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A QUARTERLY MODEL OF THE AUSTRALIAN AGRICULTURAL SECTOR*

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Several farm sector econometric models are reviewed initially and the aggregation problem highlighted. A thirty-equation model of the Australian agricultural sector is specified in which farm output, stocks and exports and the domestic demand for farm products are endogenous, as well as farm, export and retail prices. Disaggregation is into food and non-food components of unprocessed output, and the processing of food is traced through to final demand. The model is estimated by a modified 2SLS procedure using quarterly data covering the period 1960-1970.

In a recent review of the state of the art of econometric modelling of the agricultural sector, King [9] drew attention to the relative paucity of models of the agricultural sector as a whole. With the signal exceptions of Karl Fox's contribution to the Brookings-SSRC model [4] and, more recently, the IAC's IMPACT model [15], econometric models of national economies have tended to treat the agricultural sector as exogenous (see, for example, Evans and Klein [3], Norton and Henderson [14]). At the other extreme there has been a good deal of progress in the construction of models relating to individual commodities.¹ In the present paper we describe a quarterly econometric model of the Australian agricultural sector which exemplifies some of the problems and possibilities of agricultural sector modelling in an open economy.

A major question confronting builders of econometric models of the agricultural sector has been the choice of a level of aggregation. At one extreme is a model such as that of Egbert [2] which concentrates on explaining annual aggregate supply and demand for the U.S. agricultural sector as a whole without any consideration of the structure of component industry or commodity groups. The endogenous variables in Egbert's model are total agricultural output, domestic consumption of agricultural products, farm prices and the level of farm stocks; imports and exports are assumed to be exogenous. Models such as Egbert's may be relatively straightforward to specify and estimate, but their usefulness for policy analysis and forecasting is limited by their highly aggregative nature.

At the other extreme, an agricultural sector model may aggregate upwards from individual commodities, such as in Cromarty's [1] pioneering work of the late 1950s. He specified supply equations, and demand equations for consumption, inventories and government stocks,

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¹ For a discussion of issues in this context see Labys [10] and McFarquhar [11]. A survey of agricultural sector and industry models to 1972 may be found in Rutledge and Throsby [17].

for each of twelve industry groups in the U.S. agricultural sector, and estimated the model from annual data. A model such as this is potentially valuable for its identification of economic forces affecting individual farm industries and for stressing interindustry linkages, but its specification and possibly also its estimation may be more difficult than in the case of more highly aggregated models.

Fox's contribution to the Brookings model lies somewhere between these two extremes. Whilst it treats the agricultural sector as a whole, it does proceed as far as a crop/livestock disaggregation. It includes not only the customary demand, supply and price relationships, but also equations explaining net farm income, agricultural investment and employment, the provision of public finance for the agricultural sector and foreign trade in agricultural products. Fox's model is particularly distinguished by its emphasis on the relationships between farm and non-farm sectors by virtue of its role as part of a larger model of the U.S. economy.

Objectives

Amongst the above models, ours is conceptually most similar to that of Fox. It treats the Australian agricultural sector as a whole, but disaggregates into 'food' and 'nonfood' components which are further specified in terms of either 'unprocessed' or 'processed' output. This level of disaggregation was chosen as that which would allow a model to be built with more descriptive realism than a wholly aggregate model, yet which could still be estimated from data series which were largely aggregate in nature.

Other model-building exercises relating to the Australian agricultural sector which are either antecedents to, or have been developed concurrently with, our own include those of Gruen *et al.* [5], Mules [12], Powell [15], Smith and Smith [20] [21], and the New England programming model ('APMAA') [8] [23]. However, no previous study has attempted to portray the joint determination of prices and quantities for the agricultural sector as a whole. Therefore, given the exploratory nature of our work, our objectives have been oriented towards methodology rather than policy analysis. As a result we do not proceed empirically in this paper beyond a straightforward evaluation of the model *per se*. Although models of the type constructed here are ultimately useful for structural analysis and/or forecasting, our purpose is simply to investigate the problems and possibilities of constructing such a model in the hope that subsequent research will build on these results. In this respect our work might be compared with Neville's [13] model of the Australian economy. Just as that model may be seen as a precursor of subsequent more detailed models of the Australian economy (for example, [14]), so will our model, it is hoped, lead in due course to more refined models of the agricultural sector.

Specification

The model consists of three interdependent submodels, for farm output and farm prices, agricultural exports and export prices, and domestic retail demand and prices. Altogether there are fifteen behavioural equations and fifteen identities. Broadly, agricultural output, either food or non-food, is classed as 'unprocessed' as it leaves the farm

gate. We follow the movement of these supplies either to exports of unprocessed output, stocks, or domestic disappearance. The latter output is either demanded domestically for final consumption in unprocessed or processed form, or is processed for export. For that part of output entering a processing sequence, it is possible to follow its progress through to final demand only in the case of food; the ubiquitous role of nonfood farm products (especially wool, hides, industrial crops) in manufactured goods makes it impossible to isolate retail demand for nonfood products of rural origin, although a proxy for retail prices of nonfood farm products is obtainable in the 'Clothing and Drapery' index from the six-capitals CPI.

In the following description we use the subscript $t = 1, \dots, T$ to indicate quarterly time periods, and superscripts uf , un , pf and pn to denote unprocessed food, unprocessed nonfood, processed food and processed nonfood respectively. Variables other than indices are measured in millions of Australian dollars unless otherwise specified.

Farm Output and Prices

Equations (1) to (4) below determine the behaviour of gross farm output and farm gate prices:

$$GVC_t^{uf} = f(PF_{t-1}^{uf}, W_{t-1}^{uf}, GVC_{t-1}^{uf}) \quad (1)$$

$$GVC_t^{un} = f(PF_{t-1}^{un}, W_{t-2}^{un}, GVC_{t-1}^{un}) \quad (2)$$

$$PF_t^{uf,un} = f(GVC_t^{uf,un}, PF_{t-1}^{uf,un}) \quad (3), (4)$$

where GVC = value of gross farm output at constant prices;

PF = index of farm-gate prices;

W = index of weather conditions affecting farm output.

Equations (1) and (2) are aggregate supply response equations. Output is assumed to respond to lagged price via an adaptive expectations mechanism which leads to the inclusion of both lagged price and lagged output as explanatory variables. A partial adjustment mechanism is embodied in equations (3) and (4). It is assumed that prices do not fully respond immediately to quarterly movements in aggregate output, largely because of market imperfections which inevitably occur when production is spread over a geographic region as large as Australia. The pervasive influence of weather on farm output is represented in the supply equation. A longer weather lag is hypothesized for nonfood (principally wool) than for food (principally annual crops, meat and dairy). The weather indexes constructed for this study comprised quarterly rainfall indexes aggregated from regional data for the beef, wheat, dairy and sheep industries, and then combined into composite food and nonfood indexes (W^{uf} and W^{un} respectively).²

Exports and Export Prices

Because of Australia's significant market power in trade in some important commodities (wool, food grains, dairy products), export prices cannot be regarded as entirely exogenous in a model of this type. We therefore postulate joint determination of export quantities and

² See further in Throsby [22], pp. 14, 90-93.

prices according to a scheme which is logically similar to the supply equations above; i.e. exports are explained in part by lagged prices, and prices are determined in part by current exports, according to the following specifications:

$$XC_t^{uf,un,pf} = f(PX_{t-k}^{uf,un,pf}, CX_t^{uf,un,pf}, GVC_t^{uf,un,pf}, XC_{t-1}^{uf,un,pf}) \quad (5), (6), (7)$$

$$PX_t^{uf,un,pf} = f(XC_t^{uf,un,pf}, CX_t^{uf,un,pf}, PX_{t-1}^{uf,un,pf}) \quad (8), (9), (10)$$

where XC = value of farm exports at constant prices;

PX = index of export prices;

CX = index of volume of competing exports from foreign competitors.

In specifying the nature of the lag distribution of export prices on quantities, it is assumed that lag effects do not begin to be felt until after k periods, where k is a parameter to be empirically determined. Applying a Koyck transformation to appropriate lag equations embodying such an assumption leads to estimating equations as in (5), (6) and (7). With the possible exception of wool, most agricultural commodities move relatively quickly through domestic marketing channels and into the export trade; consequently exports tend to fluctuate with production as is also reflected in these equations. The specification of the lag on price in the price equations (8), (9) and (10) derives again from an assumed partial adjustment mechanism.

The above specification of relationships for export prices and quantities is fairly simple. A greater elaboration might sensibly be carried out at a finer level of disaggregation. In a separate paper [18] we pursue this question by specifying for individual agricultural commodities a structure for the joint determination of domestic and export demands and export prices. On a separate commodity basis it is possible, amongst other things, to be more precise about the lags in response of export demand to movements in the domestic-export price differential than is feasible in the aggregate equations specified above.

Domestic Retail Demand and Prices

As mentioned above, our treatment of the demand for nonfood output is limited to the domestic disappearance of unprocessed products, whereas in the case of food, retail demand for processed output can be isolated:

$$CPHC_t^{un} = f(PRC_t^{pn}, YPHC_t) \quad (11)$$

$$PR_t^{pn} = f(PF_t^{un}, WRP_t) \quad (12)$$

$$CPHC_t^{pf} = f(PRC_t^{pf}, YPHC_t) \quad (13)$$

$$PR_t^{pf} = f(PF_t^{uf}, WRP_t) \quad (14)$$

$$VAC_t^{pf} = f(CC_t^{pf}, WRPC_t) \quad (15)$$

where $CPHC$ = value of consumption per head of farm products at constant prices;

PRC = index of retail prices deflated by movements in all other consumer prices;

$YPHC$ = personal disposable income per head at constant prices;

PR = index of retail prices;

WRP = index of wage rates in processing industries at current prices (measured as average weekly earnings of employees in the food, drink and tobacco group of the manufacturing sector);

VAC = value added in processing at constant prices;

CC = value of aggregate consumption at constant prices;

$WRPC$ = WRP deflated by CPI.

Equations (11) and (13) are orthodox demand equations. Equations (12) and (14) explain the relationship between farm and retail prices in terms of wage rates in food processing industries, a proxy conventionally taken for factors influencing marketing margins for agricultural products. The estimating equation (15) for value added in the processing of food output is derived from the hypothesis that value added as a proportion of total final consumption of processed food is related to the same sorts of factors as determine marketing margins.³ Note that the variables in equation (15) are measured in constant prices; hence this equation is independent of the price effects which equation (14) attempts to capture.

Identities

In addition to the above fifteen behavioural equations, the model includes fifteen identities.⁴ Since they involve no lagged variables, we omit time subscripts in specifying them below.

The first set of identities comprises the basic supply/demand balance equations for unprocessed food and nonfood and processed food:

$$GV^{uf,un} + M^{uf,un} = C^{uf,un} + X^{uf,un} + \Delta S^{uf,un} \quad (16), (17)$$

$$C^{uf} + FISH + M^{pf} + VA^{pf} = C^{pf} + X^{pf} \quad (18)$$

where GV = gross value of farm output at current prices;

M = value of imports of farm products at current prices;

C = value of domestic consumption of farm products at current prices;

X = value of exports of farm products at current prices;

ΔS = change in the value of farm stocks at current prices;

$FISH$ = value of domestically produced and consumed fish at current prices;

VA = value added in processing at current prices.

In the quantification of equations (16) and (17), unprocessed farm output is defined as output in the form in which it leaves the farm. Thus on the left-hand sides of equations (16) and (17), GV embraces all farm output, and M comprises unprocessed imports (a numerically small group consisting mainly of tobacco, coffee and tea). The left-hand

³ An identity between PF , VA and PR notionally exists, but cannot be specified here because of the nature of these variables— PF and PR are indices, not unit prices, and VA is an aggregate measure. Hence we must specify the relationship between these variables in terms of stochastic equations, as postulated in equations (12), (14) and (15).

⁴ Not including a routine set of identities which could be specified to yield total agricultural sector variables as the sums or weighted averages of the corresponding food and nonfood variables.

sides of (16) and (17) thus measure the supply of all unprocessed agricultural products to the domestic market. The variables \bar{X} and ΔS in (16) and (17) comprise only those products exported or moving into or out of store in their unprocessed state, mainly wool, hides and skins, meat, grain, and fresh fruit and vegetables. The variable C in (16) and (17) thus represents the movement of all unprocessed products into the domestic system where they are processed and then either consumed locally or exported.

As mentioned earlier, the processing sequence could be quantified only for the food portion of total output. This was because consumption figures were available at retail only for food products; it was impossible on the nonfood side to identify intermediate and final demand (both domestic and export) for all processed products containing some non-food agricultural component (e.g. woollen and cotton finished and semi-finished goods, tobacco products, industrial materials using non-edible vegetable oils, etc.). Thus equation (18) takes as its starting point the supply to the domestic market of unprocessed agricultural food output (C^{uf} from equation (16)). This has to be augmented with the output of fisheries, as the consumption variable for food on the utilization side of the identity includes retail consumption of fish. No information was obtainable about stock movements for food at the retail level, hence to the extent that they are important between quarters, they will contribute to the instability of the residually-determined variable in equation (18), viz. VA . This latter variable represents value added in processing, packaging and distribution of unprocessed food supply and in further processing, packaging and/or distribution of processed food imports.

The distinction between processed and unprocessed food is difficult to maintain precisely. The variable C^{pf} in equation (18) comprises all food demanded at retail including fresh fruit, vegetables and meat which have not been exported via equation (16) and have therefore been transferred via C^{uf} to equation (18). In relation to exports, grains, meats, eggs and fresh fruit and vegetables are classified as unprocessed, whilst dairy products, sugar, flour, and dried and canned fruit and vegetables are regarded as processed.

The valuation of all the variables in equations (16) and (17) was in terms of gross unit values, i.e. at farm gate prices. This necessitated a revaluation of the variable X^{un} so that it would be expressed in the same terms as the other variables in equation (16).⁵

A second group of identities specifies the determination of constant-price series:

$$GVC^{uf,un} = GV^{uf,un}/PF^{uf,un} \quad (19), (20)$$

$$XC^{uf,un,pf} = X^{uf,un,pf}/DX^{uf,un,pf} \quad (21), (22), (23)$$

$$CC^{un} = C^{un}/PF^{un} \quad (24)$$

$$CC^{pf} = C^{pf}/PR^{pf} \quad (25)$$

$$VAC^{pf} = VA^{pf}/CPI \quad (26)$$

$$PRC^{pf,pn} = PR^{pf,pn}/CPI \quad (27), (28)$$

⁵ See further in Throsby [22], pp. 5-6.

where DX = export price deflator (differs from PX for technical reasons embodied in the data);

CPI = index of all consumer prices.

Finally, two identities define per capita variables:

$$CPHC^{un,pf} = CC^{un,pf}/POP \quad (29), (30)$$

where POP = total population of Australia (millions).

Endogenous Variables

The model described above consists of thirty equations, and contains thirty endogenous variables which are detailed in Table 1.

TABLE 1
Classification of Endogenous Variables

Variable	<i>uf</i>	<i>un</i>	<i>pf</i>	<i>pn</i>
<i>GV</i>	x	x		
<i>GVC</i>	x	x		
<i>C</i>	x	x	x	
<i>CC</i>		x	x	
<i>X</i>	x	x	x	
<i>XC</i>	x	x	x	
<i>CPHC</i>		x	x	
<i>VA</i>			x	
<i>VAC</i>			x	
<i>S</i>	x	x		
<i>PF</i>	x	x		
<i>PX</i>	x	x	x	
<i>PR</i>			x	x
<i>PRC</i>			x	x

x indicates appearance of variable as an endogenous variable in the model.

Data and Estimation

The model was estimated using quarterly data covering the period 1960(3) to 1970(4) (i.e. $T = 46$). Full details of data series used and their sources are available elsewhere (Throsby [22]).

A constant term was included in each estimated equation, together with three dummy variables to account for seasonal effects.

Despite the fact that the behavioural equations (1) to (15) are linear, the model as a whole is not because of nonlinearities in certain of the identities. In such cases, usual estimation procedures may be inappropriate. We have used a modification of 2SLS suggested by Kelejian [7] by approximating each reduced form equation by a first-order polynomial in the predetermined variables, a method used previously by Prato [16]. In the estimation of the demand and retail price equations, (11) to (14), which were affected by serial correlation in the residuals, a Hildreth-Lu procedure [6] was employed to estimate the structural coefficients.

Results

The estimated regression coefficients of the behavioural equations are reported in Table 2, together with estimates of their asymptotic standard

TABLE 2
Details of Estimates of Behavioural Equations

Eqn.	Dep. Var.	Explanatory Variables					\bar{R}^2
1. Farm Output and Prices ^(a)							
		PF_{-k}	GVC	GVC_{-1}	W_{-k}	Const	
1	GVC^{uf}	8.035 (3.911)	—	0.338 (0.156)	1.108 (0.838)	-176.398 (364.265)	0.822
2	GVC^{un}	0.147 (0.396)	—	0.651 (0.129)	0.207 (0.187)	140.220 (64.249)	0.926
3	PF^{uf}	0.780 (0.102)	0.005 (0.005)	—	—	17.099 (8.543)	0.678
4	PF^{un}	0.901 (0.084)	-0.087 (0.038)	—	—	43.950 (18.489)	0.768
2. Exports and Export Prices ^(a)							
		PX_{-k}	GVC	XC	XC_{-1}	CX	
5	XC^{uf}	1.198 (0.942)	0.071 (0.055)	—	0.591 (0.128)	—	0.658
6	XC^{un}	0.608 (0.337)	0.604 (0.164)	—	0.275 (0.150)	—	0.737
7	XC^{pf}	0.064 (0.094)	0.037 (0.031)	—	0.604 (0.142)	—	0.545
8	PX^{uf}	0.783 (0.091)	—	0.001 (0.021)	—	0.086 (0.043)	0.810
9	PX^{un}	0.956 (0.095)	—	-0.030 (0.046)	—	—	0.739
10	PX^{pf}	0.783 (0.101)	—	-0.157 (0.164)	—	-0.167 (0.161)	0.739

3. Domestic Retail Demand and Prices

		<i>PRC</i>	<i>PF</i>	<i>YPHC</i>	<i>WRP(C)</i>	<i>CC</i>	Const
11	<i>CPHC</i> ^{un}	-12.599 (6.859)	—	0.047 (0.026)	—	—	10.263 (7.618)
12	<i>PR</i> ^{un}	—	-0.116 (0.032)	—	0.975 (0.986)	—	9.555 (6.909)
13	<i>CPHC</i> ^{pt}	-4.799 (8.844)	—	0.056 (0.042)	—	—	3.344 (0.702)
14	<i>PR</i> ^{pt}	—	0.426 (0.257)	—	1.482 (0.189)	—	-32.397 (8.665)
15	<i>VAC</i> ^{pt}	—	—	—	-2.186 (5.546)	0.921 (0.350)	-132.299 (290.749)

(^a) where $k =$ length of lag : in equations 1, 3, 4, 8, 9, 10, $k = 1$
in equation 2, $k = 2$
in equation 5, $k = 4$
in equation 6, $k = 6$
in equation 7, $k = 8$

errors shown in parentheses. Adjusted R^2 statistics are given, although they admit no meaningful interpretation in simultaneous equations models such as this.

In evaluating the overall estimated model, we follow the procedure of paying primary attention to the explanatory power of the fitted equations and to the signs rather than the statistical significance of estimated regression coefficients. The implication of the latter point is that the essential hypotheses embodied in a model of this sort are expressed in terms of the postulated direction of the relationships between variables, as reflected in the signs of regression coefficients. In large-scale time-series models, experience suggests that in testing conventional null hypotheses on estimated regression coefficients for other than lagged dependent variables, the probability of making Type I errors may be set rather higher than usual because, despite the estimation procedure used, the individual influences of explanatory variables cannot be completely separated.

Accordingly we may classify our estimated equations into three types:

- (a) those with regression coefficients of expected sign at reasonable levels of significance;
- (b) those with regression coefficients of expected sign but of lower significance; and
- (c) those with 'wrong' signs on important regression coefficients.

Equations (1), (4), (6), (11), (12) and (14) may be said to fall into the first group, whilst equations (2), (5), (7), (9), (10) and (13) may be classified in group (b). Thus, twelve of our fifteen equations may be said to be good, or at least to be reasonably consistent with the underlying hypotheses. The remaining three equations (3), (8) and (15) fall into group (c).

Looking at the interdependent submodels separately, we have estimated supply and prices for unprocessed farm output in a way which supports to a large extent the hypotheses of the joint determination of these variables as specified earlier. The exception is the food price equation where the sign on current output is incorrect, and most of the explanation comes from lagged price. It is noted that the domestic prices of over half of the farm output of food products in Australia are administered, whereas those of nonfood commodities are primarily market determined. Hence it would be expected that the responsiveness of price to supply would be more marked for nonfood than for food products.

Similar remarks relate to the export quantity and price equations. Here again, administered pricing dominates the market for food products, whereas prices for non-food commodities are set more nearly by market forces. Thus, the only product group for which both price and quantity equations are reasonably satisfactory is the unprocessed non-food group. Of the unprocessed food estimates, the price equation does not capture any supply effect, and gives a contrary sign on competing exports, whilst the quantity equation for processed food exhibits relatively low levels of significance (though 'correct' signs) on the major explanatory variables.

Finally, the domestic demand and retail price equations conform largely to expectations. The difference between the signs on PF in the two price equations is explained by the fact that whilst all retail prices have risen, farm prices for nonfood have tended downwards over the

sample period at a time when farm prices for food products have risen. The expected role of factors affecting the marketing margin in increasing real value added in food processing is not borne out in equation (15), where the coefficient on *WRPC* has the wrong sign and a low level of significance.

Conclusions

The purpose of the study reported in this paper has been to explore the possibility of constructing a quarterly econometric model for the Australian agricultural sector. Viewed as an exploratory effort the results are encouraging in that a nontrivial system of structural relationships has been constructed with a majority of estimated coefficients conforming to sensible expectations. The results seem to confirm the workability of the general specification developed here for agricultural sector modelling. Hence, the experience of this study should be relevant to other model builders. Our conclusions in this respect are as follows.

The estimation of supply, demand and price relationships is more straightforward for domestic variables than for exports. Nevertheless, some progress can be made towards integrating the external sector into models such as this, especially when the country has significant international market power in commodities whose prices are not subject to substantial institutional rigidities. If the latter conditions do not obtain, export prices must either be taken as exogenous, or else the model must embody a much more detailed specification of the process of price formation in world markets than was possible in the present case.

The specification of lagged effects in the behavioural equations of this model has relied principally on the use of geometric lag distributions. Our results emphasize the difficulties inherent in attempting to interpret coefficients estimated under these sorts of assumptions. Whilst our results are not inconsistent with the hypothesis of such lag structures, they could also be explained in other ways. In particular, the explanatory significance of lagged dependent variables may result more from properties of the disturbance term in estimating equations than as a result of the aptness of the lag hypotheses. It may be suggested that alternative lag distributions (e.g. polynomial weights) may be preferable inasmuch as under such assumptions more discriminating tests may be possible. In general, however, these alternatives are not without difficulties of their own (see, for example, Schmidt and Waud [19]).

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