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FACTOR MARKET INCIDENCE OF AGRICULTURAL TRADE LIBERALIZATION: SOME ADDITIONAL RESULTS

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Liberalization of trade implies changes in producer prices, which has consequences for farm income, agricultural employment and asset values. The relative incidence of the effect of changes in prices on fixed factors depends on the relative magnitude of the Morishima elasticities of substitution in agricultural production.

The high profile which agriculture has enjoyed over the course of the Uruguay Round of the GATT negotiations has stimulated a great deal of research into the possible consequences of multilateral trade liberalization. A broad sample of this work is summarized in the recent volume edited by Goldin and Knudsen (1990). Despite this wealth of studies, there remains tremendous uncertainty about the likely consequences for world prices of individual agricultural products.[1] Consequently many policy makers have been somewhat disillusioned regarding the ability of agricultural economists to conclude much at all about the likely consequences of trade liberalization for the ultimate variables of interest, namely farm income, agricultural employment and asset values.

The analysis of agricultural trade liberalization can be partitioned into two parts. The first piece of the research puzzle pertains to the likely consequences for world commodity prices. This has been the primary emphasis of most agricultural trade modeling efforts to date and will not be considered here. Instead, the aggregate farm price level will be treated as being exogenously determined. This enables a sharp focus on the second part of the research problem: assessment of the consequences of such a price shock for farm asset returns, factor employment and farm income.

The assumption of exogenous commodity prices is only strictly appropriate for a small, open economy. However, by partitioning the research problem in this manner, a number of valuable insights may

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[1] See, for example, their summary table in chapter 17 of that volume.

be obtained in the absence of any consensus regarding the likely change in world agricultural commodity prices. Furthermore, in many cases it is possible to say something about the consequences of agricultural trade liberalization for *aggregate* farm prices in particular countries. For example, few would argue with the proposition that liberalization of OECD agricultural policies may be expected to raise the price of a representative basket of products supplied by Australian farmers. Similarly, EC farmers would be expected to see lower prices, on average, following liberalization measures.

The model used in this paper is very similar to the simple partial equilibrium model used in an earlier paper to analyze the role that technology and factor mobility play in determining the impact of reductions in agricultural subsidies (Hertel, 1989). The formal propositions in that paper refer to the long run, which is characterized by the notion that nonland inputs are in perfectly elastic supply. From a policy point of view, the short to medium run is arguably the most relevant. This paper focuses on the relative incidence of a reduction in agricultural support when multiple fixed factors are present. The type of question to be answered here may be posed as follows: Which factor will experience a greater increase in rental rates, following an increase in farm producer prices, land or capital? It will be shown that the answer to this question hinges entirely on the relative sizes of the Morishima elasticities of substitution between these two inputs.

This breakdown in the composition of a change in aggregate farm income is of interest, because the mix of factor ownership differs greatly across farms. For example, some farmers own their land, while others rent it. If the rental rate on land rises, the former group benefits, while the latter does not. Similarly some farm households are net suppliers of labor, while others rely heavily on hired help to meet their labor requirements. A change in the rental rate on farm labor affects household income of these two groups differentially.

The implications of simultaneous changes in both commodity price and acreage restrictions will be explored in further results. Variable input use will also be examined. Finally, the paper provides a convenient measure of the change in farm household welfare associated with an exogenous shock to the composite price of agricultural output will be provided in the paper.

Analytical Results

A partial equilibrium model of the farm sector

The analysis begins with the same basic partial equilibrium model outlined in Hertel (1989), only specialized to the case where there are two groups of fixed factors in the agricultural sector: land (L) and nonland (K) inputs.[2] All remaining inputs are assumed to be in perfect-

[2] Intermediate cases, where some factors are partially mobile, are easily handled. However they add no new intuition.

ly elastic supply, i.e. $dp_v/p_v = \hat{p}_v$. Also, constant returns to scale in production is assumed. The response of the farm sector to an exogenous shock in output price, $\hat{p}_o = \rho$ may be obtained by simultaneous solution of the following three equation system:

$$(1) \qquad \rho = c_L \hat{p}_L + c_K \hat{p}_K$$

$$(2) \qquad 0 = \hat{q}_L = c_L \sigma_{LL} \hat{p}_L + c_K \sigma_{LK} \hat{p}_K + \hat{q}_0$$

$$(3) \qquad 0 = \hat{q}_K = c_L \sigma_{KL} \hat{p}_L + c_K \sigma_{KK} \hat{p}_K + \hat{q}_0.$$

Equation (1) requires that receipts be exhausted on expenditures. Since the price of variable inputs is fixed, the full impact of any change in product price will be absorbed by the fixed factor rental rates, weighted by their cost shares (c_i). Equations (2) and (3) enforce the restriction that the availability of L and K is fixed. The parameters σ_{ij} are Allen partial elasticities of substitution, so that $c_j \sigma_{ij} = \eta_{ij}$ is the output-constant, derived demand elasticity for input i with respect to a change in the price of input j. Output in this case can only be expanded by substituting variable inputs for L and K.

The partial equilibrium expressions for $\hat{p}_L$ and $\hat{p}_K$ are vastly simplified if we also introduce the concept of the Morishima elasticity of substitution: μ_{ji}. Following Blackorby and Russell (1989), μ_{ji} is defined as the proportionate change in (q_i/q_j), following a one percent change in (p_i/p_j) caused by a perturbation in p_j, with all other input prices and output level fixed. (In this paper a somewhat different problem is examined, since q_L and q_K are *fixed*. Nonetheless the same definition may be used.) As those authors point out, these elasticities represent the many-input generalization of the elasticity of substitution between two inputs defined by Hicks and employed in the widely-used Constant Elasticity of Substitution (CES) production function. If the aggregate agricultural production function is approximated with a CES function, then $\mu_{KL} = \mu_{LK} = \sigma$, where σ is a parameter describing the (now constant) elasticity of substitution among inputs.

The Morishima elasticities are closely related to the output constant demand elasticities, (η_{ij}), and the associated Allen partial elasticities of substitution (σ_{ij}). In particular:

$$\mu_{ji} = \eta_{ij} - \eta_{jj} = (\sigma_{ij} - \sigma_{jj})c_j \, .$$

They are generally not symmetric, i.e. $\mu_{KL} \neq \mu_{LK}$, and they may be negative in sign (Morishima complements). However, since $\eta_{jj} < 0$, it is entirely possible that two goods are output-constant complements $(\eta_{ij} < 0)$ yet Morishima substitutes $(\mu_{ji} > 0)$. Indeed, Morishima complementarity is a relatively rare occurrence.

Changes in short-run rental rates

Solution of (1) – (3) results in the following changes in endogenous rental rates, and the level of output:

(4) $\hat{p}_L = [\mu_{KL}/(c_L\mu_{KL} + c_K\,\mu_{LK})]\rho$

(5) $\hat{p}_K = [\mu_{LK}/(c_L\mu_{KL} + c_K\,\mu_{LK})]\rho$

(6) $\hat{q}_o = \varepsilon_s\rho.$

Here $\mu_{KL} = \eta_{LK} - \eta_{KK}$ and $\mu_{LK} = \eta_{KL} - \eta_{LL}$ are the Morishima elasticities of substitution between land and other fixed inputs. $\varepsilon_s = c_L c_K\,(\sigma_{LL}\sigma_{KK} - \sigma^2_{LK}) \,/\, [-c_L c_K(\sigma_{LL} - 2\sigma_{LK} + \sigma_{KK})]$ is the implied commodity supply elasticity of agriculture (Hertel, 1989). (For the sake of discussion, it is assumed that ρ, the product price shock, is positive. However, the following results are equally applicable to the case where $\rho < 0$.)

Dividing (4) by (5) yields the condition: $\hat{p}_L/\hat{p}_K = \mu_{KL}/\mu_{LK}$ which leads to the first proposition.

Proposition One: The relative factor incidence of an exogenous product price shock depends entirely on the Morishima elasticities of substitution between the two groups of fixed factors. If $\mu_{KL} > \mu_{LK}$, then the rental price of land will rise by more than that of nonland fixed factors. If $\mu_{KL} < \mu_{LK}$, the reverse is true. If $\mu_{KL} = \mu_{LK}$, then the relative incidence will be equal for the two groups of fixed inputs.

In order to obtain further intuition about this result, consider the instance where $\mu_{KL} > \mu_{LK}$. This means that, *if* L and K were permitted to vary, the proportionate change in (q_L/q_K) following a one percent change in (p_L/p_K) owing to a change in p_K, would be larger than the proportionate change owing to a one percent change due to a perturbation of p_L. That is, the optimal capital-land ratio is more sensitive to a price change in the p_K coordinate direction. Thus it is not surprising that relatively more of the benefits would be absorbed by land, when $\mu_{KL} > \mu_{LK}$.

The CES Case: At this point it is instructive to consider the special case in which agricultural technology may be characterized by a CES production function. Applying the result that $\mu_{ij} = \mu_{ji} = \sigma$ gives the following:

(7) $\hat{p}_L = c_F^{-1}\,\rho$

(8) $\hat{p}_K = c_F^{-1}\rho$

(9) $\hat{q}_O = \sigma[(1 - c_F) / c_F]\rho$

where $c_F = (c_L + c_K)$ = the share of fixed factors in total costs in agriculture, so that $(1 - c_F)$ = the cost share of variable inputs.

The interaction between factor mobility, factor substitution, and the incidence of a price shock is illustrated in equations (7)-(9). Because $\mu_{KL} = \mu_{LK}$, both factor prices rise by the same proportion. Furthermore, this proportional increase (for a given value of ρ) becomes greater as the share of fixed factors in total costs falls (i.e., c_F^{-1} rises). Offsetting

this is the fact that the farm product supply elasticity increases as c_F falls, since $\varepsilon_s = \sigma(1-c_F) / c_F$. If farm level demand were not perfectly elastic, this would have the effect of forcing more of the adjustment onto those purchasing the farm products, i.e., $|\rho|$ would diminish. Finally, note that increasing σ also serves to the increase supply responsiveness of agriculture.

Acreage effects

In those cases where acreage set-aside programs are employed (e.g., in the United States), there is another important piece of the factor market puzzle, following agricultural trade liberalization. This pertains to the likely impact of releasing idled acreage. Once again, it is useful to present results for the case of two fixed factors. Appropriate modification of equation (2), to introduce a proportional increase in acreage equal to $\hat{q}_L = \gamma \geq 0$, yields a revised partial equilibrium solution:

(4′) $\hat{p}_L = \mu_{KL}\rho/D - c_K\gamma/D$

(5′) $\hat{p}_K = \mu_{LK}\rho/D + c_L\gamma/D$

(6′) $\hat{q}_O = \varepsilon_s\rho + c_L\mu_{KL}\gamma/D$,

where $D = (c_L\mu_{KL} + c_K\mu_{LK})$ is the same denominator as before (equations (4) and (5)).

Note that the first terms on the right hand side of equations (4′)-(6′) are identical to those in (4)-(6). The added effect of the acreage shock is given by the second term in (4′)-(6′). If it is assumed that L and K are Morishima substitutes, then D is positive and increased acreage lowers land rents and raises the price of nonland fixed factors. The larger the share of nonland fixed factors, relative to the cost share of land (all else constant), the greater the decline in land rents and the smaller the increase in returns to nonland fixed factors.

Continuing with the assumption of Morishima substitutes, the output effect of releasing acreage may be seen to be positive, as expected. It is also larger, the larger $c_L\mu_{LK}$ is relative to $c_K\mu_{LK}$. Using the formulae for the Morishima elasticities of substitution in terms of the Allen partial elasticities of substitution (and noting that $\sigma_{ij} = \sigma_{ji}$) yields: $(c_L\mu_{KL} - c_K\mu_{LK}) = c_Lc_K(\sigma_{LL} - \sigma_{KK})$. But $\sigma_{ii} \leq 0$, so that this difference becomes (positively) large when $|\sigma_{LL}|$ is small, relative to $|\sigma_{KK}|$. In other words, the output effect of increased acreage will be large when it is relatively more difficult to substitute towards land, than it is to substitute towards the nonland fixed factors. Conversely, if it is relatively easy to substitute land for other inputs (i.e., when $|\sigma_{LL}|$ is large, relative to $|\sigma_{KK}|$), then the predominant effect of increasing acreage will be to lower yields and the output effect ($\hat{q}_O$) will be small.

When $\mu_{KL} = \mu_{LK} = \sigma$ (the CES case), equation (6′) reduces to the following:

(9′) $\hat{q}_O = \sigma[1-c_F)/c_F]\rho + (c_L/c_F)\gamma.$

In other words, when the Morishima elasticities of substitution between land and capital are equal, the output effect of increased acreage depends solely on the share of land in total fixed factor costs (c_L/c_F). As c_L approaches c_F, the increased acreage translates into an equiproportional increase in output when product price is *exogenous*.

These results are formalized in the following proposition:

Proposition Two: Assuming land and nonland fixed factors are Morishima substitutes, an increase in planted acreage (holding product price constant) will lower land rents and raise the rental rate on the nonland input. Output will increase, with the magnitude of this being greater as $c_L\,\mu_{KL}$ increases relative to $c_K\mu_{LK}$. In the CES case, the output effect of a given acreage change depends solely on the relative size of the two cost shares: $c_L/(c_K + c_L)$.

Note, finally that the basic framework outlined above may be further extended to incorporate the effects of exogenous input price shocks, such as a change in the price of feedstuffs.[3]

Variable input demand in the long run

If the long run is defined as that period over which nonland inputs are in perfectly elastic supply, then the proportional change in variable input demand may be expressed as follows:

[3] Incorporation of an exogenous input price shock (e.g. an increase in feed prices) into this framework results in the following cumulative effects on fixed factor rents and output:

$$\hat{p}_L = [\mu_{KL}\rho^* - c_K\gamma^* + c_K\,\delta^*]/D$$

$$\hat{p}_K = [\mu_{LK}\rho^* - c_L\gamma^* + c_L\delta^*]/D$$

$$\hat{q}_O = [\varepsilon_s\rho^* - c_K\mu_{KL}\,\gamma^* + c_K\mu_{LK}\;\delta^*]/D\,,$$

where D is the same as above, but price and acreage shifters have been modified, and a shifter for nonland fixed inputs has been introduced to capture the impact of this price change on the scarcity of nonland fixed factors: $\delta^* = -\eta_{KE}\hat{p}_E$. The exogenous output price change has been modified to take account of the effect of the increased feed price on profits, i.e., $\rho^* = \rho - c_E\hat{p}_E$. The acreage shifter has also been modified to take account of the fact that increased feed prices may indirectly stimulate the demand for land. Thus: $\gamma^* = \gamma - \eta_{LE}\,\hat{p}_E$.

As a result of these modifications, a somewhat more damaging net producer price effect is anticipated, since $\rho^* < \rho < 0$. On the other hand, the reduction in net availability of fixed factors (provided η_{KE} and $\eta_{LE} > 0$) will tend to bolster the rental rates for those factors. The net effect on land rents depends on the relative size of these two forces. In particular p_L is increased if $c_K(\sigma_{LE} - \sigma_{KE}) > 1$, where σ_{ij} represents the Allen partial elasticity of substitution between i and j. Similarly p_K is positively enhanced only if $c_L(\sigma_{KE} - \sigma_{LE}) > 1$. Of course in the CES case, $\sigma_{LE} = \sigma_{KE} = \sigma$ and the feed price shock unambiguously lowers p_K and p_L.

$$(10) \qquad \hat{q}_V = \eta_{VL}\,\hat{p}_L + \hat{q}_O = \eta_{VL}\,\hat{p}_L + (c_L^{-1}\,\sigma_{LL} - \upsilon_{LL})\hat{p}_O$$

where υ_{LL} is the acreage supply response to a one percent perturbation in land rents, and σ_{LL} is the own-price Allen partial elasticity of substitution for land. Multiplying the righthand term by c_L/c_L, making use of the long-run result that $\hat{p}_O = c_L\,\hat{p}_L$, and introducing the definition of the Morishima elasticity of substitution, yields:

$$(11) \qquad \hat{q}_v = [\eta_{VL} - \eta_{LL}) + \upsilon_{LL}]\,c_L^{-1}\,\hat{p}_O$$

$$= (\mu_{LV} + \upsilon_{LL})\,c_L^{-1}\,\rho.$$

Expression (11) motivates the third proposition.

Proposition Three: The long-run proportionate change in demand for variable inputs in agriculture, following a product price shock of proportion ρ, is given by $(\mu_{LV} + \upsilon_{LL})\,c_L^{-1}\,\rho$. Thus $(\hat{q}_V/\rho) > 0$ as long as $\mu_{LV} > 0$. Only when land and the variable input in question are relatively strong Morishima complements, such that $\mu_{LV} < -\upsilon_{LL} < 0$ will the sign of $(\hat{q}_V/\rho)$ be negative.

Assessing the change in farm household welfare

How is farm household welfare likely to be affected by a change in the price received for output? Changes in the well-being of the farm household can be measured in terms of the compensating variation induced by a given price shock, relative to initial real income. This may be approximated as follows (see Appendix):

$$(12) \qquad CV/RI = \hat{R}I = \alpha \sum_{j=1}^{J} c_j^{*}\,\hat{p}_j,$$

where $\hat{R}I$ is the proportional change in real income, c_j^{*} is the initial share in net farm income of payments to primary factor j, and $\hat{p}_j$ represents the proportional change in the jth rental rate. The parameter α is the share of farm income earned on the farm, net of farm factor payments flowing to nonfarm households. If α is equal to one, then proportional changes in the share-weighted primary factor price changes in agriculture translate into an equiproportional change in the aggregate farm household's real income. In the case of most industrialized economies, α will be less than one, reflecting the importance of off-farm employment in farm household income. Thus the proportional drop in real income will be dampened by nonfarm earnings, the returns to which are assumed exogenous in this partial equilibrium analysis.

Finally, note that unlike the change in net farm income, quantity changes do not appear in equation (12). Implicit in this expression is

the assumption that if resources leave agriculture, they do so in order to receive a comparable wage rate. Thus *household* earnings are unaffected. For this reason inputs which are in perfectly elastic supply to the farm sector play no role whatsoever in determining $\hat{R}I$.

Substitution of equations (4) and (5) into (12) yields the following expression for the change in farm household welfare as a function of the exogenous shock in farm prices:

$$\hat{R}I = \alpha[(c_L/\bar{c})\hat{p}_L+(c_K/\bar{c})\,\hat{p}_K] = \alpha(\rho/\bar{c}), \tag{13}$$

where $\bar{c}$ is the share of net farm income in total receipts. If all primary factors of production are in fixed supply, then $(c_L + c_K) = \bar{c}$.

In the case where trade liberalization also involves the release of previously voluntarily idled land in response to a higher producer price (e.g., deficiency payments in the United States), then (12) must be modified. This is because when the output subsidy is removed, there is no longer any reason to idle the acreage, and it may once again be planted. This in turn generates added income (all else constant) and must be reflected in a modified version of (12).

$$\hat{R}I = \alpha\left[\sum_{j \neq L}^{J} c_j^{*}\hat{p}_j + c_L^{*}(\hat{p}_L + \gamma)\right], \tag{12'}$$

where $c_j^{*} = c_j/\bar{c}$ and $\gamma = \hat{q}_L$.

From (4′), (5′) and (12′), the following change in real income is established, following simultaneous perturbations in output price and acreage:

$$\begin{aligned} \hat{R}I &= \alpha\,\{\,(c_L/\bar{c})\,[\mu_{LK}\rho/D - c_K\gamma/D + \gamma] \\ &\quad + (c_K/\bar{c})\,[\,\mu_{KL}\rho/D + c_L\gamma/D\,]\,\} \\ &= \alpha\,[\,(\rho + c_L\gamma)/\bar{c}]. \end{aligned} \tag{13'}$$

At this point it is useful to summarize the results regarding the real income changes in the form of a proposition.

Proposition Four: The change in aggregate farm household well-being (measured as a proportion of initial income), following a product price exogenous shock of proportion ρ, may be approximated based solely on information about cost and income shares. In particular, $\hat{R}I = (\alpha/\bar{c})\,\rho$, where $\bar{c}$ is the share of earned income in total farm receipts, and α is the net share of farm income earned off-farm. When ρ includes the effect of eliminating payments for idling acreage then an additional term: $\alpha(c_L/\bar{c})\,\gamma$ must be added, where $\gamma = \hat{q}_L$ = the proportion of acreage which was previously withheld from production.

Numerical Illustration

The Morishima elasticities of substitution derived from the demand elasticities for Australian agriculture reported in Table 3 of Lawrence (1990) are presented in Table 1. Note that this matrix is asymmetric and the diagonal elements are not defined. Further, there is only one (insignificant) negative off-diagonal element — as against 14 in the original matrix of demand elasticities. This is an empirical demonstration of the earlier point that Morishima complementary is a rare occurrence.

Relative factor incidence

Application of the above propositions to the estimates presented in Table 1, permits several conclusions to be drawn about the potential effects of an aggregate price rise for Australian agriculture. Begin with proposition one. The return to fixed factor i will be disproportionately affected provided $\mu_{ji} > \mu_{ij}$, where j is the second fixed factor (or a composite of other fixed factors). Inspection of the Morishima elasticities in Table 1 indicates that the elasticities in the operator labor row are particularly small, relative to other values in the Table. This means that optimal input intensities in Australian agriculture are relatively insensitive to changes in the shadow price of labor, i.e. $\mu_{oplabor,j}$ is small, relative to other values in the Table. This fact is reflected in the small sum for the operator labor row. Note that the column sums are uninformative, since they involve summation over different price perturbations. Furthermore, since:

$$\sum_i \mu_{ij} \sum_i (\eta_{ji} - \eta_{ii}) = -\sum_i \eta_{ii} ,$$

all column sums must be equal.

Because operator labor is very likely to be in fixed supply in the short to medium run, and because Australian agriculture appears quite insensitive to movements in its shadow price, this factor price is very likely to move disproportionately with shocks to sectoral product prices. For example, when the other fixed factor is land, the fact that $\mu_{oplabor,land} \cong 0$ means that virtually all of the impact of r will be reflected in $\hat{p}_{oplabor}$. When paired with capital, as fixed factors, we have:

$$\hat{p}_{oplabor} / \hat{p}_{capital} = \mu_{capital,oplabor}/\mu_{oplabor,capital}$$
$$= 0.29/0.01 = 29$$

Once again, there is a tremendous discrepancy in the way the product price shock is shared. Livestock is the only other input with a row sum less than one. Here: $\hat{p}_{oplabor}/\hat{p}_{livestock} = 0.04/0.02 = 2.0$, in the case where operator labor and livestock are the only two fixed factors.

In the short run it is expected that more than two factors will be in relatively fixed supply and the precise outcome will depend on the

TABLE 1
Morishima Elasticities of Substitution in Australian Agriculture

	Land	Operator Labor	Capital	Livestock	Hired Labor	Services	Materials	Row Total
Land	—	0.07	0.27	0.05	0.17	0.17	0.37	1.10
Operator Labor	–0.00	—	0.01	0.02	0.04	0.02	0.04	0.13
Capital	0.29	0.26	—	0.30	0.25	0.33	0.20	1.63
Livestock	0.04	0.09	0.18	—	0.02	0.10	0.24	0.67
Hired Labor	0.22	0.25	0.18	0.12	—	0.33	0.22	1.32
Services	0.64	0.62	0.95	0.65	0.87	—	1.23	4.96
Materials	1.11	1.01	0.71	1.16	0.95	1.35	—	6.29
Column Total	2.30	2.30	2.30	2.30	2.30	2.30	2.30	
Cost Share	0.22	0.07	0.06	0.10	0.13	0.25	0.18	1.01*

Source: Calculated from Table 3 of Lawrence (1990) by applying the formula: $\mu_{ji} = (\eta_{ij} - \eta_{jj})$.
* Cost shares do not sum to one due to rounding error.

TABLE 2
Morishima Elasticities of Substitution in U.S. Agriculture

	Land	Durable Equipment	Buildings	Labor	Feed	Chemicals	Other	Row Total
Land	—	0.22	0.21	0.20	0.25	0.26	0.27	1.41
Durable Equipment	0.34	—	0.40	0.19	0.45	0.42	0.52	2.32
Livestock & Buildings	0.42	0.50	—	0.48	0.52	0.48	0.58	2.98
Labor	0.11	–0.07	0.23	—	0.19	0.01	0.58	1.05
Feed	0.33	0.42	0.34	0.23	—	0.33	0.12	1.77
Chemicals	0.52	0.52	0.49	0.42	0.50	—	0.62	3.07
Other	0.97	1.10	1.02	1.17	0.78	1.19	—	6.23
Column Total	2.69	2.69	2.69	2.69	2.69	2.69	2.69	
Cost Share	0.07	0.12	0.14	0.20	0.23	0.07	0.17	1.00

Source: Calculated from Table 4 of Hertel (1989) by applying the formula: $\mu_{ji} = (\sigma_{ij} - \sigma_{jj})\, c_j$.

factor supply elasticities for each of the seven inputs. However, computer simulation of this more general model indicates that, regardless of what is assumed about the other inputs, as long as operator labor is in fixed supply, it will bear a disproportionate share of the shock to product prices.

It is instructive to contrast the above findings with those based on a set of estimated Morishima elasticities of substitution for U.S. agriculture, as reported in Table 2. These are computed from Table 4 of Hertel (1989) and are also based on a seven-input, aggregate cost function. However, the input categories are not the same. Furthermore, there are several critical differences in the way in which the two data sets were constructed.[4] Thus any comparisons should be made with some caution. Inspection of the row sums in Table 2 shows that labor (this time an aggregate of both operator labor and hired labor) is once again the input with the smallest total. That is, U.S. agriculture is also relatively insensitive to changes in the shadow price of labor. Furthermore, a comparison of $\mu_{labor,j}$ with $\mu_{j,labor}$ indicates that, regardless of which factor j it is paired with, the return to labor will always exhibit a disproportionate movement with respect to a product price shock.

Long run variable input demand

The third proposition derived above pertains to the likely consequences of an exogenous product price shock for long-run variable input demand. (The second proposition relates to the release of idled acreage and will not be discussed further, since it does not apply in the Australian case.) If it is assumed that quality-adjusted, arable land is

[4] These U.S. estimates are based on Ball's data set for U.S. agriculture. It consists of time series data for the period 1948-79. Most importantly, the rental rates for farm assets incorporate expected capital gains/losses. This is not the case with the Lawrence data set. For reasons discussed in his paper, asset rental rates are equal to a constant real rate of return plus the rate of depreciation. Lawrence's time series is shorter (8 years), but it is available for 6 individual states, giving a total of 6 x 8 = 48 pooled observations. Both of these differences make it reasonable to expect that the Lawrence data exhibits much less variability in asset rental rates, which in turn may explain the smaller estimated Morishima elasticities of substitution among agricultural assets. This translates into striking differences in implied supply elasticities for aggregate agricultural output. Applying the formula given in Hertel (1989), the aggregate supply elasticity may be shown to be a function of the submatrix of elasticities of substitution among fixed factors. When land, labor and capital are all held fixed, Lawrence's estimates give a value of $\varepsilon_s = 0.003$, whereas those from Table 2 give a much larger aggregate supply response, namely $\varepsilon_s = 0.53$.

The use of expected capital gains in the calculation of asset rental rates for the U.S. data set also has a substantial impact on the fitted shares, which indirectly influences ε_s and μ_{ij} . For example, the 1977 fitted cost share for land in the U.S. was only 0.07 (see Table 2, bottom row). This is because this was a period of rapid appreciation in U.S. land values. Consequently, the perceived cost of holding land was very low. This causes c_L^{-1} to be quite large thus leading to an overstimate of long-run U.S. supply response.

the only factor in fixed supply in the long run, then with $\upsilon_{LL} = 0$, we have $\hat{q}_v/\rho = \mu_{LV}\, c_L^{-1} = 4.52\,\mu_{LV}$.

Applying this formula to the first row of elasticities in Table 1, yields the following percentage increases for variable inputs, given a one percent increase in product prices: capital = 1.23 per cent, livestock = 0.23 per cent, hired labor = 0.77 per cent, services = 0.78 per cent, and materials = 1.66 per cent. (Aggregate output increases by 0.71 per cent.) In contrast, the first row of the estimated Morishima elasticities of substitution for the U.S. indicate a much more even increase in long-run factor demands, with μ_{LV} bounded by 0.21 on the low side and 0.27 on the upper end.

Household incidence

Finally, turn to Proposition Four which bears on the question of changes in farm household welfare following a price shock. While the Morishima elasticities of substitution play a role in determining the relative incidence across fixed factors, they are not necessary for assessing the change in aggregate farm household well-being. For this, only estimates of $\bar{c}$ are required, the share of farm household income in total receipts, and α, the net share of farm income earned off-farm. Based on the cost shares from the Lawrence study, and subsuming hired labor into the aggregate farm household, we have $\bar{c} = 0.58$. That is, when evaluated at mean prices and output for the sample in question, a predicted 58 per cent of farm costs went to remunerate land, labor and capital in Australian agriculture. Thus $\hat{RI} = 1.73\ (\alpha\rho)$. Since it is expected $\alpha < 1$, this means that a one percent rise in aggregate farm prices raises farm household real income by something less than 1.73 per cent.

Summary and Conclusions

As the GATT negotiations over agricultural liberalization struggle through the 'home stretch' there is heightened interest in the potential short-run consequences for domestic agriculture of the ensuing change in producer prices. The approach taken in this paper has been to partition this problem into two parts. The first involves determining the change in producer prices following global trade liberalization. This is the focus of numerous large-scale, quantitative modelling efforts and it is not tackled here. The second part of the problem involves determining the incidence of a given world price shock in the case of a particular domestic farm sector. Partitioning the problem in this way facilitates the derivation of qualitative results which shed light on the role of technology in determining the relative incidence, among fixed factors, of a producer price shock. In particular, this incidence is shown to depend on the relative magnitude of the Morishima elasticities of substitution in agricultural production.

The qualitative results also indicate the importance of relative cost shares in determining the incidence of exogenous shocks to the farm sector. For example, the partial equilibrium change in the farm household's real income can be approximated based solely upon information about cost and income shares. No information about technology is needed. Yet as a profession, agricultural economists devote little attention to estimating and reporting these shares. When expected capital gains are taken into account, the cost of holding farm assets becomes particularly volatile. How much have these cost shares varied in recent years? What is the best estimate of current cost shares in Australian agriculture? There is a clear need to focus more attention on estimating economically meaningful cost and income shares.

In addition to facilitating derivation of qualitative results, a second advantage of partitioning the research program into two parts has to do with the considerable uncertainty associated with the world price effects of multilateral agricultural trade liberalization. By deriving a set of expressions for the domestic incidence of an exogenous producer price shock, it is possible for the domestic implications of these diverse price projections to be explored and revised as new evidence becomes available.

Of course in practice the world price effects of agricultural trade liberalization depend importantly on domestic factor market adjustments. The problems are not separable — particularly for large countries. Nevertheless, even after the global trade problem has been adequately modelled, the results outlined in this paper can be useful for analyzing and contrasting the domestic incidence of trade liberalization, as predicted by global models based upon differing assumptions. In particular, agricultural economists would be well-advised to pay relatively more attention to the Morishima elasticity of substitution as a means of characterizing agricultural technology and drawing inferences about the potential incidence of multilateral trade liberalization.

APPENDIX
Approximating Changes in Farm Household Welfare

The utility maximization problem

Consider the utility maximization problem[5] for a representative farm household:

$$\text{Maximize } U(q_1, \ldots, q_N)$$

$$\text{(A.1)} \qquad \text{subject to } \sum_{n=1}^{N} p_n q_n = \lambda .$$

[5] These derivations follow quite closely the work of W. J. Keller (Ch. 7) in *Tax Incidence: A General Equilibrium Approach*, Amsterdam: North Holland, 1980.

The solution of (A.1) yields N optimal demand equations. If a commodity (e.g., labor) is supplied, rather than demanded, then $q_n < 0$. Thus, in the absence of transfer payments (λ=0), the left hand side of the budget constraint must sum to zero (i.e. purchases = income). It will also be useful to define the variable, υ, which represents the household's disposable income. This must equal earned income plus transfers.

Now, totally differentiate the utility function, and substitute in the first order conditions associated with (A.1). This gives:

$$\text{(A.2)} \qquad dU = \sum_{n=1}^{N} (\partial U/\partial q_n)\, dq_n = \sum_{n=1}^{N} \psi\, p_n\, dq_n ,$$

where ψ is the marginal utility of income. Multiplying the right hand side of (A.2) by (υ/υ) and (q_n/q_n) and factoring out ψ and υ gives:

$$\text{(A.3)} \qquad dU = \upsilon\, \psi \sum_{n-1}^{N} (p_n\, q_{n/\upsilon}) = u\psi \sum_{n=1}^{N} c_n^o\, \hat{q}_n ,$$

where c_n^o is the budget share associated with good and $\hat{q}_n$ is the proportional change in the demand for good n. Thus (A.3) represents the marginal change in a household's utility as a share-weighted index of quantity changes. Note further, that c_n^o is negative when good n is supplied. So, for an increase in labor supply from the farm household, $c_n^o\, \hat{q}_n < 0$, implying disutility associated with more hours of work. Of course an increase in the consumption of goods and services results in $c_n^o\, \hat{q}_n > 0$. Thus, if a given perturbation permits net increase in consumption, we expect $dU > 0$, and the household is better off.

Derivation of the compensating variation

In order to relate changes in utility to changes in prices, the budget constraint must be totally differentiated, yielding:

$$\text{(A.4)} \qquad \sum_{n=1}^{N} (\hat{p}_n + \hat{q}_n) = d\lambda/\upsilon = \hat{\lambda} .$$

(Note that the proportional change in transfer is defined with respect to disposable income.)

Now, it is possible to determine how much income the farm household requires to compensate it for the loss sustained due to trade liberalization. Formally, it is necessary to solve for $\hat{\lambda}$ such that $dU = 0$. From (A.3), $dU = 0$ if and only if $\sum_{n=1}^{N} c_n^o\, \hat{q}_n = 0$. Thus, by (A.5) the formula is obtained for the household's compensating variation, as a proportion of initial income:

$$\text{(A.5)} \qquad -\hat{R}I = \hat{\lambda} = \sum_{n=1}^{N} c_n^o \hat{p}_n \hat{p}_n$$

In other words, to hold utility constant and keep the household on its budget constraint, it must receive a proportional change in its transfer

equal to $\sum_{n=1}^{N} c_n^o \hat{p}_n$, which is just the budget share-weighted sum of price changes.

Now if: (a) the household in question represents the entire farm sector, (b) all income is earned from farming, (c) the rate of taxation in agriculture is equal across factors (i.e., $p_{Fi}/p_i = p_{Fj}/p_j$), and (d) initial transfers are zero ($\lambda = 0$), then $c_j^o = -c_j/\bar{c}$. That is, the budget shares associated with primary factors (i.e., land, labor and capital) equal the negative of their share in earned income. Assuming further, that consumer price changes are negligible (i.e., $\hat{p}_i = 0$ for $q_i > 0$), we have:

$$\text{(A.6)} \qquad \hat{R}I = \sum_{j=i}^{J} c_j^* \hat{p}_j ,$$

where c_j^* is the budget share for factor j, under assumptions (a)-(d).

If only a fraction (α) of the farm household's disposable income is based on farm earnings, then $c_j^* = (\alpha)(-c_j/\bar{c})$ and so:

$$\text{(A.7)} \qquad \hat{R}I = \alpha \sum_{j=i}^{J} c_j^* \hat{p}_j ,$$

A further subtlety about (A.7) involves the possible ownership of agricultural assets by nonfarm households. To handle this, α should be viewed as farm income divided by farm income plus the difference between farm household earnings from nonfarm sources and nonfarm household earnings from the farm sector.

Finally, if policy liberalization also relaxes the set-aside constraint, on idled acreage, then earned income from land is augmented by the change in planted acreage. This adds another term to the left-hand side of (A.7): $\alpha c_l^* \hat{q}_l$, l = land.

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