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THE ELASTICITY OF AGGREGATE AUSTRALIAN AGRICULTURAL SUPPLY: ESTIMATES AND POLICY IMPLICATIONS

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Annual time series data for the period 1950-51 through 1975-76 are used to estimate the price elasticity of aggregate Australian agricultural supply using two methods. The short-run elasticity is estimated to be highly inelastic but it has been increasing through time. The preferred estimate of the long-run elasticity is in the relatively inelastic range and it has also been increasing through time. Some implications of these results for intersectoral resource flows and compensatory assistance, the cost-price squeeze, the effects of the mineral boom and monetary policy are discussed.

Introduction

The relative importance of agriculture in the Australian economy has changed significantly over the past three decades. Between 1953-54 and 1980-81, the share of agriculture in the gross domestic product fell from 19 per cent to 6 per cent, the contribution of agriculture to export earnings fell from 84 per cent to 45 per cent and the index of prices received to prices paid by farmers almost halved (BAE 1981). Not surprisingly, there has been an increase in the relative importance of 'macro-level' agricultural issues in contemporary policy debates, especially issues relating to resource transfers into and out of agriculture. For example, Harris et al. (1974, para 2.42) raised the issue of the price responsiveness of farm output in discussing the prospects for reducing the cost-price squeeze on Australian agriculture, arguing that the greater use of purchased inputs has probably made farm output more responsive to price changes. In addition, a number of authors, including Harris et al. (1974), Gregory (1976), Snape (1977), Smith and Smith (1978) and Stoeckel (1979), have debated the effects of mineral development and the tariff on resource use in agriculture as a whole.

There have been numerous Australian studies of the supply response for particular agricultural commodities and there have been a few studies in which the supply response for several broad product categories has been reported. Examples of the latter include Gruen et al. (1967), Wicks and Dillon (1978) and Vincent, Dixon and Powell (1980). However, these authors have not provided estimates of the supply elasticity for Australian agricultural output as a whole. This elasticity is one measure of the responsiveness of total agricultural resource use to changes in relative prices. Given the changes in the relative position of agriculture within the economy and the nature of contemporary policy debates, it seems timely to investigate the magnitude of this elasticity and, in particular, to investigate whether this magnitude has altered as a result of various developments within the agricultural sector. These are the aims in the present paper.

* The authors are grateful for the useful comments provided by anonymous referees but wish to accept all responsibility for errors.

After discussing some factors that may have caused a change in the aggregate supply elasticity, the two regression-based methods employed in the study are outlined. The regression models are described, followed by a brief discussion of the data. Results are then presented for the two methods and some comparisons are drawn with results from previous studies. Finally, the implications of the results are discussed with attention being given to intersectoral resource mobility and compensatory assistance, the cost-price squeeze, the mineral boom and monetary policy.

Factors Influencing the Aggregate Supply Elasticity

There have been a number of changes in Australian agriculture which may have affected the aggregate supply elasticity. Three such changes which the authors believe are important are the increased relative importance of purchased inputs, the increase in average farm size and the increase in the share of non-farm income in farmers' total income.

'Purchased inputs' include all inputs purchased by the farm sector from the non-farm sectors. They include current inputs such as fertiliser and fuel, durable inputs such as farm machinery and services such as marketing. Expenditure on these inputs has increased from about 30 per cent of the value of gross output in 1948-49 to over 50 per cent of the value of gross output in the late 1970s (Powell 1974; ABS 1982*b*).

Ceteris paribus, the elasticity of supply of agricultural products will vary directly with the elasticity of supply of farm inputs. Heady (1952, p. 679) provided a diagrammatic explanation of this phenomenon. Some inputs, such as operator labour, may have a supply elasticity approaching zero and could be regarded as fixed for many farmers. However, the elasticity of supply of some purchased inputs might be considerable. For example, Australia probably faces a perfectly elastic supply for many imported inputs. In general, the resources used in the (domestic) production of purchased inputs and, indeed, some of the purchased inputs, have alternative uses. In addition, farmers' elasticity of demand for inputs with respect to output prices might be greater in the case of those inputs which have to be purchased compared to those inputs which are provided from currently-owned resources and for which cash payments are not required. Viewing the output supply elasticity as the sum, across all inputs, of the product of the production elasticity and the elasticity of input use with respect to output price (Griliches 1959), then *ceteris paribus*, the increased use of purchased inputs would make for a greater aggregate supply elasticity.

On the other hand, there are at least two arguments to support the notion of a declining aggregate supply elasticity as a result of the increased relative importance of purchased inputs. First, some purchased durable inputs (e.g. harvesters) have highly specialised uses and, once purchased, tend to remain in use over a wide range of output prices (Johnson 1960). Second, while a greater dependence on purchased inputs might have increased farmers' sensitivity to product price changes in planning output (dQ/dP in the supply elasticity formula), there has been a substantial decline in the ratio of the index of the real price of output to the index of the volume of output (Plunkett 1977, p. 2.30). The net effect of these changes could be a lower supply elasticity. On balance, it is not obvious to the authors that the aggregate supply elasticity for Australian

agriculture should have increased as a result of the increased relative importance of purchased inputs.

Other trends which have been occurring may have had an impact on the aggregate supply elasticity. First, the volume of inputs used in Australian agriculture has been increasing (dividing 1981 BAE data on total farm costs by the index of prices paid produced a figure of 12 per cent for the increase in the volume of inputs between 1953-54 and 1980-81). It is at least possible that the elasticity of production of some inputs has decreased as their use has been intensified. Viewing the supply elasticity in the disaggregated fashion suggested by Griliches (1959), lower producion elasticities make for a lower supply elasticity, *ceteris paribus*. Second, the average size of farms has increased considerably. Based on ABS (1982*a*) data, average farm size increased by 43 per cent between 1958-59 and 1979-80.[1] Perhaps the larger, more commercially-oriented farms are characterised by a greater relative importance of purchased inputs in the total input mix. But it was argued previously that this would not necessarily lead to greater supply responsiveness. A reduction in the range of product mix might accompany increased farm size (small mixed farms compared with large specialised farms) with less scope for switching resources among different enterprises and, hence, a lower supply responsiveness.

Finally, off-farm income is becoming an increasingly important component of farmers' total incomes (Riethmuller and Spillman 1978; Robinson, McMahon and Quiggin 1982). If there is an increasing propensity on the part of farmers to seek off-farm earnings, this should operate in the direction of increasing the aggregate supply elasticity.

Summing up, it is difficult to judge *a priori* how the aggregate supply elasticity has changed over time. Furthermore, there are no estimates of this important parameter available as far as the authors are aware. The most direct manner of clarifying these issues is through an empirical analysis of the available data.

Methods

In principle it would be possible to estimate an aggregate supply elasticity for Australian agriculture using normative procedures. However, this approach was viewed as too demanding of data and computational effort. In addition, it is not well suited to analysing the time responsiveness of the aggregate supply elasticity. Another alternative would have been to construct an estimate of the aggregate supply elasticity by taking a weighted sum of estimates of own and cross-price supply elasticities for components of the aggregate. To implement this procedure one requires a reliable and exhaustive set of cross-price elasticities in addition to own-price elasticities. Although estimates of several own and cross-price elasticities of supply are available, they are not sufficiently comprehensive to estimate the aggregate supply elasticity by this procedure and resource constraints did not permit the authors to estimate the necessary component elasticities. Furthermore, the procedure would be unwieldly for investigating the time responsiveness of the aggregate elasticity.

[1] Prior to 1975-76, all agricultural establishments with an area of one hectare or more were included. Subsequently, establishments with less than $1500 estimated value of agricultural production were excluded.

The two methods that were used in this study were based on regression analyses of time series data. The first (or 'direct' method) involved regressing an index of aggregate output on price indexes and other relevant variables. The second (or 'indirect' method), following Griliches (1959), involved the estimation of the elasticities of demand with respect to output price for each input category, the estimation of the production elasticity for each input category, and summation of the products of these elasticities across input categories. Both these procedures have been reviewed by Rayner (1970*a*, *b*). While he seems to favour the indirect method, both methods were used here since the direct method is not demanding in terms of computation and the estimates so obtained can be used as a 'check' on the estimates obtained from the indirect method.

Detailed discussions of the indirect method, and the assumptions involved therein, can be found in Heady and Tweeten (1963), Tweeten and Quance (1969) and Rosine and Helmberger (1974). In the present study, five input categories were specified: labour, plant and machinery, operating inputs, land improvements and unimproved land. The rather coarse categorisation was necessitated by the extent of available data. For each input category, regression techniques were used to estimate the elasticity of input demand with respect to product price. The production elasticity for each input category was estimated as the input's share of the gross value of production. While this procedure has been employed in several overseas studies of aggregate supply elasticity, it is restrictive. In particular, the procedure rests on the assumptions that farmers are profit maximisers and the underlying production function is of the Cobb-Douglas form. Certainly these assumptions will be invalid for some farmers but it is difficult to know the extent to which they are at odds with the real world.

Three methods for estimating input shares have been used in past studies and all three are used here: the non-normalised gross output method, the normalised gross output method (normalised over capital inputs and labour only) and the total expenditure method (normalised over all inputs). Discussions of these methods can be found in Tyner and Tweeten (1965), Rayner (1970*b*), Young (1971), Rosine and Helmberger (1974), Shumway et al. (1979) and Pandey (1981).

Regression Models

Log-linear functional forms were used for all the regression models. This decision was based on pre-testing (linear forms generally resulted in elasticity estimates which were inconsistent with *a priori* expectations and low $\bar{R}^2$s) and computational ease (the estimated regression coefficients are estimates of the required elasticities). All equations were estimated by OLS under the assumptions that all explanatory variables could be regarded as predetermined (see Pandey 1981, pp. 34-6) and that the estimated residuals from the five input demand equations had low or zero correlations (the estimated correlation coefficients were all less than 0.3).

One of the objectives of the present study was to test whether the aggregate supply response has changed over time. It seems reasonable to assume that, if the responsiveness has changed, the change would have been gradual. The main justification for this assumption is that, at the aggregate level, the factors that may have affected farmers' respon-

siveness to price changes, such as the proportion of purchased inputs, have themselves changed gradually over time.

In general, the model specifications in this study allowed for the size of certain parameters to change in a linear fashion over time. If the actual time path of these parameters is nonlinear, then the specification here provides a linear approximation, the accuracy of which is greater the shorter the time period under consideration (26 years in this study) and the more gradual the rate of change in the parameters.

The specification used for the direct estimate of the short-run aggregate supply elasticity was as follows:

$$\text{(1)} \quad \log GO_t = \beta_0 + \beta_1 T + \beta_2 \log (PR/PP)_{t-1} + \beta_3 T \log (PR/PP)_{t-1} + \beta_4 \log X_{2,t-1} + \beta_5 DD_t + \beta_6 \log NFP_{t-1} + u_t,$$

where GO = index of gross farm output deflated by index of prices received by farmers (base year 1949-50);
PR = index of prices received by farmers for all products (base year 1949-50);
PP = index of prices paid by farmers for all inputs;
X_2 = index of the closing stock of capital (unimproved land, plant and machinery, livestock, and improvements to land) in constant prices (base year 1949-50);
DD = 0 for normal years and 1 for drought years;
T = time trend (T = 5 for 1950-51 to T = 30 for 1975-76);
NFP = non-farm profitability;
u = random disturbance term; and
t = time subscript.

Following Griliches (1960), a 'partial adjustment' version of this model (i.e. with the lagged dependent variable included on the RHS) was also estimated in an attempt to obtain an estimate of the long-run aggregate supply elasticity.

In equation (1), a linear time trend has been included as an index of technological change and a single dummy variable has been used to capture the effect of drought years. The non-farm profitability variable has been included on the assumption that agricultural output depends not only on the relative prices of farm outputs and inputs, but also on the relative prices of outputs and inputs in the non-farm sectors. A detailed discussion of other aspects of the specification in equation (1) can be found in Pandey (1981, pp. 38-41).

The general specification for the five input demand functions was as follows:

$$\text{(2)} \quad \log DX_{i,t} = \alpha_0 + \alpha_1 T + \alpha_2 \log (PR/PX_i)_{t-1} + \alpha_3 T \log (PR/PX_i)_{t-1} + \alpha_4 \log (PX_j/PX_i)_{t-1} + \alpha_5 \log DX_{i,t-1} + \alpha_6 Z_t + u_t,$$

where DX_i = an index of the quantity demanded of the ith input (base year 1949-50);
PR = an index of prices received by farmers for all products (base year 1949-50);
PX_i = an index of prices paid by farmers for the ith input;
PX_j = an index of the price of substitute inputs;
Z = other explanatory variables specific to the particular demand function;

T = time trend ($T = 5$ for the 1950-51 to $T = 30$ for 1975-76);
u = random disturbance term; and
t = time subscript.

The output price used in the demand function for plant and machinery was the index of prices received for crop products because of the greater importance of plant and machinery in crop compared to livestock production. In the case of the demand for land improvements, the index of prices received for livestock products was used as the output price. Theoretically, the same output price (i.e. an index of the price of aggregate output) should have been used in all the input demand functions. However, it was thought that some conceptual rigour could be sacrificed in order to obtain more acceptable estimates of the input demand elasticities with respect to product price. It may be noted, in passing, that Griliches (1959) and Rayner (1970*b*) also used an index of crop prices, rather than the index of prices for all products, in estimating a demand function for machinery. Further justification of the specifications used for each input demand function can be found in Pandey (1981, pp. 41-6).

Data

The bulk of the data consisted of time series measuring prices, value of output and input usage for the period 1950-51 through 1975-76. The principal data sources were Powell (1974) and the update of Powell's data provided by Fleming (1979). Hence, the data deficiencies outlined by those authors apply to the present study. At the time the empirical work was undertaken (late 1980), insufficient published data were available to extend the time series beyond the most recent figures provided by Fleming (1979).[2]

Results

The direct method

The estimate of equation (1), and the estimate of this equation with the lagged dependent variable included as a regressor, were unsatisfactory. The coefficient on the variable measuring non-farm profitability, the estimated short-run supply elasticity and the coefficient on the lagged endogenous variable were all quite small relative to their estimated standard errors.[3] A decision was made to delete the non-farm profitability variable and to add a two-period lag on the price ratio variable. Although these revisions did not improve the estimate of the equation containing the lagged endogenous variable, they resulted in the estimate of the short-run supply function shown in equation (3) (estimated standard errors in parentheses).

The estimate represented by equation (3) is better, partly as a result of the fact that a one-period lag is inappropriate when there is overlap between production years and financial years (as in the case of wheat). More important, perhaps, is the fact that the quantity of livestock available for slaughter, the amount of wool produced and even some crop production are results of decisions taken earlier than one period in the past.

[2] A complete listing of the data is given in Pandey (1981, pp. 97-105) and can be obtained from the authors.

[3] The authors have refrained from couching the discussion in terms of significance levels in those instances where pre-testing of a model was undertaken (see Wallace 1977).

$$(3)\quad \log GO_t = \underset{(0.70)}{0.44} + \underset{(0.01)}{0.02T} - \underset{(0.10)}{0.28} \log (PR/PP)_{t-1} + \underset{(0.003)}{0.01T} \log (PR/PP)_{t-1}$$
$$- \underset{(0.11)}{0.19} \log (PR/PP)_{t-2} + \underset{(0.006)}{0.02T} \log (PR/PP)_{t-2}$$
$$+ \underset{(0.15)}{0.87} \log X_{2,t-1} - \underset{(0.02)}{0.10}\, DD_t$$
$$\bar{R}^2 = 0.98;\ d = 2.21$$

Point and interval estimates of the two-year aggregate supply elasticity computed from equation (3) are shown in Table 1. The estimates for the years 1950-51 through 1955-56 are unsatisfactory in that they are negative. The estimates for the remaining years are positive but perhaps the estimated rate of increase in the elasticity of 0.03 annually and the elasticity estimates of about 0.5 for the early 1970s are somewhat high.

The indirect method

Input demand functions. As with the direct estimate of the supply function, some revisions had to be made to the general specification of the input demand functions given by equation (2). The greatest problems were experienced with the equations for plant and machinery, land improvements and unimproved land. Undoubtedly, these problems were partly due to data imperfections and high collinearity.

TABLE 1

Estimates of the Short-Run (Two-Year) Aggregate Supply Elasticity for Selected Years[a]: Direct Method

Year	Estimated value of two-year elasticity	'90 per cent' confidence interval[c]	
		Lower limit	Upper limit
1955-56	−0.09 (0.08)[b]	−0.23	0.05
1965-66	0.28 (0.13)	0.05	0.50
1975-76	0.66 (0.19)	0.33	0.98

[a] The two-year elasticity was calculated as $(-0.28 - 0.19 + 0.01T + 0.02T)$. The results in equation (3) were rounded to two decimal places. However, the estimates presented in this table were calculated prior to rounding.

[b] Figures in parentheses are estimated standard errors (*SE*) which were calculated for the summed coefficients using the following formula:

$$SE = [\Sigma \text{var}\ (\alpha_i) + \Sigma\ \Sigma\ \text{cov}(\alpha_i, \alpha_j)]^{0.5} \text{ for } i \neq j.$$

[c] These intervals were computed as if pre-testing of the model had not taken place. Bearing in mind Wallace's (1977) warning about interpreting confidence levels when pre-testing has occurred, the true 90 per cent confidence intervals are probably wider than the intervals shown here; hence the quotation marks.

In the context of the present study, the key parameter estimate in each input demand equation is the elasticity with respect to product price. The three 'problematic' input categories mentioned immediately above together comprise capital inputs. There seems to be some doubt as to whether the demand for capital inputs in Australian agriculture is responsive to product prices. For example, in two early studies, Campbell (1952) and Gutman (1955) emphasised the role of output price in investment decisions in the pre-World War II years. However, in two more recent empirical studies, Glau (1971*b*) and Waugh (1977) found that output price was not an important variable in explaining farm investment behaviour. A more detailed discussion of these and other studies relevant to the issue can be found in Powell (1982). The authors' view is that the demand for capital inputs might well be completely inelastic with respect to output price in the short run of, say, one year. The long-run demand is more likely to be price responsive but it is difficult to judge the nature of the lag involved. One would expect the length of time before any response occurs and the 'shape' of the lag to differ among farmers. The approach adopted in this study (based partly on estimation results and previous research) was to assume that the elasticity of demand for unimproved land with respect to output price is zero. Griliches (1959) made a similar assumption in relation to the U.S.A. As well, it was decided to assume alternative values for the elasticities of demand for the other capital inputs: one value based on our econometric estimates and an alternative value of zero.

The econometric estimates of the various input demand elaticities are provided in Table 2. Details of the equations from which they are derived are provided in the Appendix. Due to the natue of the deflation procedure used in this study, the own-price elasticies of input demand are the negative of the elasticities with respect to output price. The estimates of the short-run own-price elasticities derived in this way are generally lower compared with estimates reported elsewhere (Table 3). The estimates of the own-price elasticity of demand for labour reported by Ryan and Duncan (1974), Joyce (1975), and Bhati (1978) vary between -0.4 and -0.5. These studies were based on simultaneous equations models (except Joyce's) and different variable definitions to those employed in the present study. The McKay et al. (1980) estimates of the own-price elasticities were derived using a cost-function approach and pertain to the sheep industry only rather than to the agricultural sector as a whole. Assuming that the demands across industries are independent, the aggregate demand elasticity will be a weighted average of the demand elasticities in particular industries. Hence, it is not surprising to find that the demand elasticities reported here differ from those reported by McKay et al. (1980). Similarly, it is not surprising that the estimates in this study differ from those reported by Ellahi (1981) since the latter were estimated using a cost function model and N.S.W. (as opposed to Australian) data.

The estimates of the long-run elasticities presented in Table 2 have been obtained as the ratio of the estimated values of the short-run elasticity to the adjustment coefficient. As the expected value of a ratio of random variables is not equal to the ratio of the corresponding expected values, the estimator of the long-run elasticity is biased. Using the approximation formula suggested by Hayya, Armstrong and Gressis

TABLE 2

Estimates of Short-Run (One-Year) and Long-Run Input Demand Elasticities with Respect to Output Price

Input	Elasticity[a]	
	Short-run	Long-run
Plant and machinery	0.20 (0.07)	1.18 (0.37)
Land improvements	$-0.24+0.02T$ [b] $(0.0143+2\times10^{-5}T^{2})^{0.5}$	$-1.41+0.12T$ $(0.8365-0.1211T+5.3\times10^{-3}T^{2})^{0.5}$
Unimproved land	0[c]	0
Operating inputs	$-0.11+0.02T$ $(0.0078+2\times10^{-5}T^{5})^{0.5}$	$-0.26+0.05T$ $(0.0486-4.9\times10^{-3}T+3\times10^{-4}T^{2})^{0.5}$
Labour	$-0.01+0.01T$ $(0.0013+4\times10^{-6}T^{2})^{0.5}$	$-0.02+0.02T$ $(0.0061+8\times10^{-4}T+5\times10^{-5}T^{2})^{0.5}$

[a] Approximations to the standard errors are in parentheses. The standard errors of the long-run elasticities were estimated by using an approximation procedure suggested by Hayya et al. (1975).

[b] $T=5$ for 1950-51, . . ., 30 for 1975-76.

[c] The estimates of the short-run elasticity and the coefficient on the lagged endogenous variable in the case of unimproved land were extremely small relative to their estimated standard errors and, hence, the elasticities for this input category are reported as zero.

(1975), the expected value of the estimator of the long-run elasticity can be derived as:

$$E(\hat{r})=r+[1/\delta_2^2]\,[r\,\mathrm{var}(\delta_2)-\mathrm{cov}(\delta_1,\delta_2)], \tag{4}$$

where r, δ_1 and δ_2 are the estimators of the long-run elasticity (r), the short-run elasticity (δ_1) and the adjustment coefficient (δ_2), respectively. The estimated covariance terms were negative for all inputs except plant and machinery. Hence, the estimators of the long-run elasticity for improvements to land, operating inputs and labour are positively biased. As the covariance term for plant and machinery was positive, the direction of bias is unknown.

Input shares (production elasticities). The input shares calculated by the non-normalised gross output method were quite different from those calculated by the other two methods and, in general, their sum tended to be less than unity for the early years in the sample period and greater than unity for the later years. Hence, these estimates were regarded as unacceptable. Due to the absence of any *a priori* basis for choosing among the series of input shares computed from the other two methods (total expenditure method and normalised gross output method), each was used in providing alternative estimates of the aggregate supply elasticity. However, in order to reduce some sharp fluctuations in the computed shares (which are probably due to measurement errors), three-year moving averages of the shares were used.[4]

[4] A listing of the input shares and a more detailed discussion of factor share estimation are provided in Pandey (1981) and can be obtained from the authors.

TABLE 3

Comparison of Input Demand Elasticities

Study	Period	Input category						
		Labour	Plant and machinery	Land improvements	Unimproved land	Operating inputs	Livestock	Capital
1. Ryan and Duncan (1974)	1948-49 to 1967-68	0.5	–	–	–	–	–	–
2. Joyce (1975)	1949-50 to 1970-71	−0.4 to −0.5	–	–	–	–	–	–
3. Bhati (1978)	1952-53 to 1974-75	−0.4	–	–	–	–	–	–
4. McKay et al. (1980)[a]	1976-77	−0.67	–	–	−0.24	−0.96	−0.13	−1.20
5. Ellahi (1981)[b]	1977-78	−2.87; −5.02[c]	−0.38	−0.08[d]	–	−0.62	–	–
6. This study[e]	1975-76	0.29	0.20	0.36	0	0.49	–	–
	1977-78[f]	0.32	0.20	0.42	0	0.55	–	–

[a] Estimates for the Australian sheep industry.
[b] Estimates for N.S.W.
[c] Estimate of −2.87 is for operator labour and −5.02 for employee labour.
[d] Includes land and improvements to land.
[e] Estimates are with respect to output prices but because of the deflation procedure used the elasticity with respect to input price is the negative of that with respect to the output price.
[f] Estimates for years outside the estimation period.

Indirect estimates of the aggregate supply elasticities. The demand and production elasticities were combined to obtain estimates of the short- and long-run aggregate supply elasticities. The alternative estimates based on the two different sets of factor shares were very similar, although the difference increased slightly over time. Hence, only the estimates derived from the factor shares calculated on the total expenditure basis are reported (Table 4).

The long-run elasticities were derived by combining the production elasticities and the long-run demand elasticities. As the size of the adjustment coefficient differed among inputs, it is difficult to define the number of years corresponding to the 'long run'. However, since the smallest adjustment coefficient was 0.17 (plant and machinery), one might consider the long run to be at least five years.

The rates of increase in the elasticities were estimated by fitting a linear trend to the computed elasticities for the period 1955-56 through 1975-76. Because the production elasticities were not expressed as a function of time, it was not possible to compute the rate of increase in the elasticity as the derivative of the elasticity formula with respect to time (as was the case for the direct estimate). The four trend coefficients shown in Table 4 were significant at the one per cent level.

The estimated elasticities fall within the range of estimates reported for the U.S.A. and the U.K. (e.g. Griliches 1959, 1960; Rayner 1970*b*; Colman and Rayner 1971). The estimates are generally lower than the individual commodity supply elasticities reported in other Australian studies such as Wicks and Dillon (1978) and Vincent et al. (1980). This result is expected, given that there are resource flows between pairs of commodities (as evidenced by the cross-price elasticities reported in the Australian studies).

Based on the evidence in Table 4, and bearing in mind the results from the direct estimation procedure, the short-run aggregate supply response is highly inelastic but it has been increasing gradually over time. There is a substantial difference between the alternative sets of estimates of the long-run aggregate supply response. In the authors' judgment the 'set 1' estimates, particularly the estimated rate of increase, are somewhat high. This may be a reflection of bias in the estimated long-run input demand elasticities (this bias was positive in the case of three inputs and of unknown direction in the case of one input). While it can be expected that there would be some upward bias in the 'set 2' estimates of the long-run elasticity, the magnitudes and estimated rate of increase seem quite plausible. However, irrespective of which set of long-run elasticities is preferred, it seems reasonable to conclude that the long-run elasticity has been increasing through time.

Policy Implications

The results reported here have implications for some general issues within contemporary policy debate: intersectoral resource mobility and compensatory assistance, the ability of farmers to cope with a cost-price squeeze, the effects of the mineral boom on Australian farmers and the implementation of monetary policy. These are discussed in turn in this section.

TABLE 4

Estimates of the Short-Run (One Year) and Long-Run Aggregate Supply Elasticities for Selected Years: Indirect Method

Year	Set 1[a]			Set 2[b]		
	Short-run elasticity	'90 per cent' confidence interval[c]	Long-run elasticity	Short-run elasticity	'90 per cent' confidence interval[c]	Long-run elasticity
1955-56	0.06 (0.03)[d]	0.01 – 0.11	0.17 (0.05)	0.05 (0.03)	0.001 – 0.10	0.11 (0.05)
1965-66	0.22 (0.03)	0.17 – 0.27	0.69 (0.08)	0.16 (0.03)	0.11 – 0.21	0.38 (0.08)
1975-76	0.34 (0.03)	0.29 – 0.39	1.10 (0.09)	0.25 (0.03)	0.20 – 0.30	0.57 (0.09)
Linear trend[e]	0.01		0.05	0.01		0.02

[a] Set 1 estimates are based on the econometric estimates of the input demand elasticities reported in Table 2.
[b] Set 2 estimates are based on the assumption of a zero input demand elasticity (with respect to product price) for all capital input categories (i.e. plant and machinery, land improvements and unimproved land).
[c] See footnote c, Table 1.
[d] Estimated standard errors are in parentheses. They were approximated as:

$$\text{var}(e) = \sum_{i=1}^{4} e_{oi}^2 \, \text{var}(e_{pi})$$

where e = supply elasticity;
e_{oi} = elasticity of production for the ith input (assumed to be non-stochastic); and
e_{pi} = elasticity of demand for the ith input with respect to output price.

[e] Computed by fitting a linear trend to the estimated elasticities for 1955-56 through 1975-76. For all trend equations, the $\bar{R}^2$ exceeded 0.98 and the trend coefficient was significant at the one per cent level.

Inter-sectoral resource mobility and compensatory assistance

One of the arguments that has been advanced for compensatory assistance for farmers is that protection elsewhere in the economy distorts relative returns in agriculture compared to the rest of the economy, causing less resources to be employed in agriculture than otherwise would be the case. It seems quite logical to argue that, because agricultural input prices (especially wages) are determined, in part, by conditions and events in the rest of the economy (tariff levels, wage decisions and inflation), changes in the rest of the economy will have an effect on the supply of agricultural products.

Although there is no benchmark on what constitutes low resource mobility as measured by the elasticity of supply, the elasticity estimates reported here (especially for the short run) do not seem consistent with large and rapid resource transfers between agriculture and the rest of the economy. It is noteworthy that, when the variable measuring non-farm profitability was included in the direct specification of the supply function, its estimated coefficient was very small relative to its estimated standard error. This may have been due to multicollinearity problems rather than a real lack of importance of this variable. Exclusion of this variable when it is, in fact, a relevant variable would impart a downward bias to the estimated supply elasticity because of its positive correlation with the output price variable.

If resources are not highly mobile between the agricultural and non-agricultural sectors, how do farmers respond to relative price changes? One possibility is that they decrease their use of purchased inputs relative to operator labour (and perhaps land) in times of falling agricultural prices, and vice versa. This is not a novel explanation: Johnson (1950) explained the constancy of US agricultural output during the 1930s depression on the basis of the low mobility of land and labour out of agriculture.

If the authors are correct in believing that resource mobility between the agriculture and non-agricultural sectors is low, spokesmen for particular agricultural industries might have a stronger efficiency argument for compensatory assistance if they argue on the grounds that their particular industry is lightly protected compared to other agricultural industries. In other words, the differing levels of protection within agriculture, rather than between agriculture and other industries, might be the more important stimulus to resource flows.

The cost-price squeeze

The conventional wisdom is that, on the whole, Australian farmers have coped with the decline in the terms of trade for agriculture through productivity increases (Gruen 1970; Glau 1971*a*). If farm output continues to become more responsive to price changes, less reliance will need to be placed on productivity increases as a means of offsetting the effects of adverse price movements. Although resources do not appear to be highly mobile between the farm and non-farm sectors, the rate of mobility has been increasing, albeit slowly.

In general, economic policies aimed at increasing the level of employment in the non-farm sector will facilitate resource movements out of agriculture in response to cost-price pressures. However, current

Australian policy makers are placing a relatively heavy emphasis on reducing inflation. Some economists believe that there is a trade-off between unemployment and inflation. If this is the case, then a continued emphasis on the inflation front, while lowering the costs of domestically-produced farm inputs, could stifle any trend toward increased mobility of resources out of agriculture.

The mineral boom and monetary policy

A crucial parameter determining the effects of the rapid increase in mineral exports on the agricultural sector is the elasticity of supply of agricultural exports (Gregory 1976). *Ceteris paribus*, this elasticity will increase as the elasticity of aggregate supply increases, since it is a weighted function of the aggregate supply elasticity and the aggregate domestic demand elasticity. It will exceed the aggregate supply elasticity and increase with the aggregate supply elasticity provided the aggregate demand elasticity is negative and relatively stable. As an example, assuming the short-run aggregate supply and demand elasticities to be 0.3 and −0.2, respectively, and assuming that about 60 per cent of gross output is exported, the export supply elasticity would be about 0.63 in the short run. Based on the Gregory model, if the elasticity of aggregate supply continues to increase, one could expect greater adjustment in the agricultural sector in the future as mineral development continues. The lowering or removal of the tariffs on manufactured products would help offset this need for adjustment and, indeed, there may be a greater case for tariff reduction or removal on these grounds rather than on the grounds of farm to non-farm resource transfers.

Finally, it can be expected that the implementation of domestic monetary policies will become more difficult as a result of an increasing elasticity of aggregate agricultural supply causing an increasing elasticity of supply of agricultural exports. The demand for rural exports is considered by many to be highly elastic and volatile. This being the case, the extent of fluctuations in rural export earnings will increase as the elasticity of supply of exports increases. These fluctuations result in fluctuations in the domestic money supply, thus rendering the implementation of monetary policy more difficult.

Conclusions

The aims of this study were to obtain an estimate of the price elasticity of aggregate Australian agricultural supply and to determine whether this elasticity has been changing over time. The short-run elasticity is estimated to be about 0.3 and the long-run elasticity is estimated to be about 0.6 or close to 1.0, depending on assumptions made about the elasticity of demand for capital items with respect to output price. Furthermore, the short-run elasticities appear to have been increasing by about 0.01 annually.

The results do not seem consistent with large resource transfers between the farm and non-farm sectors. However, if the elasticity of aggregate supply continues to increase, it can be concluded that less reliance will need to be placed on productivity increases to offset the cost-price squeeze in Australian agriculture. As well, the results imply that the elasticity of supply of exports has been increasing over time. Provided

the aggregate demand elasticity is relatively stable, a continuation of this trend will lead to greater adjustment of the agricultural sector in response to the mineral boom and, probably, greater instability in export earnings from agriculture. The latter renders the implementation of monetary policy more difficult.

APPENDIX

The input demand equations listed below were used to derive the elasticities in Table 2 (figures in parentheses are standard errors; h and m are the Durbin statistics, Durbin 1970).

Plant and machinery

$$\log PM_t = \underset{(0.01)}{0.14} + \underset{(0.06)}{0.20} \log (PRC/PPPM)_{t-1} + \underset{(0.06)}{0.26} \log EXGO_t + \underset{(0.04)}{0.83} \log PM_{t-1}$$

$$\bar{R}^2 = 0.99;\ h = 1.01$$

Improvements to land

$$\log IMP_t = \underset{(0.03)}{-0.06} - \underset{(0.12)}{0.24} \log (PRLVT/PPIMP)_{t-1} + \underset{(0.01)}{0.02}\, T \log(PRLVT/PPIMP)_{t-1} - \underset{(0.10)}{0.46} \log (PLAB/PPIMP)_{t-1} + \underset{(0.24)}{0.89} \log EXGO_t + \underset{(0.13)}{0.83} \log IMP_{t-1}$$

$$\bar{R}^2 = 0.98;\ h = 2.12$$

Unimproved land

$$\log LAND_t = \underset{(0.01)}{-0.01} + \underset{(0.001)}{0.003}\, T + \underset{(0.01)}{0.01} \log (PR/PLAND)_{t-1} + \underset{(0.0004)}{0.0002}\, T \log (PR/PLAND)_{t-1} + \underset{(0.20)}{0.61} \log LAND_{t-1}$$

$$\bar{R}^2 = 0.99;\ m = 0.13$$

Operating inputs

$$\log OE_t = \underset{(0.56)}{-1.40} + \underset{(0.006)}{0.01}\, T - \underset{(0.09)}{0.11} \log (PR/PP)_t + \underset{(0.005)}{0.02}\, T \log (PR/PP)_t + \underset{(0.12)}{0.29} \log GO_t + \underset{(0.15)}{0.58} \log OE_{t-1}$$

$$\bar{R}^2 = 0.95;\ h = 0.04$$

Labour

$$\log LAB_t = \underset{(0.015)}{0.02} - \underset{(0.04)}{0.01} \log(PR/PLAB)_{t-1} + \underset{(0.004)}{0.01}\, T \log(PR/PLAB)_{t-1} + \underset{(0.15)}{0.52} \log LAB_{t-1}$$

$$\bar{R}^2 = 0.97;\ h = 0.41$$

Variable definitions

EXGO = expected value of gross output estimated as a lagged three-year moving average of past production (Powell 1974; BAE 1980).

GO = index of gross farm output deflated by the index of prices received by farmers for all products, 1949-50 = 100 (Powell 1974; BAE 1980).

IMP = index of stock of improvement capital in constant prices, 1949-50 = 100 (Powell 1974; Fleming 1979).

LAB = index of labour employed on farms (hired plus owner operator plus family labour) in adult male equivalents, 1949-50 = 100 (Powell and Condon 1980).

LAND = index of the area of unimproved land in rural holdings, 1949-50 = 100 (Powell 1974; ABS 1976).

NFP = Profitability in the non-farm sector measured as the net operating surplus per unit of gross output in the manufacturing and mining sectors (ABS 1977; ABS 1982*b*).

OE = index of expenditure on operating inputs in constant prices, 1949-50 = 100 (Powell 1974; Fleming 1979).

PLAB = index of the price of labour based on wage rates for primary industries, 1949-50 = 100 (Powell 1974; ABS 1982*b*).

PLAND = index of the price of unimproved land, 1949-50 = 100 (Powell 1974; Fleming 1979).

PM = index of the stock of plant and machinery in constant prices, 1949-50 = 100 (Powell 1974); updated by using Powell's (1974) procedure.

PP = index of prices paid by farmers for all inputs, 1949-50 = 100 (BAE 1980).

PPIMP = index of prices paid by farmers for improvements to land, 1949-50 = 100 (Powell 1974); updated using procedures suggested by Powell (1974).

PPPM = index of prices paid by farmers for plant and machinery derived as a weighted average of the index of prices paid for machinery (0.67) and the index of prices paid for motor vehicles (0.33), 1949-50 = 100 (Powell 1974; BAE 1980).

PR = index of prices received by farmers for all products, 1949-50 = 100 (BAE 1980).

PRC = index of prices received by farmers for crops, 1949-50 = 100 (BAE 1980).

PRLVT = index of prices received by farmers for livestock products, 1949-50 = 100 (BAE 1980).

T = time trend ($T = 5$ for 1950-51 to $T = 30$ for 1975-76).

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