.C. Thompson.