Agricultural Supply Response in ORANI

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In the ORANI general equilibrium model, the supply behaviour of agricultural industries is the crucial element shaping the response of agriculture as a whole to any exogenous shock. In this paper, elasticity formulae which measure agricultural supply behaviour in the model are derived. These elasticities are found to be very sensitive to year-on-year changes in the level of agricultural profitability, embodied within the model's data base. The appropriate procedure, therefore, is to construct a synthetic data set designed to capture the agricultural sector in a recent average year. Supply elasticities based upon these data represent the "preferred" estimates of this study.

1. Introduction

A large proportion of Australia's agricultural production is sold on overseas markets. In 1985–86, for example, exports of rural origin were estimated by the Bureau of Agricultural Economics (BAE) to constitute 74.5 per cent of the gross value of rural production (BAE 1987). This heavy exposure of Australian agriculture to world trade means that changes in the sector's prosperity are closely linked to changes in its domestic production costs relative to the world price (expressed in Australian dollars) received for its products. Hence, to analyse the effects of government policies on the Australian agricultural sector, a model capable of endogenising this cost-price ratio within an internally consistent economy-wide framework is required. Such a framework is provided by ORANI, a fully computable general equilibrium model of the Australian economy.[1]

ORANI is an extremely large model, with a structure currently large enough to accommodate up to 230 commodities (115 domestically produced and 115 imported) and 113 industries. Other features of the model include:

- an allowance for multi-product industries and multi-industry products (of special importance in agriculture);
- an explicit treatment of the substitution possibilities existing between domestically produced commodities and their imported counterparts; and
- a linear final form achieved using the approach to approximating non-linear systems pioneered by Johansen (1960).[2]

Because ORANI contains so much detail, it can be used to answer questions about many of the important issues currently affecting agriculture. For example, Higgs (1986) used the model to examine the implications of an expansion in the domestic mineral resources sector; a change in world agricultural prices; changes to the levels of protection afforded domestic manufacturing industries; a change to Australia's tax mix in favour of indirect taxation; changes in the real wage rate and in the real exchange rate; and an expansion in domestic aggregate demand. Other authors have used the model to look at the implications for agriculture of world energy price increases (Vincent, Dixon, Parmenter and Sams 1980) and of changes in the domestic crude-oil pricing policy (Dixon, Parmenter and Powell 1982).

Regardless of what exogenous shock is being examined, the crucial element in the model which determines the response of agriculture as a whole is the value implicitly assigned to the price elasticity of aggregate agricultural supply. This elasticity is a function of the model's data base, which describes the economy in a year from which all changes are measured. Because the data base is regularly updated to reflect the latest available information, the aggregate supply elasticity itself is subject to change. The primary aim of this paper, therefore, is to assess how past changes in the model's data base have

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1. The standard ORANI structure is described fully in Dixon, Parmenter, Sutton and Vincent (1982).

2. With the Johansen approach, the highly non-linear structural form of the model is replaced by a linear approximation in the percentage changes of all variables. This method introduces approximation errors which are negligible for small changes in the exogenous variables. However, for large changes, these errors may become important. If so, an Euler-style large change procedure can be employed to derive highly accurate solutions, with additional computing expense.

affected this elasticity, or to be more precise, have affected its commodity-specific (*i.e.* "micro") components. Our attention will be upon short-run rather than long-run elasticities, the time period denoted short-run being only long enough for domestic suppliers of commodities to hire labour and to expand output with their existing structure of productive fixed capital (including land).[3]

It will be shown that the "micro" elasticities are extremely sensitive to changes in the data base and especially to changes in data reflecting the level of agricultural sector profitability during any one year. Agricultural profits are very susceptible to unplanned transient occurrences such as drought and disease-related shortfalls in production. Thus, because ORANI is only concerned with projecting the systematic, not random, responses of economic variables to exogenous shocks, we have proposed that an average (or "typical") year data base be synthesised for ORANI.[4] The "micro" elasticities derived from these data are our "preferred estimates".

The remainder of this paper is organised as follows. In section 2, a brief description of the ORANI agricultural production system is offered. Formulae to allow computation of the "micro" elasticities of supply for the principal agricultural products are derived in section 3. These elasticities are defined in terms of the transformation and expansion components of the supply response of a single agricultural commodity to a change in its own price or in that of another agricultural commodity. In section 4, values of the "micro" elasticities implied by the 1968–69 and 1977–78 ORANI data bases are computed. Reasons for divergences between "micro" elasticities of supply based on these two sets of data are then discussed. The preferred elasticity values, which are based on the synthetic "typical" year data, are also presented in section 4.

2. The ORANI Agricultural Production System

The specification of ORANI makes allowance for the multi-product nature of Australian agriculture. The three largest agricultural industries identified in the model — namely, the Pastoral Zone, the Wheat-Sheep Zone and the High Rainfall Zone — are modelled as multi-product industries each producing in total nine separate commodities.[5] These three zonal industries are geographically defined, aggregating establishments faced with similar climatic/technological conditions. The basis of the zonal classification is that adopted by the BAE in its Australian Sheep Industry Survey (BAE 1976). A fourth industry, Northern Beef, is also geographically defined. It consists of specialist enterprises producing beef cattle in the Kimberley region of Western Australia, the Northern Territory and the northern region of Queensland.

There are four non-geographically defined agricultural industries. The first of these, the Milk Cattle and Pigs industry, is modelled as producing two commodities (beef cattle, and milk cattle and pigs) in fixed proportions. The remaining three industries, Other Farming (Sugar Cane, Fruits and Nuts) (hereinafter OFE), Other Farming (Vegetables, Cotton, Oilseeds and Tobacco) (hereinafter OFM) and Poultry, each is modelled as producing a single commodity.

The output technology of each industry is illustrated in Figure 2.1. The basic assumption underlying technology of this type is known as "input-output separability" (see Hasenkamp 1976, p.19). Each industry is viewed as purchasing a level of activity (or a production possibilities frontier). Inputs are regarded as non-specific to outputs, since the former merely produce a capacity for production that can be transformed into a variety of commodities. Thus, an industry's input and output decisions are treated separately, thereby yielding relatively simple supply response equations of the form:

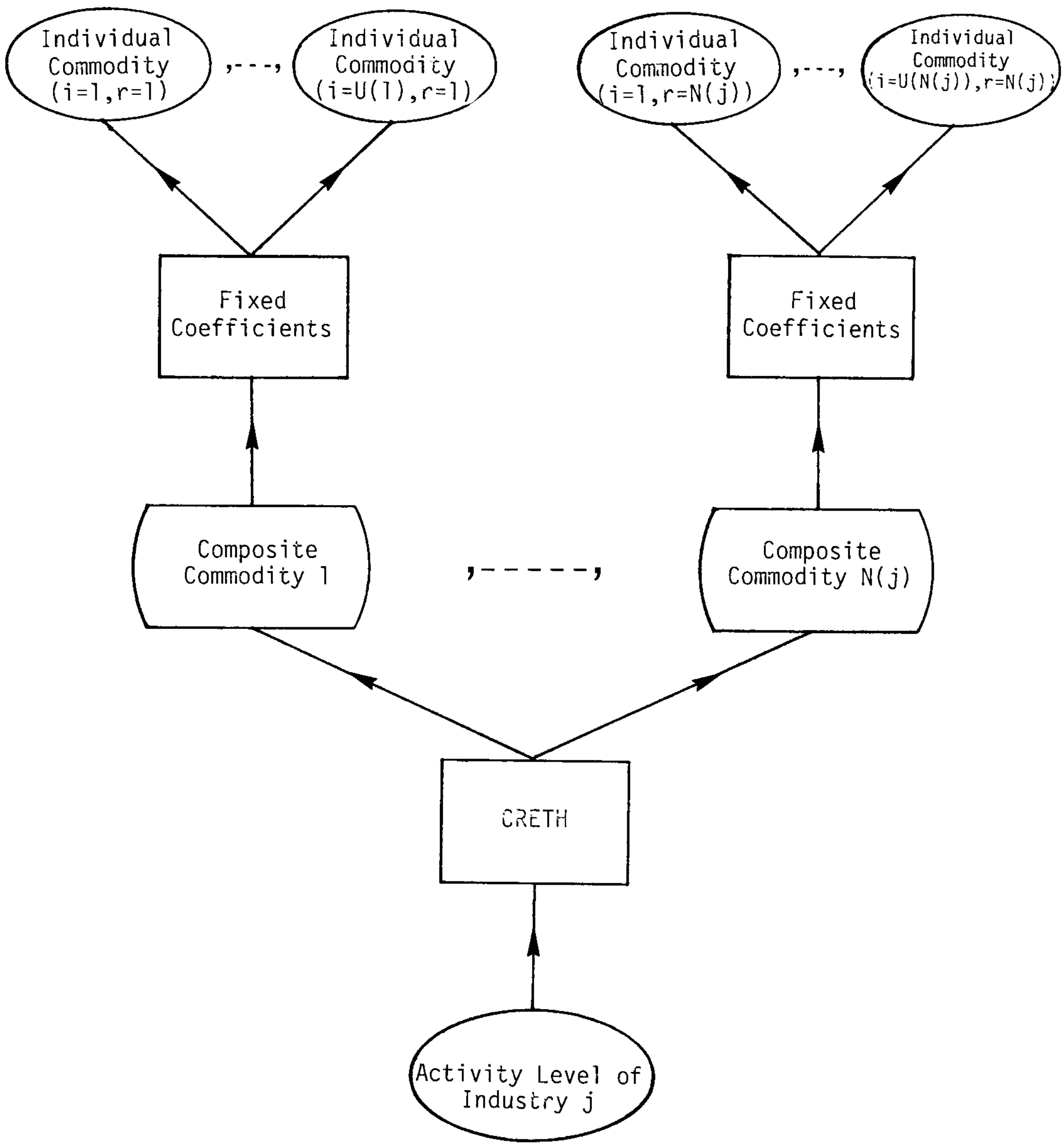
$$(2.1) \quad Y^{\ell j} = g^{\ell j}(P_1, P_2, \ldots, P_L, Z_j) \quad (\ell=1,\ldots,L;\ j=1,\ldots,G),$$

3. In ORANI, the length of the short-run corresponds to a calendar time of about 2 years — see Cooper (1983), and Cooper, McLaren and Powell (1985).

4. In the context of ORANI-type models, arguments for the development of synthetic data sets which portray the economy in a "typical" year are discussed more fully in Adams and Higgs (1986).

5. There are in total 10 agricultural commodities recognized in the model. The commodity not produced in any zone is poultry.

Figure 2.1: The Output Technology for Multi-product Agricultural Industries in ORANI



where Y^{lj} is the output of commodity l by industry j, P_l is the price of commodity l net of the cost of product specific inputs and Z_j, a scalar, is the activity level of industry j.[6] The function g^{lj} is determined as the solution to the problem of maximising an industry's revenue subject to a CRETH (constant ratios of elasticities of transformation, homothetic) production technology with given product and input prices, and with land and capital treated as fixed.[7] Where possible, partial elasticities of transformation were estimated econometrically (see Vincent, Dixon and Powell 1980). However, because of data limitations, it was necessary for the three zonal industries to aggregate a number of products of relatively minor importance in the particular zone concerned, into a miscellaneous "other products" category. The composition of these residual categories is assumed to be invariant under product price changes (see the "Fixed Coefficient" allocations in Figure 2.1). These three "other products" categories constitute the first "composite commodities" distinguished in the model. The others involve the wool-sheep mix in the Pastoral Zone in which mutton is essentially a by-product, and the product mix in the Milk Cattle and Pigs industry, which is assumed to produce the commodity "milk cattle and pigs" and the commodity "meat cattle" in fixed proportions. Details of the composite commodities produced by each industry are given in Tables 2.1 and 2.2.

Because every equation in ORANI is written in linear percentage-change form, the functions g^{lj} of equation (2.1) appear in the model as:

$$\text{(2.2a)} \quad y_{(ir)j} = y_{(r)j} \qquad (i=1,\ldots,U(r);\ r=1,\ldots,N(j);\ j=1,\ldots,8),$$

$$\text{(2.2b)} \quad y_{(r)j} = z_j + \Phi_{(r)j}\left(p_{(r)j} - \sum_{q=1}^{N(j)} R^*_{(q)j}\, p_{(q)j}\right) \qquad (r=1,\ldots,N(j);\ j=1,\ldots,8),$$

in which:

$$\text{(2.2c)} \quad \Phi_{(r)j} \geq 0 \qquad (r=1,\ldots,N(j);\ j=1,\ldots,8),$$

and where $y_{(ir)j}$ and $y_{(r)j}$ respectively are the percentage changes in the output levels by industry j of individual commodity i and composite commodity r to which i uniquely belongs within j, and $p_{(r)j}$ is the percentage change in the price index for composite commodity r produced by industry j. In equation (2.2b), z_j is the percentage change in the activity level of industry j, $\Phi_{(r)j}$ is a transformation parameter reflecting the ease of transformability of other composite commodites produced in industry j into composite commodity r, and $R^*_{(q)j}$ is a parameter reflecting the share of composite commodity q in total revenue of industry j. (The use of lower-case letters to identify percentage-change variables is a convention adopted throughout this paper.)

The percentage change in $p_{(r)j}$ is defined as a weighted average of the percentage changes in the component commodity prices, *i.e.:*

$$\text{(2.3)} \quad p_{(r)j} = \sum_{t=1}^{U(r)} H_{(tr)j}\, p_t \qquad (r=1,\ldots,N(j);\ j=1,\ldots,8),$$

where the weight $H_{(tr)j}$ is the share of individual commodity t in the total value of output of composite commodity r produced by industry j. $R^*_{(q)j}$ is related to the transformation parameters $\{\Phi_{(r)j}\}$ and the shares $\{R_{(s)j}\}$ of composite commodities in j's total revenue, by:

$$\text{(2.4)} \quad R^*_{(q)j} = \Phi_{(q)j}\, R_{(q)j} \Big/ \left(\sum_{s=1}^{N(j)} \Phi_{(s)j}\, R_{(s)j}\right) \qquad (q=1,\ldots,N(j);\ j=1,\ldots,8).$$

6. Note that the notation used in equation (2.1) must be carefully distinguished from the notation used in the remainder of this paper. The derivation of equation (2.1) is described fully in Dixon, Parmenter, Powell and Vincent (1983). The Z_j variable reflects j's overall capacity to produce — "more inputs yield a higher Z_j and a higher Z_j corresponds to an expanded production possibilities set" (Dixon, Parmenter, Sutton and Vincent 1982, p.22).

7. CRETH transformation frontiers were first introduced by Dixon, Vincent and Powell (1976). The CRETH function extends Powell and Gruen's (1968) CET (constant elasticity of transformation) specification, in the same way as Hanoch's (1971) CRESH (constant ratio of substitution, homothetic) extends the CES (constant elasticity of substitution) utility function. That is, under CET, all pairwise transformation elasticities have a common value; whereas under CRETH, this restriction is relaxed.

Table 2.1: Agricultural Industries and Composite Commodities in ORANI

j	Industry	Number of composite commodities (N(j))	List of composite commodities for industry j[a]
1	Pastoral Zone	3	(r=1) wool + sheep; (r=2) other products; (r=3) meat cattle
2	Wheat-Sheep Zone	6	(r=1) other products; (r=2) wool; (r=3) sheep; (r=4) wheat; (r=5) barley; (r=6) meat cattle
3	High Rainfall Zone	4	(r=1) other products; (r=2) wool; (r=3) sheep; (r=4) meat cattle
4	Northern Beef	1	(r=1) meat cattle
5	Milk Cattle and Pigs	1	(r=1) meat cattle + milk cattle and pigs
6	OFE	1	(r=1) ofe
7	OFM	1	(r=1) ofm
8	Poultry	1	(r=1) poultry

(a) The symbol ofe is used to denote the commodity other farming (sugar cane, fruit and nuts). Similarly ofm denotes the commodity other farming (vegetables, cotton, oilseeds and tobacco).

Table 2.2: Components of Composite Commodities

(j,r)	Industry (j)/composite (r)[(a)]	Number of Individual commodities (U(r))	List of individual commodities in composite r[(a)]
(1,1)	Pastoral Zone/wool + sheep	2	(i=1) wool; (i=2) sheep
(1,2)	Pastoral Zone/other products	6	(i=1) wheat; (i=2) barley; (i=3) other cereal grains; (i=4) milk cattle and pigs; (i=5) ofe; (i=6) ofm
(1,3)	Pastoral Zone/meat cattle	1	(i=1) meat cattle
(2,1)	Wheat-Sheep Zone/other products	4	(i=1) other cereal grains; (i=2) milk cattle and pigs; (i=3) ofe; (i=4) ofm
(2,2)	Wheat-Sheep Zone/wool	1	(i=1) wool
(2,3)	Wheat-Sheep Zone/sheep	1	(i=1) sheep
(2,4)	Wheat-Sheep Zone/wheat	1	(i=1) wheat
(2,5)	Wheat-Sheep Zone/barley	1	(i=1) barley
(2,6)	Wheat-Sheep Zone/meat cattle	1	(i=1) meat cattle
(3,1)	High Rainfall Zone/other products	6	(i=1) wheat; (i=2)barley; (i=3) other cereal grains; (i=4) milk cattle and pigs; (i=5) ofe; (i=6) ofm
(3,2)	High Rainfall Zone/wool	1	(i=1) wool
(3,3)	High Rainfall Zone/sheep	1	(i=1) sheep
(3,4)	High Rainfall Zone/meat cattle	1	(i=1) meat cattle
(4,1)	Northern Beef/meat cattle	1	(i=1) meat cattle
(5,1)	Milk Cattle and Pigs/ meat cattle + milk cattle and pigs	2	(i=1) meat cattle; (i=2) meat cattle and pigs
(6,1)	OFE/ofe	1	(i=1) ofe
(7,1)	OFM/ofm	1	(i=1) ofm
(8,1)	Poultry/poultry	1	(i=1) poultry

(a) The symbol ofe is used to denote the commodity other farming (sugar cane, fruit and nuts). Similarly ofm denotes the commodity other farming (vegetables, cotton, oilseeds and tobacco).

For industry j, the number of composite commodities, N(j), and the number of individual commodities comprising each composite, U(r)(r = 1,...,N(j)), are given in Tables 2.1 and 2.2.

3. Own and Cross Price Elasticities of Agricultural Commodity Supply in ORANI

In ORANI, the change in output of an agricultural commodity arising from a change in a relative output commodity price can be conveniently separated into two components. The first results from movements around the CRETH transformation frontiers of each agricultural industry producing that commodity (denoted the transformation effect), and the second from the movement of the frontiers themselves (denoted the expansion effect). The nature and direction of both effects are illustrated in Figure 3.1.

In Figure 3.1, the curve $T(Z_0)$ represents a transformation frontier for a single hypothetical industry which produces two commodities. The production of commodity 1 is identified as Y_1, while the production of commodity 2 is identified as Y_2. The position and shape of the curve are dependent respectively on the value for Z (the industry's generalised capacity to produce, a concept introduced in equation (2.1)), and the particular production technology employed by the industry. An increase in Z causes an outward movement in the transformation frontier, while a decrease causes an inward movement. We assume that the shape of this frontier is formed from a CRETH-like homothetic production function (which imposes the restriction that the transformation frontier shifts out in a product-neutral way). The straight line $P(R_0)$ is the gross revenue line for given prices of commodities 1 and 2 (respectively denoted by P_1 and P_2) and level of gross revenue (denoted by R).

The bundle of commodities (denoted $A(a_1, a_2)$) which maximises the representative firm's revenue, for given levels of inputs and input prices, is given as the point of tangency between $T(Z_0)$ and $P(R_0)$, *i.e.* where:

$$(3.1) \quad MRT_{12} = \frac{P_2}{P_1} ,$$

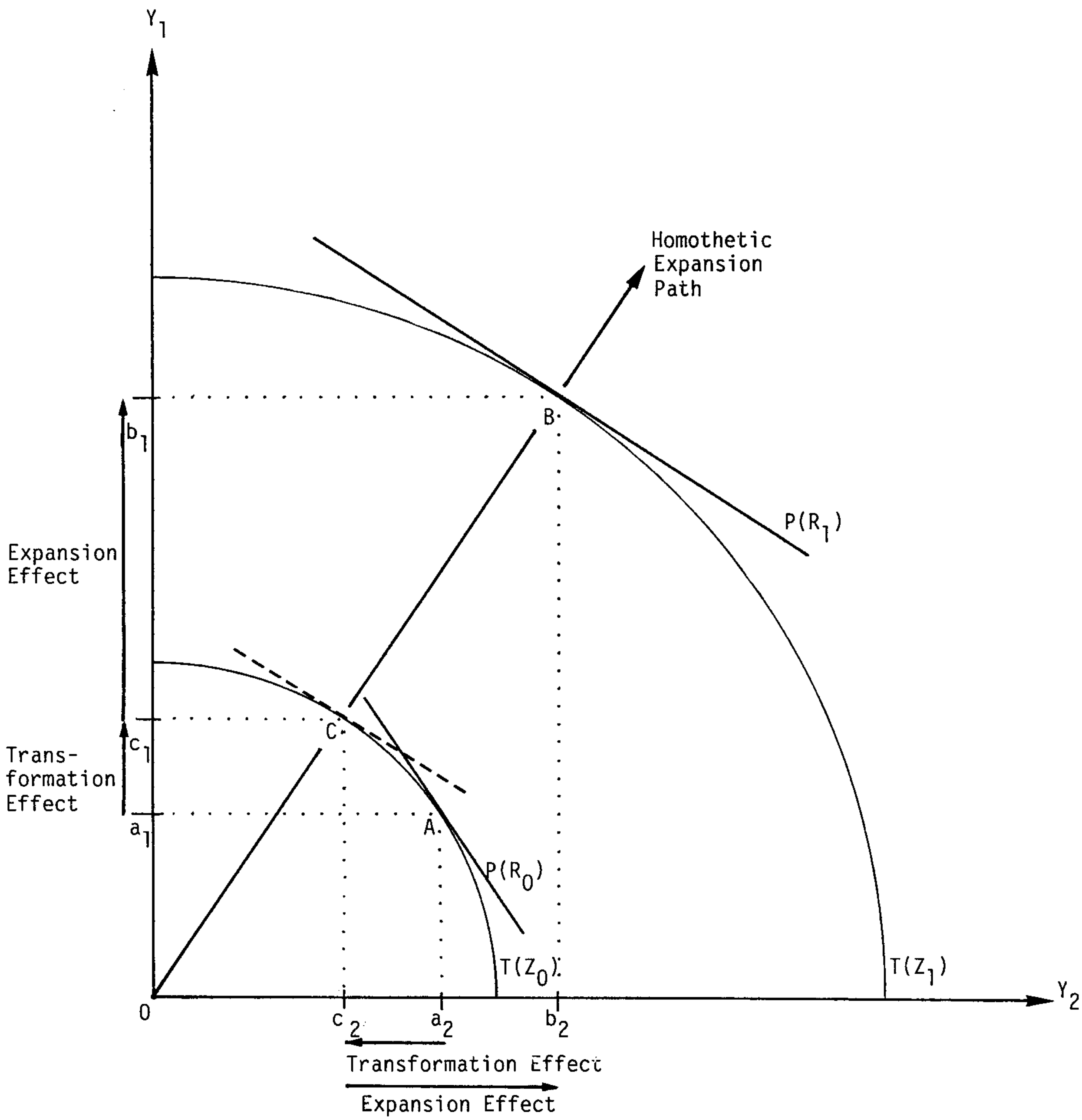
in which MRT_{12} denotes the marginal rate of transformation between commodities 1 and 2.

The industry's response to an increase in the price of (say) commodity 1, with all input prices and the price of commodity 2 held constant, is encapsulated in Figure 3.1. As depicted, the change in price causes the gross revenue line to rotate from $P(R_0)$ to $P(R_1)$. The consequent change in industry profitability (and input application) is reflected as an expansion of the production frontier from $T(Z_0)$ to $T(Z_1)$. In Figure 3.1 the new desired output combination is represented by the point $B(b_1, b_2)$ showing that the production of both commodities has increased as a result of the change in P_1. The "own" transformation effect associated with this *ceteris paribus* increase in P_1 is illustrated as a change in Y_1 from a_1 to the point c_1. This change reflects the increase in production of commodity 1 induced by the increase in P_1 with the industry, by accepting a reduction in revenue, forced to remain on $T(Z_0)$. In contrast the "own" expansion effect, which is depicted as the change in Y_1 from c_1 to b_1, is the effect of the increase in Z alone, while holding the ratio of prices, P_1/P_2, at its new value. The corresponding "cross" transformation and expansion effects measure the change in production of commodity 2 depicted by the movements a_2 to c_2 and c_2 to b_2, respectively.

For short-run simulations of ORANI, the change in production of a particular agricultural commodity arising from a change in a relative agricultural product price can be measured as an elasticity. Similarly, the transformation and expansion components of the change in overall output can also be expressed as elasticities. Formulae for these elasticities are derived below.

Before deriving the relevant formulae we must first remedy a weakness in our current notation. In any given agricultural industry j, an individual commodity is produced via at most *one* composite commodity r. For instance when j = 1 (the Pastoral Zone), the only value permissible for r when considering the individual commodity wool is one, indicating the Pastoral Zone specific composite whose components are the individual commodities "wool" and "sheep" (see Tables 2.1 and 2.2). It is therefore desirable (and often necessary) to have a notation that excludes the subscript r. To achieve this objective we can devise five new symbols which are adopted as convention where appropriate:

Figure 3.1: The Transformation and Expansion Effects of a Change in a Relative Commodity Price



$$\phi_j^{(i)} = \{\phi_{(r)j} : i \varepsilon r\} \quad (j=1,\ldots,\sigma),$$

$$H_j^{(i)} = \{H_{(ir)j} : i \varepsilon r\} \quad (j=1,\ldots,8),$$

$$H_{(i)j}^{(t)} = \{H_{(tr)j} : i \varepsilon r\} \quad (j=1,\ldots,8),$$

$$R_j^{*(i)} = \{R_{(r)j}^{*} : i \varepsilon r\} \quad (j=1,\ldots,8),$$

and

$$Y_j^{(i)} = \{Y_{(ir)j} : i \varepsilon r\} \quad (j=1,\ldots,8).$$

These five symbols may be explained as follows:

i) $\Phi_j^{(i)}$ is the CRETH transformation parameter pertaining to the composite commodity r, produced by industry j, to which individual commodity i uniquely belongs within j;

ii) $H_j^{(i)}$ is the share of individual commodity i produced by industry j, within the total value of the composite commodity r to which i uniquely belongs within j;

iii) $H_{(i)j}^{(t)}$ is the share of individual commodity t within the composite commodity r produced by industry j, to which individual commodity i uniquely belongs within j;

iv) $R_j^{*(i)}$ is the modified share for the composite commodity r produced by industry j which uniquely contains individual commodity i within j; and

v) $Y_j^{(i)}$ is the output of individual commodity i produced by industry j.

In ORANI, the total production of agricultural commodity i, Y_i, can be written in percentage change form as:

$$(3.2) \quad y_i = \sum_{j=1}^{8} S_{(i)j}\, y_j^{(i)} \qquad (i=1,\ldots,10),$$

where $S_{(i)j}$ is the base-period share contributed by industry j to the total production of individual commodity i.

Substitution of (2.2b) and (2.3) into (3.2) yields (after appropriate changes in notation):

$$(3.3) \quad y_i = \sum_{j=1}^{8} S_{(i)j}\{z_j + \phi_j^{(i)}(\sum_s H_{(i)j}^{(s)} p_s - \sum_{q=1}^{N(j)} R_{(q)j}^{*} \sum_{t=1}^{U(q)} H_{(tq)j}\, p_t)\} \qquad (i=1,\ldots,10).$$

Our next step is the elimination of z_j for all j from equation (3.3). This is done using the following expression for short-run industry supply in ORANI:[8]

$$(3.4) \quad z_j = \frac{\sigma(1 - S_{Kj})}{S_{Kj}}\{p_{0j}/S_{Vj} - p_{Mj}(\frac{1}{S_{Vj}} - 1) - p_{\ell j}\} \qquad (j=1,\ldots,8),$$

where:

- σ is the constant elasticity of substitution between primary factors of production;[9]
- S_{Kj} is the fixed factor (land and fixed capital) share in industry j's total primary factor costs;
- p_{Oj} is the percentage change in the basic price of j's output;
- p_{Mj} is the average percentage change in the prices paid by industry j for intermediate inputs;
- S_{Vj} is the share of primary inputs in j's total costs; and
- p_{lj} is the percentage change in the money wage rate.

According to equation (3.4), the greater is the base-period share of fixed factors in total primary factor inputs, the less responsive is that industry to a change in the average price received for its production.

For each of the eight agricultural industries, it can be shown that:

8. A full derivation of equation (3.4), which first appeared in Dixon, Parmenter, Sutton and Vincent (1982, p.309), is given in Higgs (1986, pp.240–253).

9. Reasons for abandoning the CRESH input specification (as illustrated in figure 2.1) in favour of the more restrictive CES specification are discussed in Dixon, Parmenter, Sutton and Vincent (1982, p.189). The value for σ is set at 0.5 for all industries in short-run simulations. The choice of 0.5 was based on a survey and review of the empirical literature by Caddy (1976).

$$(3.5) \quad p_{0j} = \sum_{q=1}^{N(j)} R_{(q)j} \sum_{t=1}^{U(q)} H_{(tq)j}\, p_t \qquad (j=1,\ldots,8),$$

and that:

$$(3.6) \quad p_{Mj} = \sum_{n=1}^{G} S^{M}_{(n)j}\, p_n \qquad (j=1,\ldots,8),$$

where G is the total number of commodities in the model unidentified by source; $S^{M}_{(n)j}$ is the share of effective units of commodity n in the total cost of intermediate inputs to the current production of industry j; and P_n is the price paid by j for an effective unit of input n.[10]

Substitution of equations (3.4), (3.5) and (3.6) into equation (3.3) yields:

$$(3.7) \quad y_i = \sum_{j=1}^{8} S_{(i)j} \left\{\frac{\sigma(1-S_{Kj})}{S_{Kj}} \left(\sum_{q=1}^{N(j)} R_{(q)j} \sum_{t=1}^{U(q)} H_{(tq)j}\, p_t\right)/S_{Vj}\right\} - \sum_{j=1}^{8} S_{(i)j} \left\{\frac{\sigma(1-S_{Kj})}{S_{Kj}} \left(\sum_{n=1}^{G} S^{M}_{(n)j}\, p_n \left(\frac{1}{S_{Vj}} -1\right) - p_{\ell j}\right)\right\} + \sum_{j=1}^{8} S_{(i)j}\, \phi_j^{(i)} \left[\sum_s H^{(s)}_{(i)j}\, p_s - \sum_{q=1}^{N(j)} R^{*}_{(q)j} \sum_{t=1}^{U(q)} H_{(tq)j}\, p_t\right] \qquad (i=1,\ldots,10).$$

To derive an expression for the supply elasticity of agricultural commodity i with respect to the price of agricultural commodity t, $\eta_{i,t}$, we set $p_t = 1$ for the one value of t on the right of equation (3.7), and $p_{t^*} = 0$, for all other values $(t^* \neq t)$. Under these constraints the term contained with square brackets reduces to:

$$H_j^{(t)} \left(\delta_{i,t,j} - R_j^{*(t)}\right),$$

where $\delta_{i,t,j}$ is unity when individual commodities i and t are both contained within the same composite commodity in industry j, and is zero otherwise. Similarly,

$$\sum_{q=1}^{N(j)} R_{(q)j} \sum_{t=1}^{U(q)} H_{(tq)j}\, p_t$$

becomes

$$R_j^{(t)}\, H_j^{(t)}$$

and

$$\sum_{n=1}^{G} S^{M}_{(n)j}\, p_n$$

becomes

$$S^{M}_{(t)j}.$$

Thus

$$(3.8) \quad \eta_{i,t} = \sum_{j=1}^{8} S_{(i)j} \left\{\frac{\sigma(1-S_{Kj})}{S_{Kj}} \left(R_j^{(t)} H_j^{(t)} / S_{Vj} - S^{M}_{(t)j} \left(\frac{1}{S_{Vj}} - 1\right)\right)\right\} + \sum_{j=1}^{8} S_{(i)j}\, \phi_j^{(i)}\, H_j^{(t)} \left(\delta_{i,t,j} - R_j^{*(t)}\right) \qquad (i,t=1,\ldots,10).$$

From equation (3.3), one can deduce that the transformation component of the supply elasticity of commodity i with respect to the price of commodity t, $\eta^{T}_{i,t}$, is:

$$(3.9) \quad \eta^{T}_{i,t} = \sum_{j=1}^{8} S_{(i)j}\, \phi_j^{(i)}\, H_j^{(t)} \left(\delta_{i,t,j} - R_j^{*(t)}\right) \qquad (i,t=1,\ldots,10).$$[11]

10. An "effective unit" of a commodity is a CES aggregation of local and imported commodites bearing the same name.

11. Equation (3.9) is derived by setting $z_j = 0$ for all j and $p_t = 1$ for one value of t on the right of equation (3.3) and $p_{t^*} = 0$ for all other values $(t^* \neq y)$. Thompson (1982) derived a similar expression for $\eta^{T}_{i,t}$. However, her analysis was only concerned with own-price elasticities (*i.e.* the case where i = t).

Finally, the expansion component, $\eta^E_{i,t}$, can be found by setting:

$$\eta^E_{i,t} = \eta_{i,t} - \eta^T_{i,t} \qquad (i,t=1,\ldots,10), \tag{3.10}$$

that is:

$$\eta^E_{i,t} = \sum_{j=1}^{8} S_{(i)j} \left\{ \frac{\sigma(1-S_{Kj})}{S_{Kj}} \left(R_j^{(t)} H_j^{(t)}/S_{Vj} - S^M_{(t)j} \left(\frac{1}{S_{Vj}} - 1 \right) \right) \right\} \qquad (i,t=1,\ldots,10). \tag{3.11}$$

Even though own price elasticities calculated according to equation (3.9) are constrained to be positive, there is no negativity constraint on the cross price elasticities as is the case at the composite commodity level. Consider, for a particular industry, a *ceteris paribus* increase in the price of one individual commodity, and therefore in the CRETH modified price (equation 2.3) of the composite commodity containing that individual commodity. This price increase will lead to an increase in the production of that composite commodity and therefore to all individual commodities contained therein. Take, for example, a *ceteris paribus* unit increase in the price of the individual commodity wool. Via the process outlined above, an increase in production by the Pastoral Zone of both wool and sheep occurs. On the other hand, since sheep and wool occur in different composites in each of the High Rainfall and Wheat-Sheep Zones, the unit increase in the price of wool leads to declines in the output of sheep in these two industries. Depending on the values for the parameters $S_{(i)j}$, $\Phi_j^{(i)}$, $H_j^{(t)}$ and $R_j^{*(t)}$, (for j = 1, 2, 3, i = 2 and t = 1), an overall increase in the production of sheep may eventuate, thus implying that $\eta^T_{2,1}$ is positive.

The elasticities obtained from equations (3.8), (3.9) and (3.11) refer to percentage changes in *planned* commodity outputs in response to *expected* price changes. In constructing the ORANI data base, the output of agricultural industries has been defined as the sum of cash receipts from the sale of agricultural commodities plus the market value of changes in inventories. Changes in the value of inventories are included because:

> . . . the farmer has considerable flexibility over the stage at which products are marketed. For example livestock can be withheld from the market if seasonal conditions are favourable. Such strategies involve changes in inventories which must be accounted for somewhere. Rather than modify the structure of the livestock supply equations to reflect inventory behaviour, we have defined the decision variable to represent output whether actually sold or in the form of a change in inventories. (Vincent, Dixon and Powell 1980, p.232)

Planned outputs may differ from actual outputs due to climatic factors such as drought. Furthermore, setting p_t to x represents, in the mind of the producer, a *permanent* increase of x per cent in the expected price of commodity t. Therefore, the total supply elasticity, $\eta_{i,t}$, though constrained by the short-run assumption of a constant stock of fixed capital, may be greater than would be the case if x were considered to be only a transitory price change.

4. Values of Supply Elasticities Implied by the 1968–69, 1977–78 and "Typical Year" ORANI Data Bases

The ORANI data base is organised into two essentially independent files. The larger of these contains input-output data and provides the basis for computing all cost and revenue shares. This file has been regularly updated since the original 1968–69 data became available. The latest data, reflecting the year 1977–78, were introduced in 1984 (see Blampied 1985). The smaller file contains values for miscellaneous parameters (such as CES substitution elasticities) that have, where possible, been estimated econometrically, and which are updated less frequently than the input/output data.

Values of $\eta^T_{i,t}$ and $\eta^E_{i,t}$ for selected commodities as implied by ORANI's 1968–69 and 1977–78 data bases are presented in Table 4.1. As shown, the sensitivity of the expansion components to the data base employed is significantly greater than the sensitivity of the corresponding transformation components (see for example the expansion and transformation components of the own price elasticities for wool, wheat and meat cattle). The relatively insensitive behaviour exhibited by the transformation components is a result of the extensive use of sales share data in their derivation. Of the parameters appearing in equation (3.9), two ($\Phi_j^{(i)}$ and $\delta_{i,t,j}$) are relatively invariant to changes in the ORANI data base. The remaining three parameters ($S_{(i)j}$, $H_j^{(t)}$ and $R_j^{*(t)}$) are shares formed from a section of the Input/Output data file (known as the Make Matrix) which contains the commodity composition of the output of each agricultural industry. Shares of each com-

Table 4.1: Transformation and Expansion Components of Selected Own and Cross Price Elasticities of Supply in ORANI as implied by the 1968–69 and 1977–78 ORANI Data Bases(a)

Response in the planned output of commodity i		Commodity t whose expected price changes									
		1968-69 data base					1977-78 data base				
		wool	sheep	wheat	meat cattle	milk cattle and pigs	wool	sheep	wheat	meat cattle	milk cattle and pigs
wool	T	0.1557	0.0004	-0.1055	-0.0141	-0.0108	0.1603	0.0002	-0.0848	-0.0197	-0.0060
	E	0.1695	0.0467	0.0630	0.0681	0.0150	0.7894	0.3145	0.3550	0.5112	0.0352
sheep	T	0.0015	0.1572	-0.0987	-0.0137	-0.0150	0.0005	0.1565	-0.0717	-0.0191	-0.0074
	E	0.1583	0.0450	0.0706	0.0652	0.0152	0.7530	0.3145	0.3590	0.5004	0.0384
wheat	T	-0.1308	-0.0361	0.4838	-0.1307	-0.0525	-0.1229	-0.0434	0.7476	-0.2324	-0.0441
	E	0.0816	0.0269	0.1139	0.0405	0.0116	0.5426	0.2286	0.6238	0.3100	0.0415
meat cattle	T	-0.0200	-0.0058	-0.1494	0.2697	-0.0289	-0.0190	-0.0077	-0.1551	0.3192	-0.0126
	E	0.0965	0.0273	0.0304	0.1355	0.0697	0.4943	0.2021	0.1842	0.8576	0.1851
milk cattle and pigs	T	-0.0174	-0.0071	-0.0681	-0.0329	0.0418	-0.0088	-0.0045	-0.0442	-0.0189	0.0107
	E	0.0243	0.0073	0.0077	0.0800	0.2253	0.0517	0.0236	0.0171	0.2794	1.2880

(a) Reading across each row, the first number in each column refers to the transformation component of the elasticity of the commodity identified by that row with respect to the price of the commodity identified by that column. The second number in the column is the corresponding expansion component.

Table 4.2: The Share of Individual Commodity i in the Total Production of Each Zonal Multi-product Industry, Computed from the 1968–69 and 1977–78 ORANI Data Bases

ORANI industry	Data base	The share in total industry production of commodity									
		wool	sheep	wheat	barley	other grains	meat cattle	milk cattle and pigs	ofe	ofm	poultry
Pastoral Zone	1968-69	0.6177	0.1268	0.0957	0.0008	0.0055	0.1369	0.0000	0.0000	0.0166	0.0000
	1977-78	0.4591	0.1221	0.1279	0.0077	0.0325	0.2445	0.0000	0.0062	0.0000	0.0000
Wheat-Sheep Zone	1968-69	0.2514	0.0883	0.4432	0.0330	0.0457	0.0882	0.0296	0.0099	0.0107	0.0000
	1977-78	0.2232	0.1016	0.3132	0.0793	0.0982	0.1283	0.0213	0.0127	0.0222	0.0000
High Rainfall Zone	1968-69	0.4627	0.1311	0.0314	0.0121	0.0230	0.2292	0.0553	0.0552	0.0000	0.0000
	1977-78	0.3779	0.1729	0.0085	0.0133	0.0525	0.2936	0.0172	0.0046	0.0595	0.0000

Source: 1968-69 and 1977-78 ORANI Data Bases.

modity in the total value of production of each zonal multi-product industry, computed from the two historical data bases, are given in Table 4.2. From this table it is clear that, with few exceptions, the value of each share differs only moderately between the data bases. It is this relative stability that constrains the sensitivity of $\eta^T_{i,t}$ for all i and t.

To explain the volatile behaviour of the expansion components to changes in the data base, we refer to a revised form of equation (3.11) which omits the term $S^M_{(i)j}(1/S_{Vj} - 1)$ on the basis that, regardless of which data base is employed, $S^M_{(i)j}$ is very close to zero for all t. That is, we adopted the simplification:

$$(4.1) \quad \eta^E_{i,t} = \sum_{j=1}^{8} S_{(i)j} \left\{ \frac{\sigma(1-S_{Kj})}{S_{Kj}} R_j^{(t)} H_j^{(t)} / S_{Vj} \right\} \quad (i,t=1,\ldots,10).$$

As previously explained, the production shares $S_{(i)j}$, $R_j^{(t)}$ and $H_j^{(t)}$ are relatively invariant to changes in the Input/Output data file. The primary factor share S_{Vj}, with the exception of the Northern Beef and Milk Cattle and Pigs industries, also exhibits little variation across data bases (see Table 4.3). Therefore, the significant element in the sensitivity of $\eta^E_{i,t}$ is the fluctuation in the ratio of the share of variable factors to the share of fixed factors $[(1-S_{Kj})/S_{Kj}]$, the volatility of which is demonstrated in Table 4.4. This ratio varies inversely with the Gross Operating Surplus (GOS) of the industry (see Adams and Higgs 1983). GOS is the excess of output of the industry over costs incurred in producing that output, but before deducting depreciation provisions, dividends, interest, royalties and land rent payments and direct taxes payable (see Australian Bureau Statistics 1981, p.192). Thus, GOS represents a measure of the sum of returns to owners of land, fixed capital and working capital employed in the

Table 4.3: The Share of Primary Inputs in the Total Inputs to Current Production of Industry j, Computed from the 1968–69 and 1977–78 ORANI Data Bases

ORANI industry	Shares of primary inputs in total costs ($S_V(j)$)	
	1968-69	1977-78
Pastoral Zone	0.562	0.543
Wheat-Sheep Zone	0.641	0.543
High Rainfall Zone	0.566	0.539
Northern Beef	0.664	0.433
Milk Cattle and Pigs	0.608	0.474
OFE	0.587	0.601
OFM	0.587(a)	0.601(a)
Poultry	0.219	0.324

(a) This share has been constrained to that of the OFE industry.

Source: 1968-69 and 1977-78 ORANI Data Bases.

Table 4.4: The Ratio of the Share of Variable Factors in Total Primary Inputs to the Share of Fixed Factors in Total Primary Inputs, Computed from the 1968–69 and 1977–78 ORANI Data Bases

ORANI industry	The ratio of variable to fixed factors(a)	
	1968-69	1977-78
Pastoral Zone	0.4817	2.7793
Wheat-Sheep Zone	0.3589	2.3322
High Rainfall Zone	0.6644	2.7327
Northern Beef	0.4153	1.6028
Milk Cattle and Pigs	0.4200	1.5927
OFE	0.7612	1.2205
OFM	0.4287	1.2198
Poultry	1.2205	1.5654

(a) Fixed factors here are defined to include only Land and Fixed Capital. As elsewhere in this paper, Owner Operators' labour has been treated as a variable factor.

Source: 1968-69 and 1977-78 ORANI Data Bases.

industry, and the return to the Owner-Operator for entrepreneurial input.

Thus, according to equation (4.1), η^{E}_{it} for all i and t is inversely related to the degree of agricultural sector profitability reflected in the Input/Output data file.

To summarise our findings so far: estimates of short-run supply elasticities of agricultural commodities implied by ORANI are sensitive to changes in the model's data base. This sensitivity is largely a result of movements in the ratio, $(1-S_{Kj})/S_{Kj}$, which in turn is inversely related to the data base estimate of industry j's GOS.

To isolate our estimates of short-run supply elasticities from the volatile nature of agricultural profitability, we have constructed, for the agricultural sector, an artificial Input/Output data file designed to capture the sector in an average or "typical" year. Each of its elements is an average of values over the 13 year period 1967–68 to 1979–80 (for comprehensive details see Adams 1984). Higgs (1985) has incorporated these data into the current 1977–78 Input-Output data file. Transformation and expansion components of short-run own and cross price elasticities of agricultural commodity supply as implied by the typical year enhanced 1977–78 data base are presented in Table 4.5. These are our preferred estimates.

5. Concluding Remarks

It has been shown above that agricultural industries' supply elasticities in the ORANI model are very sensitive to the particular data base employed in preparing simulations. The main cause of this volatility is year-to-year variation in profitability in agriculture. Most of the ORANI policy simulations reported in the literature have been based on the 1968–69 data

Table 4.5: Transformation and Expansion Components of Own and Cross Price Elasticities of Supply in ORANI as Implied by the "Typical Year" Enhanced 1977–78 Data Base(a)

Response in the planned output of commodity i		Commodity t whose expected price changes									
		wool	sheep	wheat	barley	other grains	meat cattle	milk cattle and pigs	ofe	ofm	poultry
wool	T	0.1548	-0.0018	-0.0947	-0.0086	-0.0147	-0.0149	-0.0075	-0.0010	-0.0115	0.0000
	E	0.3043	0.1064	0.0879	0.0201	0.0216	0.1086	0.0124	-0.0003	0.0095	-0.0000
sheep	T	-0.0048	0.1607	-0.0870	-0.0094	-0.0183	-0.0141	-0.0096	-0.0017	-0.0157	0.0000
	E	0.2775	0.1075	0.0977	0.0220	0.0240	0.1060	0.0140	-0.0002	0.0093	-0.0000
wheat	T	-0.1552	-0.0547	0.5660	-0.0443	-0.0975	-0.1435	-0.0536	-0.0017	-0.0155	0.0000
	E	0.1747	0.0735	0.1748	0.0314	0.0241	0.0577	0.0139	-0.0008	0.0022	-0.0000
barley	T	-0.0734	-0.0309	-0.2310	0.4404	-0.0057	-0.1271	-0.0047	0.0028	0.0296	0.0000
	E	0.1959	0.0815	0.1579	0.0294	0.0243	0.0686	0.0141	-0.0006	0.0038	-0.0000
other grains	T	-0.1372	-0.0656	-0.5558	-0.0062	0.4807	-0.1980	0.2551	0.0192	0.2079	0.0000
	E	0.2270	0.0958	0.1305	0.0264	0.0253	0.0872	0.0147	-0.0004	0.0067	-0.0000
meat cattle	T	-0.0279	-0.0102	-0.1645	-0.0279	-0.0398	0.3451	-0.0189	-0.0045	-0.0513	0.0000
	E	0.2039	0.0763	0.0486	0.0121	0.0145	0.2567	0.0836	-0.0020	-0.0019	-0.0000
milk cattle and pigs	T	-0.0115	-0.0056	-0.0501	-0.0008	0.0418	-0.0154	0.0223	0.0017	0.0177	0.0000
	E	0.0191	0.0082	-0.0244	-0.0044	-0.0068	0.0684	0.9465	-0.0111	-0.0581	-0.0000
ofe	T	-0.0012	-0.0008	-0.0013	0.0004	0.0025	-0.0028	0.0013	0.0002	0.0018	0.0000
	E	0.0026	0.0010	-0.0098	-0.0002	-0.0053	0.0011	0.0001	1.5960	-0.0274	-0.0000
ofm	T	-0.0182	-0.0095	-0.0149	0.0054	0.0351	-0.0431	0.0182	0.0023	0.0245	0.0000
	E	0.0343	0.0130	-0.0127	0.0013	-0.0083	0.0134	0.0015	-0.0653	2.6110	-0.0000
poultry	T	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	E	-0.0000	-0.0000	-0.1823	-0.0341	-0.0587	-0.0000	-0.0000	-0.0000	-0.0000	2.9540

(a) Reading across each row, the first number in each column refers to the transformation component of the elasticity of the commodity identified by that row with respect to the price of the commodity identified by that column. The second number in the column is the corresponding expansion component.

base. Recently, however, the 1977–78 data base has been used. It appears that the advantages flowing from the more recent vintage of the latter data may be offset by the atypical nature of that year's set of Input/Output accounts for agriculture. The appropriate procedure, then, is to construct synthetic agricultural data for a "typical year". These data have been used to generate the "preferred" ORANI supply elasticity estimates for agricultural commodities tabulated in Table 4.5.

The effect on ORANI as a whole of using the typical agricultural data set is examined in Adams and Higgs (1986). Their approach is to compare the results from the model of a 25 per cent across-the-board tariff cut simulation computed with the non-typical and the typical 1977–78 data bases. They conclude that the output response of the agricultural industries to a tariff cut computed with the two data bases is significantly different; while the output response of the non-agricultural industries is in general very similar. Out of 104 non-agricultural industries, only 8 exhibit differences between their output projections computed with the two data bases of greater than 0.20 percentage points.

References

Adams, P. D. (1984), "The Typical Year Data Base for the Agricultural Sector of ORANI 78", IMPACT *Preliminary Working Paper* No. OP-45, IMPACT Research Centre, University of Melbourne.

Adams, P. D. and Higgs, P. J. (1983), "The Disaggregation of Gross Surplus for the Agricultural Sector of ORANI", IMPACT *Preliminary Working Paper* No. OP-40, IMPACT Research Centre, University of Melbourne.

Adams, P. D. and Higgs, P. J. (1986), "Calibration of Computable General Equilibrium Models from Synthetic Benchmark Equilibrium Data Sets", IMPACT *Preliminary Working Paper* No. OP-57, IMPACT Research Centre, University of Melbourne.

Australian Bureau of Statistics (1981), *Australian National Accounts — Concepts, Sources and Methods*, Cat. No. 5216.0.

Bureau of Agricultural Economics (1976), *The Australian Sheep Industry Survey: 1970–71 to 1972–73*, Australian Government Publishing Service, Canberra.

Bureau of Agricultural Economics (1987), "Statistics", *Quarterly Review of the Rural Economy* 9(1), 104–23.

Blampied, C. W. (1985), "A Listing of the 1977–78 Balanced ORANI Data Base with the Typical-Year Agricultural Sector Implemented", IMPACT Research Memorandum, IMPACT Research Centre, University of Melbourne (Archive No. OA-262).

Caddy, V. (1976), "Empirical Estimation of the Elasticity of Substitution: A Review", IMPACT *Preliminary Working Paper* No. OP-09, IMPACT Research Centre, University of Melbourne.

Cooper, R. J. (1983), "A Tariff Experiment on the Interfaced ORANI-MACRO System", IMPACT *Preliminary Working Paper* No. IP-17, IMPACT Research Centre, University of Melbourne.

Cooper, R. J., McLaren, K. R. and Powell, A. A. (1985), "Short-Run Macroeconomic Closure in Applied General Equilibrium Modelling: Experience from ORANI and Agenda for Further Research", in J. Piggott and J. Whalley (eds), *New Developments in Applied General Equilibrium Analysis*, Cambridge University Press.

Dixon, P. B., Parmenter, B. R. and Powell, A. A. (1982), "Farm Incomes and the Real Exchange Rate in Australia: Evidence from the ORANI Model", IMPACT *Working Paper* No. G-41, IMPACT Research Centre, University of Melbourne.

Dixon, P. B., Parmenter, B. R., Powell, A. A. and Vincent, D. P. (1983), "The Agricultural Sector of ORANI 78: Theory, Data and Application", in A. C. Kelley, W. C. Sanderson and J. G. Williamson (eds), *Modelling Growing Economies in Equilibrium and Disequilibrium*, Duke Press Policy Studies, Durham.

Dixon, P. B., Parmenter, B. R., Sutton, J. and Vincent, D. P. (1982), *ORANI: A Multisectoral Model of the Australian Economy*, North-Holland, Amsterdam.

Dixon, P. B., Vincent, D. P. and Powell, A. A. (1976), "Factor Demand and Product Supply Relations in Australian Agriculture: The CRESH/CRETH Production System", IMPACT *Preliminary Working Paper* No. OP-08, Impact Research Centre, University of Melbourne.

Hanoch, G. (1971), "CRESH Production Functions", *Econometrica* 39(September), 695–712.

Hasenkamp, G. (1976), *Specification and Estimation of Multiple-Output Production Functions*, Springer-Verlag, Berlin.

Higgs, P. J. (1985), "Implementation of the Adams' Typical Year for the Agricultural Sector in the ORANI 1977–78 Data Base", IMPACT *Preliminary Working Paper* No. OP-49, IMPACT Research Centre, University of Melbourne.

Higgs, P. J. (1986), *Adaptation and Survival in Australian Agriculture*, Oxford University Press.

Johansen, L. (1960), *A Multi-Sectoral Study of Economic Growth*, North-Holland, Amsterdam.

Powell, A. A. and Gruen, F. H. (1968), "The Constant Elasticity of Transformation Production Frontier and Linear Supply System", *International Economic Review* 9(3), 315–28.

Thompson, L. (1982), "Supply Elasticities for ORANI Agricultural Industries", IMPACT Research Memorandum, IMPACT Research Centre, University of Melbourne (Archive No. OA-147).

Vincent, D. P., Dixon, P. B., Parmenter, B. R. and Sams, D. C. (1980), "Implications of World Energy Price Increases on the Rural and Other Sectors of the Australian Economy", in K. M. W. Howes and R. A. Rummery (eds), *The Impact of Changes in Energy Costs on the Rural Sector of the Australian Economy*, Commonwealth Scientific and Industrial Research Organisation, Perth.

Vincent, D. P., Dixon, P. B. and Powell, A. A. (1980), "The Estimation of Supply Response in Australian Agriculture: The CRESH/CRETH Production System", *International Economic Review* 21(1), 221–42.