Estimation of Factor Demand and Substitution in the Australian Pig Industry: A Dual Approach

Benjamin L. Buetre and Fredoun Z. Ahmadi-Esfahani *

This study seeks to estimate the rate by which inputs in Australian pig production are substituted for one another when prices change. It employs a dual approach to response analysis. Using cost shares of inputs and input price indexes for the period 1977-78 to 1990-91, a set of equations derived from a transcendental logarithmic function is estimated with symmetry and homogeneity constraints imposed. The results indicate that, with the exception of the demand for feed which is a vital production input, pig producers are very responsive to own price changes. The estimated elasticities generally differ in magnitude from similar studies of the Australian agricultural sector, and suggest that, at a lower level of aggregation, farmers are more flexible in changing input mix.

1. Introduction

Neoclassical economic theory postulates that producers respond to changes in input prices by utilising the optimum quantity of an input so that its value of marginal product is equal to the input price. When output price changes, however, the marginal product of an input has to adjust to make it equal to the ratio of input and output prices. Adjustment of input use, however, depends on the rate by which factors are substituted for one another. If a factor is not substitutable, there is no alternative but to reduce the utilisation of that factor when its price increases. The consequence is a reduction in output that may affect the farm's competitiveness.

This study seeks to estimate the rate by which inputs in Australian pig production are substituted for one another when prices change. Knowledge of this is important in understanding the effects of price changes and in developing policy proposals. To that end, a transcendental logarithmic (translog) cost function is employed. Implied in this model is the assumption of a single output industry which is appropriate for the pig industry because of the dominance of livestock in the industry's turnover[1]. The data used in the analysis are input cost shares and input price indexes for the period 1977-78 to 1990-91. The results indicate that pig producers are highly responsive to changes in prices of inputs and they have considerable flexibility in using these inputs. The estimated elasticities generally differ in magnitude from similar studies of the Australian agricultural sector, and suggest that at a lower level of aggregation, farmers are more flexible in changing input mix.

The organisation of the article is as follows. First, an overview of the pig industry is provided. Then previous Australian findings are reviewed. Subsequently, the empirical model, data and procedures are presented. The results of estimation are discussed prior to conclusions.

2. An Overview of the Pig Industry

Pig production in Australia dates from the early days of British colonisation. Pigs were initially attached to the household and fed on garbage and swill, but the growth of the dairy industry in the early part of the 19th century led to the development of a commercial pig industry based on skim milk (Bureau of Agricultural Economics (BAE) 1972). This development led to improvements in feeds and feeding, breeding and housing that increased productivity on farms. In 1974-75, the number of enterprises with 50 head of pigs or more was 3,298; by 1977-78, it was 3,694 enterprises (Australian Bureau of Statistics (ABS) 1990 and Australian Meat and Livestock Corporation (AMLC) 1989). By 1980-81, the number of enterprises engaged in pig production declined to 3,015, and by 1987-88 this number further declined to

* Department of Agricultural Economics, University of Sydney. The authors wish to thank two anonymous reviewers and David Godden for their useful comments and suggestions on earlier drafts.

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[1] ABS data indicate that between 1986-1988, the average sales from crops in farms engaged in pig production comprised only 3.6 per cent of the total revenue. Sales from livestock comprised 91 per cent while sale of livestock products which came from pig-dairy farms accounted for only 5.4 per cent.

1,664; more than 50 per cent below that of the 1977-78 level. Pig numbers, on the other hand, steadily increased from 1.4 million in 1960 to 2.7 million in 1988 (AMLC 1989). This indicates increasing intensification of pig farms with average pig population per enterprise increasing dramatically.

A survey conducted by the BAE during the period 1967-70 showed that farms engaged in pig production were also engaged in cereal and dairy production (BAE 1972). Returns from pigs were 97 per cent in the specialist farms while in the pig-cereal and pig-dairy farms, the shares of returns from pigs were 17 per cent and 36 per cent, respectively (BAE 1972, pp. 34-35). However, a recent survey conducted by the ABS for the periods 1986-88 indicated that pig farms were becoming increasingly specialised. On average, sales from livestock comprised 91 per cent, while sales from crops and livestock products comprised only 9 per cent of the total revenue[2].

In summary the pig industry appears to have transformed itself into large scale production units implying that small scale farming has become unprofitable. Among the factors that could explain this transformation are changes in input prices. For instance, by 1987-88, the price index for machinery, equipment and motor vehicles had increased by 96 per cent over its 1980-81 level, representing the highest increase among inputs. Prices for services and overheads followed with a 93 per cent increase from 1980-81. Other inputs such as chemicals and medicines, marketing expenses, and energy increased at least 50 per cent. Only the price of fodder and feedstuff increased at a relatively low rate of 25 per cent (Australian Bureau of Agricultural and Resource Economics (ABARE) 1991a). In contrast, the index of prices received by pig farmers increased only 24 per cent during the same period, although this has not been a smooth upward trend. In 1983-84, for instance, the index of prices received for pigs declined by 16 per cent from the previous year's level (ABARE 1991b). With the consumer price index increase of 81 per cent from 1980-81 to 1987-88, it is clear that pig producers' terms of trade have increasingly deteriorated. The "cost-price squeeze" seems to hold in the pig industry.

3. Previous Australian Findings

In Australia, early studies of factor demand and elasticities of substitution in the agricultural sector were reported by Powell (1969) and Vincent (1977). These two studies concentrated on capital and labour inputs using the Constant Elasticity of Substitution (CES) production function. Their findings showed that these two factors had a positive elasticity of substitution of less than unity, an indication of weakly substitutable inputs. In another study, Duncan (1972) fitted a CES production function to wool production data for New South Wales. He specified wool production per labour unit as a function of real wages, time, rainfall and lagged output. The production function fitted reasonably well but a number of the standard errors were high indicating multicollinearity and imprecise estimates. His estimate of the partial elasticity of substitution between labour and capital was 0.06.

Vincent, Dixon and Powell (1980) estimated supply response in Australian agriculture using the Constant Ratios of Elasticities of Substitution, Homothetic/Constant Ratios of Elasticities of Transformation, Homothetic (CRESH/CRETH) approach where the partial elasticities of substitution and transformation varied proportionally. From the CRETH side, all the transformation elasticities and cross-price elasticities estimated had the expected negative signs. However, consistent with the findings of Duncan, many of the parameters had high standard errors. Using a dual approach, Vincent (1977) applied a model of input demand for the factors land, labour and capital in Australian agriculture. He defined input use as endogenous, while factor cost shares and input prices were specified as exogenous variables. His elasticity estimates were all statistically significant and all close to zero. This finding was similar to that obtained by Duncan (1972).

McKay, Lawrence and Vlastuin (1980) estimated a system of input share equations which were derived from a translog cost function to estimate input demand and substitution for the Australian sheep

[2] Apparently, the sales of livestock in farms engaged primarily in pig production referred to by ABS are pigs and not culled dairy cattle which command low market value.

industry. Cost share equations were estimated for labour, land, livestock, capital and materials and services. Output was omitted from the specification by assuming that inputs and aggregate output were separable. Their finding of the elasticity of substitution between capital and labour at 1.1 was inconsistent with the estimates of the previous studies, particularly that of Vincent (1977) whose elasticity of substitution estimate between capital and labour was 0.1. Technical change was found to be labour- and land-saving. Capital and materials, labour and materials, and livestock and materials were also found to be highly substitutable (with positive elasticities of substitution and greater than one in magnitude). The estimated own-price elasticity of demand for capital at mean prices was -1.2, while those for labour, land and livestock were -0.7, -0.2, and -0.2, respectively.

In 1983, McKay, Lawrence and Vlastuin analysed their previous data set using a translog profit function. This approach was an improvement upon their 1980 study in that they specified a model that could account for the multiple output nature of the sheep industry. Three groups of outputs were considered; wool and sheep, crops, cattle and other outputs. The analysis showed that the supply of outputs was inelastic. The elasticity of demand for labour was -0.5, whereas in their previous cost function study the estimate was -0.7. The elasticity of demand for materials and services was estimated to be -1.0 which corresponds to their previous estimate. Wool and sheep outputs were found to be relatively labour intensive, while crop outputs were capital intensive. Livestock activities, in general, were found to be relatively land intensive. These findings seem to indicate that the magnitude of input substitution increases when the data are disaggregated and that this behaviour varies across sub-sectors of the agricultural sector. An additional factor that affects the estimates is the kind of model used in estimating the parameters[3].

A more recent method in using duality theory to model production technology, the generalised McFadden (GM) function, was developed by Diewert and Wales (1987). This function has been applied to Australian (Lawrence 1990 and Lawrence and Zeitsch 1990), Canadian (Lawrence 1989) and British (Zeitsch and Lawrence 1992) data. The GM function can overcome the problem in previous models which often failed to satisfy the necessary concavity in prices property of a cost function as postulated by economic theory. When the GM function fails to satisfy the curvature requirements, it can be reparameterised and the curvature requirements imposed. Using the GM cost function, Lawrence (1990) estimated input demand elasticities for Australian agriculture using a pooled cross-section and time series data. His findings were consistent with the previous estimates reported in McKay, Lawrence and Vlastuin (1980,1983).

All studies using aggregate data showed a lack of input price responsiveness in Australian agriculture. It is notable, however, that in the applications of the GM function by Lawrence (1990) and Lawrence and Zeitsch (1990), a majority of the price variables are insignificant implying large standard errors of the estimates. In both of these studies, zero coefficients were reported and this was also the case in Zeitsch and Lawrence (1992). Similar results can be found in the application of GM by Lawrence (1989) to Canadian export supply and import demand. This seeming property of GM to generate zero coefficients appears to be the cost of imposing the curvature requirements to satisfy what is implied by theory. These observations pose some difficulties in interpreting the results and cast doubts on the reliability of the estimates generated by the reparameterised GM function.

4. Empirical Model

The classical derived demand system is usually estimated from two alternative methods: profit maximisation or cost minimisation. This study utilises the existence of duality between cost and production functions via cost minimisation. According to duality theory, production functions have corresponding dual cost functions. In a multifactor setting, the corresponding cost function exists under two specific sets of conditions (McFadden 1978, pp. 8-9): (a) the marginal prod-

[3] Wall and Fisher (1987) show that partial elasticities of substitution estimated by the use of less restrictive functional forms such as the translog are rarely close to unity, a result which is inconsistent with the Cobb-Douglas form that assumes a unitary elasticity of substitution.

ucts of the inputs are non-negative implying free disposal of inputs, and (b) the marginal rates of substitution between input pairs are non-increasing. When these conditions are met, there exists a minimum cost function that corresponds to the production function that is (i) continuous, (ii) non-decreasing for each price in the input price vector, (iii) homogeneous of degree one in all variable input prices, and (iv) concave in each input price for a given level of output y. When the minimum cost is attained at competitive equilibrium, the elasticity of substitution between each input pair can be estimated.

The elasticity of substitution is an important parameter of the production process. As a pure number, it provides a useful indication of the shape of the isoquants and may assume values between zero and infinity. A large elasticity of substitution indicates that the producer has a high degree of flexibility in responding to input price changes. Conversely, when the elasticity of substitution is small, the input mix, depending on its share, can hardly be altered.

A method of estimating derived demand and the elasticity of substitution emerged with the development and application of the translog cost function by Christensen, Jorgenson and Lau (1973). Using the translog function they concluded that the assumption of commodity-wise additivity that underlies the constant elasticity of substitution function is unsuitable as a basis for representing a production possibility or price frontier (cost function) with several outputs and inputs. This method was applied by Binswanger (1974) and McKay, Lawrence and Vlastuin (1980) to estimate elasticities of derived demand. They specified a model to estimate the impact of disembodied technological innovation in the translog cost function by including a time trend as follows:

$$\ln C^*(w,y,T) = b_o + b_y \ln y + \sum_{i=1}^{n} b_{io} \ln w_i +$$

$$1/2 \sum_{i=1}^{n} \sum_{j=1}^{n} b_{ij} \ln w_i \ln w_j + \sum_{i=1}^{n} b_{it} \ln w_i T +$$

$$b_t T + b_{ty} T \ln y + 1/2 b_{yy} (\ln y)^2 + 1/2 b_{tt} (T)^2 \quad (1)$$

where w is the vector of input prices (w_i), y the quantity of output and T is the time variable. The time variable represents technological change. The factor demand functions can be derived from the cost function by partially differentiating it with respect to the input prices yielding:

$$\frac{\partial \ln C^*}{\partial \ln w_i} = b_{io} + \sum_{j=1}^{n} b_{ij} \ln w_j + b_{it} T = \varepsilon_i \quad (2)$$

where ε_i is the elasticity of total cost with respect to a change in the ith input price. By Shephard's lemma, since,

$$\frac{\partial C^*}{\partial w_i} = x_i^*, \text{ then } \varepsilon_i = \frac{\partial C^*}{\partial w_i} \frac{w_i}{C^*} = \frac{x_i^* w_i}{C^*} = S_i$$

where S_i = the share of input i in total cost. The b_{it} coefficients indicate the rate of bias of technical change. A positive value indicates that technical change is input i-using, a zero value means technical change is input i-neutral and a negative value indicates that technical change is input i-saving.

Because of errors or deviations of the actual cost shares from the cost minimising shares, a disturbance term U_i is added to the deterministic model so that the estimating system is defined as:

$$S_i = b_{io} + \sum_{j=1}^{n} b_{ij} \ln w_j + b_{it} T + U_i$$

$$i,j = V, F, L, K \text{ and } M \quad (3)$$

where: V = Livestock, F = Feed, L = Labour , K = capital, M = Other inputs and services, $w_{i,j}$ = price of input i,j and T = time variable as proxy for technical change. The classification of the inputs is consistent with those of previous studies to facilitate comparison.

All prices are assumed to be exogenous. The following restrictions have to be imposed to satisfy linear homogeneity of the cost function and symmetry of the input price parameters:

$$\sum_{i=1}^{n} b_{io} = 1 \;;\quad b_{ij} = b_{ji} \;;$$

$$\sum_{i=1}^{n} b_{ij} = 0 \;;$$

$$\sum_{i=1}^{n} b_{it} = 0 \qquad \forall j \tag{4}$$

Using the parameters of the system of equations, partial elasticities of substitution, own-price and cross-price elasticities can be estimated.

The elasticity of substitution can be computed using:

$$\sigma_{ij} = \frac{b_{ij}}{s_i s_j} + 1 \qquad \forall\, i, j;\; i \neq j \;\text{; and}$$

$$\sigma_{ii} = \frac{b_{ii} + s_i^2 - s_i}{s_i^2} \qquad \forall\, i \tag{5}$$

This is also known as the Allen elasticity of substitution. When the elasticities of substitution among factors are available, the own-price elasticity of demand can be computed as:

$$\eta_{ii} = s_i \sigma_{ii} = \frac{b_{ii}}{s_i} + s_i - 1 \qquad \forall\, i \tag{6}$$

Similarly, the cross-price elasticity of demand can be easily computed using the relation:

$$\eta_{ij} = s_j \sigma_{ij} = \frac{b_{ij}}{s_i} + s_j \qquad \forall\, i, j;\; i \neq j \tag{7}$$

Because the data used in this study are obtained by pooling time series (1978-1991) and cross-section (six states of Australia) information, it is unlikely that they are homogeneous due to regional state differences in efficiency. An approach suggested by Fuss (1977) is covariance estimation. According to this approach, regional effects are considered stochastic so that the error vector in equation (3) is composed of two stochastic components: a regional specific component and an overall (remainder) component. The weakness of the covariance approach is that the inter-regional variation is ignored, leading to inefficient estimation when this variation is known. However, as discussed in Fuss (1977), for the case of weakly non-stochastic exogenous variables and normally distributed disturbance terms, the covariance method yields asymptotic estimates and asymptotic variance-covariance matrices equivalent to those of the alternative method; namely, the error components method. Swamy and Arora (1972) demonstrate that, in small samples, the error components estimator is not necessarily more efficient than the covariance estimator when the number of regions is small. They also conjecture that when the number of regions is less than ten, the covariance estimator is the preferred estimator. In this study, all properties of estimators are asymptotic, regardless of the pooling problem. Furthermore, there are only six regions. The weight of evidence is clearly on the side of utilising the computationally more convenient covariance estimators, since they will adequately deal with both the parameter and stochastic variations (Fuss 1977). Thus, the final estimating system becomes:

$$S_i = \sum_{k=1}^{6} d_{ik} D_k + \sum_{j=1}^{n} b_{ij} \ln w_j + b_{it} T + V_i$$

D= dummy variable

k= 1,..,6 representing the six States (8)

5. Data and Procedures

The two main sources of data used in this study were ABS and ABARE. The raw data on pig farm expenditures were taken from the *Agricultural Industries Financial Statistics*, Catalogue No. 7507.0 published annually by the ABS. This publication contains estimates of the financial performance of enterprises predominantly engaged in agricultural activity within Subdivision 01 'Agriculture' of the Australian Standard Industrial Classification. Included in the publication are expenditure on materials and services, capital expenditure, interest payment, cash operating surplus and other measures of financial performance of various agricultural enterprises. For the pig enterprise, the farms covered by the survey are those with 50 or more pigs. Only the survey results for the years 1977-78 to 1990-91 were used because of the lack of details on the pig industry financial performance for the previous years. For the years 1979-80, and 1981-86, there were no surveys undertaken. This gives a total of seven years for six states of Australia producing a total of 42 observations.

Input price indexes for the pig industry are the appropriate independent variables in this study. Since time series and cross-section price data for pig production inputs are not available, it is not possible to generate an estimate for the input price indexes specific to the pig industry. An alternative is to use the indexes of prices paid by farmers. The indexes of prices paid and prices received by farmers for the various agricultural output and inputs were taken from ABARE (1991 a,b).

Cost shares were generated according to expenditure items shown in Appendix 1. For the non-durable inputs (feed, materials and services, and labour) cost shares were estimated directly from expenditure data. For the durable inputs which are grouped herein as capital, a user cost value has been derived from the current stock value, taken from the *Agricultural Industries Financial Statistics*, by assuming that farmers aim to make a given real return on their assets. A real opportunity cost rate of 4 per cent has thus been used along with a 5 per cent depreciation rate for each asset class. As no information was available on capital gains, a constant real rate of opportunity cost was assumed. The average unit of livestock was assumed not to depreciate but this required inputs in the form of livestock purchases. Consequently, the livestock input user cost consists of the real opportunity cost and the value of purchases (this method of estimating user cost of capital in agriculture follows Lawrence 1990).

The financial statistics available for pig enterprises at the state level are a summary of the financial aggregates which do not detail the different inputs in pig production. The major inputs identified in pig production are listed in Appendix 1. Livestock purchases and feed expenditure are not available from the summary statistics. Given an aggregate of the purchases and selected expenses, it is then possible to estimate the individual cost items using the ratios derived from the detailed financial statistics at the national level. Since other minor expenses are grouped into materials and services as a single input, a weighted price index was constructed using the price indexes from ABARE.

The system of equations was estimated using the Shazam Econometrics Package (White *et al.* 1990). Since the share equations add up to one, the resulting variance-covariance of the error matrix is singular. Hence, the set of equations was estimated with one of the equations deleted and its corresponding price was allowed to interact in the estimated equations by formulating the explanatory variables as price ratios. Iterative Zellner estimation was employed and ensured invariance of the parameter estimates to the equation deleted. The parameters of the deleted equation were computed using the homogeneity restrictions.

6. Results

The results of the system of equations estimation are shown in Table 1. Inspite of the low R^2s, the standard errors are low and 16 of the 25 coefficients of the price variables are significantly different from zero at the 5 per cent level of significance. High correlation among the explanatory variables resulted in the insignificance of nine coefficients. The time trend variable representing technical change failed to explain variations in the cost share equations, and was dropped. As expected, the pooling of time-series and cross-section data resulted in efficient estimates. With a Chi-square value of 51.7 and six degrees of freedom, the Breusch and Pagan LM test indicates the presence of contemporaneous correlation between the disturbances in the share equations. This means that the coefficients of the share equations are more efficient than those estimated individually. Separate individual regressions of the share equations showed larger standard errors confirming efficiency gains in joint estimation.

It is important to note that the system of equations was evaluated to check whether it satisfied the curvature condition. The signs of the determinants of the principal minors of the estimated parameters

Table 1: Estimates of the Restricted Coefficients of the Input Share Demand Equations[a]

Shares[b]	Exogenous Variables[c]											R^2
	D1	D2	D3	D4	D5	D6	pL	pK	pF	pV	pM	
SL	0.08	0.11	0.09	0.07	0.10	0.09	-0.04	-0.05	-0.11	0.07	0.14	0.14
	(8.56)	(10.95)	(8.52)	(6.29)	(9.25)	(9.95)	(-0.45)	(-1.14)	(-2.71)	(3.37)	(2.04)	
SK	0.22	0.19	0.25	0.21	0.22	0.21	-0.05	-0.19	0.16	-0.03	0.12	0.45
	(12.94)	(11.58)	(14.04)	(11.62)	(12.83)	(12.93)	(-1.14)	(-3.06)	(4.08)	(-2.09)	(2.68)	
SF	0.39	0.40	0.37	0.41	0.39	0.40	-0.11	0.16	-0.02	-0.04	0.01	0.45
	(34.93)	(35.68)	(30.96)	(34.30)	(35.04)	(37.41)	(-2.71)	(4.08)	(-0.52)	(-3.39)	(0.10)	
SV	0.08	0.08	0.08	0.08	0.08	0.08	0.07	-0.03	-0.04	-0.01	0.01	0.54
	(32.24)	(33.42)	(31.32)	(30.01)	(27.11)	(34.42)	(3.37)	(-2.09)	(-3.39)	(-1.16)	(1.53)	
SM[d]	0.23	0.22	0.21	0.23	0.23	0.23	0.14	0.12	0.01	0.01	-0.29	0.31
	(27.55)	(28.00)	(25.07)	(26.03)	(25.43)	(29.70)	(2.04)	(2.68)	(0.10)	(1.53)	(-2.97)	

[a] t-statistics are in parentheses.

[b] Cost shares of inputs L, K, F, V and M where L= labour, K= capital, F= feed, V= livestock, and M= materials and services.

[c] D1, D2, D3, D4, D5 and D6 are dummies representing the six states of Australia while pL, pK, pF, pV and pM are prices of inputs in logarithmic form.

[d] t-statistics taken from the system of equations estimated without livestock equation.

did not conform with the requirements for a concave function. Accordingly, the share equations did not seem to be well-behaved and, as such, should be treated with caution.

6.1 Elasticity of Substitution

There are different elasticities of substitution for every state at every time period but, in order to meet the objective of the study, only national estimates are presented. The elasticities of substitution are computed using the means of the cost share variables and the estimated coefficients of the cost share equations as required in equation (5). The results are presented in Table 2. The figures representing own-elasticities of substitution have no economic meaning.

These estimates indicate that farmers can technically substitute materials and services for labour, capital, feed and livestock with ease as the elasticity estimates are greater than unity. Feed can be substituted also for capital with ease and similarly with livestock which is a substitute for labour. Explaining the substitution between feed and capital is somewhat problematic because of the way producers respond. They can react to price changes of feed at a certain period, say a year, in this study. On the other hand, it may be difficult to react to changes in the price of capital because of the dynamics of the consumption of capital. Capital provides a flow of services which commences once it is in place and producers can do little about it. The large elasticity of substitution between labour and livestock may be attributed to the fact that pig farmers can produce their own breeders. When livestock input becomes costly as in the case of the breeding boars, it may be optimal for producers to hire specialist labour (say breeding technicians) to enable them to produce breeders on their own farms. Such a strategy would assure them of getting the best bloodline they desire and avoid entry of diseases which can be carried by animals coming from outside their farms.

Complements are labour and capital; labour and feed; capital and livestock; and feed and livestock. It is worth noting that unlike many previous studies which used aggregate data, capital is a labour-using input in the pig industry. This is expected as capital and livestock are complements. When livestock purchases increase, so do the livestock population, labour utilisation and capital costs in the form of depreciation. The relationships between labour and feed, and feed and livestock are rather straightforward. Feed utilisation increases with herd expansion which, in turn, increases the demand for labour. Similarly, when herd size increases, more feed has to be purchased.

Table 2: Estimated Allen Partial Elasticities of Substitution[a]

Input	Labour	Capital	Feed	Livestock	Materials and Services
Labour	-19.07	-2.14	-2.81	12.03	9.13
Capital	-2.14	-6.99	2.75	-0.66	3.39
Feed	-2.81	2.75	-1.68	-0.27	1.14
Livestock	12.03	-0.66	-0.27	-12.76	1.77
Materials and Services	9.13	3.39	1.14	1.77	-9.24

[a] Computed from the estimated coefficients of the share equations and the mean shares of the respective inputs.

6.2 Own-Price Elasticity of Demand

All of the own-price elasticities of demand estimated exhibit negative signs as required (Table 3). With the exception of feed which is vital in production, all of the own-price elasticities of demand are greater than unity. This means that when price increases, the reduction of the quantity utilised by farmers is more than the magnitude of increase in price. Inputs such as feed which have low elasticities of substitution will have low price elasticities of demand, as well. This is because farmers are not likely to reduce the purchase of feed substantially when its price increases. Feed is the most vital input that determines the growth of livestock and helps build up disease resistance among the herd. Unless the profitability of the enterprise were threatened by an increase in feed price, farmers would likely be unresponsive to changes in prices. Farmers appear to be very responsive to changes in the price of other materials and services whose own-price elasticity estimate is -2.06. Some of the components of this cost about which farmers have flexibility in usage are veterinary medicine, insurance, repair and maintenance, energy, and water and drainage.

6.3 Cross-Price Elasticity of Demand

The estimates of the cross-price elasticities are also displayed in Table 3. The interpretation of the signs of the cross-price elasticities of demand is analogous to that of the elasticity of substitution. The estimates of the cross-price and own-price elasticities change over time but the magnitudes of variations are very small. Hence, only estimates from the mid-point of the data used are reported.

The estimated cross-price elasticities are generally less than unity. However, the labour input is very responsive to price of materials and services with the cross-price elasticity of 2.04. Similarly, capital and labour are also responsive to changes in the price of feed. The remaining inputs are less responsive to changes in prices of the other factors as can be seen from their low cross-price elasticities.

7. Conclusions

The estimates of elasticities of substitution imply that pig producers are flexible in input use. When prices fluctuate, farmers change their input mixes with ease. With the exception of the demand for feed which is a vital production input, pig producers are highly responsive to own-price changes of inputs. They are, however, less responsive to relative input price changes.

These results differ from those of previous studies which used aggregate data suggesting that at a

Table 3: Estimated Own -and Cross-Price Elasticities[a, b]

Change in Quantity of:	With Respect to Price of: Labour	Capital	Feed	Livestock	Materials and Services
Labour	-1.44	-0.49	-1.09	0.99	2.04
Capital	-0.16	-1.61	1.07	-0.05	0.76
Feed	-0.21	0.63	-0.65	-0.02	0.25
Livestock	0.91	-0.15	-0.10	-1.05	0.40
Materials and Services	0.69	0.78	0.44	0.15	-2.06

[a] Computed from the means of the variables.

[b] Cross-price elasticities are not symmetrical since $S_j \sigma_{ij} \neq S_i \sigma_{ji}$.

lower level of aggregation, farmers can alter their input usage with ease. This could in part be explained by the fact that the pig industry is a small sector of the Australian economy and that a concerted move by pig producers in terms of changes in demand for pig production inputs would have little effect on the aggregate demand for farm inputs. Thus, pig producers appear to be unconstrained in procuring farm inputs.

While they are indicative of the plausibility of using the cost function to estimate factor demand and substitution in pig enterprises, the results should be interpreted with caution in the sense that the use of the cost function analysis implicitly simplifies economic behaviour.

Firstly, there is the assumption of instantaneous response of farmers to changes in economic factors such as price changes. This implies that there is no delay in planning and implementation of production decisions which is an abstraction from reality. Farmers need some period between planning and execution of decisions. However, the issue of dynamics cannot be easily addressed in cost function analyses, particularly in this study where time series and cross-section data were pooled and symmetry conditions imposed.

Secondly, the grouping of the other inputs into materials and services may not be satisfactory as the farmers may have a distinct reaction to each of the specific cost items contained in the group. An aggregator function could be employed to measure this but the present state of the data in Australia prohibits the utilisation of this method.

Thirdly, the use of the cost function imposes a constraint that the pig industry is producing a single product. Even if sale of crops and livestock products contributes only an average of 9 per cent to the turnover in the pig industry, it may still have a considerable impact on producer input utilisation. For instance, the value of cereals and milk output from the farms may be understated because some of the output is certainly given as feed to the animals which further complicates the problem in response analyses.

Finally, several avenues for further research may be suggested. First, the multi-output nature of the pig industry suggests that the data should be disaggregated to accommodate other commodities being produced on pig farms. Profit function analysis may then be applied if data requirements are met. The dynamics of production is a second area of interest. Although the pig industry has a shorter production cycle than other livestock enterprises, the complete cycle of production process could not be accommodated in one year. There is a time lag between production planning, implementation and the realisation of the output. A partial adjustment or distributed lag model may be an appropriate approach to capturing these dynamics but this may result in inefficient estimates because of the correlation of the exogenous variables.

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Appendix 1: Value and Price Sources

Group	AFS Category	ABARE Price Index
Labour	Wages, salaries and supplement	Wages
	Payments to contractors	Contractors
Capital	0.09 x Value of machinery and equipment	Interest paid or Repair and maintenance
Materials and Services	Marketing expenses	Marketing
	Payment for seed	Seed, seedlings and plants
	Payment for fertilizer	Fertilizer
	Payment for crops and pasture chemicals	Chemicals and medicines
	Payment for vet. supplies and services	Chemicals and medicines
	Payment for fuel	Fuel and lubricants
	Water and drainage charges	Electricity
	Payments to contractors	Contractor
	Repair and maintenance	Repair and maintenance
	Rent and leasing expenses	Other services
	Other selected expenses	Other services
Feed	Payments for fodder	Fodder
Livestock	Purchases of livestock	Livestock
	0.04 x Value of livestock	Livestock