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The pass-through of exchange rate changes to the prices of Australian exports of dairy and livestock products

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Agricultural exports are usually assumed to operate in perfectly competitive international markets, but many are subject to non-tariff barriers to trade that can affect the degree of pass-through of exchange rate changes to foreign currency prices. The present study uses multivariate cointegration techniques to examine the effects of exchange rate changes on the prices of Australian exports of milk products, cheese, beef, sheepmeat, and hides and skins. The results indicate that Australian dairy exports operate in competitive markets in which pass-through is complete, but there is no stable long-run relationship between exchange rates and prices for any of the other livestock products.

1. Introduction

Exchange rate changes have been recognised as an important influence on the prices of agricultural exports for many years. Since the 1970s, Schuh (1974) and others have argued that exchange rates are major determinants of agricultural trade flows. However, there appears to be little empirical evidence on the size and nature of the relationship between exchange rate movements and price adjustments for agricultural products.

A change in the value of the Australian dollar (AUD) can alter the prices of exported goods in terms of foreign currencies, making Australian products either more or less expensive to foreign buyers, and consequently affecting export demand. In this case, the exchange rate movement is said to be passed through to foreign currency import prices. Alternatively, demand may be unaffected if Australian exporters maintain constant foreign currency prices, instead absorbing the exchange rate change into the prices they receive in domestic currency terms. Pass-through to foreign currency import prices will then be zero. The way in which the effects of the exchange rate movement are passed through or shared between exporter

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and importer therefore has important implications for the shifts in external demand and internal supply that occur in response to the currency change. The present study investigates the pass-through relationship for five Australian export commodities, milk products, cheese, beef, sheepmeat, and hides and skins.[1] The relationship is estimated across an export-weighted average of all Australian export markets for each commodity over the period from 1985 to 1996.

2. Analytical framework

There is now an extensive published theoretical literature on exchange rate pass-through that suggests several possible influences on the relationship between exchange rates and traded goods prices. Authors such as Krugman (1986) and Dornbusch (1987) have identified market structure as one of the most important factors in determining the degree of pass-through. For an exporter in a perfectly competitive world market, price in domestic currency terms must always be equal to marginal cost, so that there can be no change in domestic currency price when there is a change in the exchange rate with any individual market. The foreign currency prices paid by all importers must instead change in full proportion to the movement in the exchange rate with their currency. That is, the pass-through of exchange rate changes to foreign currency prices must be complete across all destination markets.

In an imperfectly competitive world market, exporters can set domestic currency price above marginal cost. They can therefore absorb part or all of any currency change into domestic currency markups in order to maintain competitive advantage. For example, when the domestic currency appreciates, exporters may reduce markups and maintain constant foreign currency prices in order to protect sunk costs already invested in market entry, or to gain market share, or when the exchange rate movement is thought to be only temporary. Pass-through to foreign currency prices in these markets may therefore be incomplete. In addition, if there are differences in demand curves or in the costs of trading to individual markets, exporters in imperfectly competitive world markets may also be able to price discriminate by allowing the degree of incomplete pass-through to differ between destinations. This is known as pricing-to-market (Knetter 1989).

Dynamic theories of pass-through have extended the imperfectly competitive models to argue that exporters can maximise strategic advantage by

[1] The term milk products is used here to refer to concentrated milk and cream products, principally powdered milk, that have been aggregated into a separate category to distinguish them from cheese.

varying pass-through over time, generating a hysteretic, or discontinuous, relationship (Baldwin 1988; Froot and Klemperer 1989). For example, where sunk costs exist, exporters may try to absorb exchange rate changes as long as they fluctuate within a set range, the width of which will be determined by the size of the entry and exit costs. Pass-through to foreign currency prices at this stage will be zero. Once the exchange rate moves outside the range, however, pass-through to foreign currency prices will rapidly increase, as new firms enter or exit, and existing firms expand or decrease production. A structural break in the relationship between exchange rates and foreign currency prices will occur when the boundaries of the range are crossed.

Agricultural commodities are usually assumed to operate in perfectly competitive world markets, and complete pass-through to all destinations would be expected to be the usual outcome. However, a discontinuous relationship between exchange rates and prices can exist even in a perfectly competitive world market if it is affected by non-tariff barriers (NTB) or quantitative restrictions such as import quotas, import licensing restrictions and health and safety regulations, all of which are common in agricultural trade (Bhagwati 1988).[2] In markets where import quantities are restricted, buyers effectively face a supply curve that becomes vertical, or perfectly inelastic, at the quantity at which the import restraint is imposed. If exporters are already filling quotas and therefore have no capacity to sell larger volumes, they also have no incentive to lower prices when their exchange rate depreciates. Pass-through will be zero, and exporters will simply absorb the exchange rate change into increased profit margins. Similarly, if the current foreign currency price is the maximum the market will bear for the restricted import quantity, as would be expected from a profit-maximising exporter, the effects of a small appreciation will be absorbed in the import premium, and pass-through will be zero.[3]

It is only when an exchange rate appreciation is sufficiently large to overtake the premium, that pass-through, and foreign currency import prices, will rise, and be subject to the same market conditions as would normally apply. A structural break in the relationship between exchange rates and

[2] A tariff also restricts trade because it reduces the overall level of trade by increasing the relative price of imports. But a tariff will only result in a discontinuity in the pass-through relationship if a much higher tariff rate is applied to quantities above a specified minimum, for example, through a tariff rate quota (TRQ), to effectively restrict quantity imported in the same way as non-tariff barriers (NTB) or other quantitative restrictions.

[3] Bhagwati (1988) refers to the import premium as the economic rent available in markets where quantity restrictions on imports result in higher prices than would have been received in an unrestricted market.

foreign currency prices will again occur at the point where the exchange rate moves out of a set range, in a similar way to the dynamic models of imperfectly competitive markets. But here the width of the range will depend on the level of the import premium, which in turn derives from the volume of restricted imports relative to the potential quantity of unrestricted imports.

There have been many empirical studies of exchange rate pass-through for manufacturing industries. The results generally demonstrate that incomplete pass-through is a common phenomenon for manufactured goods, usually attributed to imperfectly competitive markets in a wide variety of industries and countries (see Goldberg and Knetter (1997) and Menon (1995) for comprehensive surveys).

Previous studies suggest that individual differences in market structure are also an important determinant of exchange rate effects for primary commodities. For example, Swift (2001) examined exchange rate pass-through for Australian exports of the non-ferrous metals, aluminium, copper and lead. These refined metals are homogenous commodities, manufactured to standard international specifications with little opportunity for product differentiation. Although sales are usually contracted between individual companies, international prices for all three metals are closely related to published reference prices set in open auction-type markets like the London Metal Exchange. However, production of all three non-ferrous metals is highly capital intensive, raising significant barriers to entry. Market structures are accordingly oligopolistic, dominated by a small number of large vertically integrated multinational corporations (MNC) who operate simultaneously in several countries.

In a model similar to that used here, Swift (2001) found the existence of two distinct long-run relationships, the first of which showed incomplete pass-through consistent with exporters who conform to world price movements and maintain constant foreign-currency prices following an exchange rate change.[4] However, the second relationship for each metal demonstrated an association between domestic production costs and export prices that varied with individual metals, and in which exchange rate movements were not significant. The concurrent existence of two long-run relationships

[4] The incomplete pass-through found here is consistent with the price taking behaviour often expected of exporters of homogenous commodities who are regarded as having little influence over prices determined in competitive world markets. However, as discussed previously, pass-through in a perfectly competitive market is normally expected to be complete, and the circumstances in which incomplete pass-through can occur in perfectly competitive markets are limited (see Swift (2004) for a discussion of the theoretical issues). The multiple relationships found for the three metals appear to support the conclusion that these Australian export markets are not competitive.

reflects the complexity of the industry structures for each of these commodities, and emphasises the importance of individual market conditions in the pricing decisions of Australian exporters.

For agricultural industries, relatively few commodities have been investigated, and the results are also much less clear cut than those for the manufacturing industries. Although market structure is still considered the most important issue, other influences, particularly the effects of distorting trade policies, are raised more frequently. Wheat and rice are the only agricultural commodities for which the hypothesis of a perfectly competitive world market seems to be consistently rejected in a number of studies, usually as a result of centralised selling arrangements (Pick and Park 1991; Pick and Carter 1994; Yumkella *et al*. 1994; Park and Pick 1996; Griffith and Mullen 2001). Incomplete or discontinuous pass-through is also found in the studies for beef. However, here the authors suggest that the results are caused by other influences, particularly the NTB commonly found in the beef trade, rather than imperfectly competitive market structures (Jabara and Schwartz 1987; Alston *et al*. 1992; Patterson *et al*. 1996).

For corn, cotton, and soybeans, Pick and Park (1991) find evidence for a competitive market structure, but Jabara and Schwartz (1987) and Alston *et al*. (1992) report discontinuous or incomplete pass-through for the same commodities in similar time periods. Single estimates of pass-through are also available for a few other agricultural commodities. But all show incomplete pass-through, as a result of either imperfectly competitive markets (e.g., tobacco in Pompelli and Pick (1990) and chicken in Patterson *et al*. (1996), or to the presence of NTB (for example, oranges in Alston *et al*. (1992)).[5]

The five Australian dairy and livestock products for which pass-through is estimated here are all unprocessed or lightly processed commodities exported directly by manufacturers or through commercial traders. They all sell into world markets in which Australia plays only a minor role, contributing five per cent or less to total world production on average over the period (table 1). However, the two groups differ in the share of world trade held by Australian exports. Australia is a relatively minor participant in the world export market for dairy products, which is strongly dominated by the EU. But it is one of the top two exporting countries for both beef and sheepmeat (table 1). Even for hides and skins, although Australia held only a small (four per cent) share of total exports in this category over the

[5] All of the studies of agricultural products use markup or related pricing-to-market models similar to those discussed here, but most suffer from possible estimation problems in the use of unit value data, and econometric methods that do not allow for non-stationarity of the data.

Table 1 Major shares of world production and exports for selected commodities[†]

Dairy Products				
Milk products				
Production	EU 37%	USA 9%	NZ 8%	Australia 5%
Exports	EU 37%	NZ 19%	Australia 12%	Poland 4%
Cheese				
Production	EU 43%	USA 24%	Argentina 3%	Egypt 2%
Exports	EU 47%	NZ 15%	Australia 11%	Switzerland 6%
Livestock products				
Beef				
Production	USA 20%	EU 14%	CIS 10%	Brazil 10%
Exports	Australia 20%	EU 20%	USA 14%	NZ 8%
Sheepmeat				
Production	China 16%	EU 11%	CIS 8%	Pakistan 7%
Export	NZ 53%	Australia 35%	Minor shares 12%	NA
Hides and Skins				
Production	USA 16%	CIS 12%	EU 12%	Brazil 8%
Exports	USA 29%	EU 29%	CIS 12%	Australia 4%

[†] As average percentage of total world production and exports for the period 1994–1996. NA, not applicable.
Source: FAO (2000).

period, it is the world's largest exporter of the sheepskins that form nearly half of Australian exports.

The impact of NTB on trade has also differed between the two groups, in keeping with their relative positions in world trade. Australian exports of dairy products have been largely excluded from major world markets, either directly, as with the bilateral quota agreements and other import restrictions applying to the EU and the USA, or indirectly, by the export subsidy programs of major competitors. Consequently, most Australian dairy exports over the period were sold to markets in Asia and the Middle East characterised by the Industry Commission (1991, p. 25) as 'non-quota' markets (table 2).[6] Australian exports of livestock products, conversely, have faced quotas and other NTB in almost all of the markets in which they have been sold, to the extent that this restricted market access has been claimed to be the most important influence on the industry over the period (Industry Commission 1994). Estimation of pass-through across an export weighted index of all destination markets for these two groups of commodities should therefore provide an interesting test of the impact of NTB on exchange rate effects in the world markets for these commodities.

[6] Some imports of dairy products to Japan over the period were subject to quotas on the quantities that could enter duty free, but could enter above this level at tariffs of 25–35 per cent (Podbury *et al.* 1995).

Table 2 Major markets for Australian exports†

Dairy products					
Milk products	Philippines 18%	Malaysia 15%	Taiwan 14%	Japan 13%	Singapore 12%
Cheese	Japan 36%	Saudi Arabia 21%	USA 6%	Iraq 5%	UK 5%
Livestock products					
Beef	USA 40%	Japan 39%	Korea 5%	Canada 5%	Taiwan 5%
Sheepmeat	Japan 24%	USA 11%	Saudi Arabia 9%	United Arab Emir. 9%	UK 7%
Hides and Skins	Japan 29%	Italy 26%	Korea 14%	Poland 6%	China 6%

† As average annual share of total export value over the period of estimation.
Source: ABS (unpubl. data, 1996).

3. Model and data

Most estimates of exchange rate pass-through use a reduced form markup model of traded goods prices, in which differing degrees of pass-through result from variations in profit margins as exporters strive for strategic advantage. Australian exporting firms are assumed to set foreign currency prices to importers (PM) as a percentage markup (M) over the domestic cost of production (CP).[7] CP is denominated in domestic currency (AUD) terms and converted to foreign currency using ER, the exchange rate in units of AUD per unit of foreign currency:

$$PM = M \times \left(\frac{CP}{ER}\right). \tag{1}$$

Hooper and Mann (1989) developed the most widely used version of the markup model. They argued that the markup (M) would be inversely dependent on competitive pressures in world markets, and directly dependent on the level of world demand for the commodity. Any increase in competitive pressures in world markets would be expected to result in a reduction in the average level of competitors' or world market prices in foreign currency terms (WP) relative to production costs, and a subsequent reduction in exporters' M. Conversely, a decrease in foreign demand should also result in a reduction in WP relative to production costs, and consequently a reduction in M. M is then specified as

[7] M is written in the decimal form so that $M \geq 1$.

$$M = \left[WP \Big/ \left(\frac{CP}{ER} \right) \right]^{\alpha} \tag{2}$$

assuming $0 \leq \alpha \leq 1$. Combining equations (1) and (2) gives an equation for price setting behaviour by Australian exporters:

$$PM = \left[WP \Big/ \left(\frac{CP}{ER} \right) \right]^{\alpha} \times \left(\frac{CP}{ER} \right). \tag{3}$$

Expanding equation (3) into logarithmic form gives:

$$pm = \alpha wp - (1 - \alpha) er + (1 - \alpha) cp \tag{4}$$

where lower case letters signify natural logarithms.

The coefficient on the exchange rate in equation (4), $[-(1 - \alpha)]$, represents the elasticity of foreign currency prices paid by importers with respect to the exchange rate, which, in absolute terms, is the form in which pass-through is normally defined. It shows that, for example, a 1 per cent depreciation of the AUD (1 per cent increase in *er*) results in a $(1 - \alpha)$ per cent decrease in the foreign currency prices paid by importers in the markets for Australian exports. However, pass-through for exports is usually measured in terms of the elasticity of the domestic currency prices received by exporters with respect to the exchange rate. Equation (4) can be converted to the export price form by incorporating the simple accounting relationship between the price paid by the importer and the price received by the exporter, each expressed in their own currency. Specifically, for Australian exports:

$$PM \equiv \left(\frac{PX}{ER} \right) \tag{5}$$

where PX is the price received by Australian exporters in AUD. Equation (5) can be written in logarithmic form:

$$pm \equiv px - er \tag{6}$$

and combined with equation (4), to yield the estimating equation for export price pass-through:

$$px = \alpha wp + \alpha er + (1 - \alpha) cp. \tag{7}$$

In this export price form of the equation, pass-through as defined previously as the absolute form of the elasticity of foreign currency prices paid by importers with respect to the exchange rate, is now equal to one minus the coefficient on the exchange rate (*er*).

The restrictions imposed on the parameters in equation (7) provide a framework for testing hypotheses derived from the theoretical model. In a perfectly competitive world market, α is equal to zero. Exporters set domestic currency prices (*px*) equal to cost of production (*cp*), and there will be no effect of *er* on *px*. Therefore, *er* are completely passed through to foreign currency prices (*pm*). Conversely, in an imperfectly competitive world market, exporters can absorb part or all of exchange rate changes in domestic currency prices. In the extreme case, exporters are able to maintain constant foreign currency prices and pass-through to foreign currency prices will be zero.

The estimating equation (7) is very restrictive in that it imposes the same, or related, coefficients on exchange rates, production costs and world prices. Hooper and Mann (1989) argued that firms may be more willing to absorb movements in exchange rates, which are considered to be very volatile and therefore more likely to be reversed in the future, than those in costs or world market prices, which are likely to be more sustained. They therefore estimated the model with the constraints on the coefficients relaxed, and progressively imposed and tested the restrictions. This testing procedure will also be followed here.

The time span of the relationship, and the subsequent possible joint endogeneity of the variables, must also be considered. Most of the theoretical models discussed earlier, such as Krugman (1986), Dornbusch (1987), Baldwin (1988) and Knetter (1989), have emphasised the pass-through relationship as a long-run equilibrium to which the system converges over time. In this case, a series of dynamic, multilateral, relationships between the variables in equation (7) becomes possible.

For example, *er* may affect exporters' *cp* not only directly, but also indirectly, through pass-through effects on the prices of imported inputs (Alston *et al*. 1992). Similarly, in the commodity currency models often used to explain exchange rate movements in commodity exporting countries like Australia, changes in both the *er* and *cp* can be induced by changes in *wp* in the markets for Australian exports (Freebairn 1990). To fully allow for these possibilities, the model in equation (7) is best estimated as a dynamic long-run relationship in which all of the variables may potentially be endogenous.

The model was estimated for all five commodities using monthly data for the flexible exchange rate period from July 1985 to June 1996.[8] All price

[8] The Australian Bureau of Staistics (ABS) discontinued collection of the required monthly export prices at the beginning of 1997. Although quarterly data are still available, the reduced frequency does not allow sufficient data points for reliable estimation even when continued up to the present time.

series are based on prices actually used in transactions in international trade, to reflect as far as possible the true price movements experienced by Australian exporters. Actual transaction prices such as these provide a much more reliable measure of price changes in international trade than the export unit value indices often employed in the past.[9] The indexes of *px* received by Australian exporters are compiled by the Australian Bureau of Statistics (ABS) from prices for specified standards of each commodity obtained from a monthly survey of a representative selection of exporters, with the prices weighted by export volume across all major Australian export markets for each commodity. For each commodity the *er* was similarly calculated as an export-weighted index, with the 41 countries included representing virtually all Australian export markets for each commodity.[10] Indicator commodity price indexes from international agencies represent the *wp*. They are derived from specific price quotations for each commodity in countries that are major traders of that commodity.[11] Data sources and further details of the construction of the variables are presented in the appendix.

The index representing the *er* variable is designed to measure exchange rate pass-through in terms of foreign currency prices in destination markets, as normally defined. However, the importance of the US dollar (USD) as the international trading currency for agricultural products suggests that exporters may view changes in the bilateral AUD/USD exchange rate as the most important in setting domestic export prices, rather than that of the currency of ultimate destination. The model was therefore estimated in two forms for each of the five commodities. The first long run, or cointegrating, vector proposed, Model A, includes world price and exchange rate variables

[9] For example, Kravis and Lipsey (1974, p. 261) concluded that ‘export unit-value changes are not only different from international price movements, but are almost totally unrelated to them.’ See Menon (1995) for a discussion of the data problems in pass-through estimations, and a survey of other pass-through studies that use trade-weighted indexes similar to those used here.

[10] The export price indexes represent the weighted average export prices from all Australian export markets for each commodity, which are the markets for which pass-through is being examined here. For consistency therefore the exchange rate indexes were similarly calculated using a sufficient range of exchange rates to cover all available Australian export markets for each commodity, although the export market weightings and therefore exchange rates included clearly differ between commodities. Table 2 shows the average weightings over the period for the five primary Australian export markets for each commodity. Weightings for more minor Australian export markets for each commodity are available from the author on request.

[11] As world price indexes are designed to capture movements in transaction prices across all international markets for each commodity, they are based on the pattern of total world trade, rather than that solely of Australian trade.

in foreign currency terms (*wp* and *er*, respectively), as derived previously in equation (7). The second form, Model B, incorporates the world price and exchange rate in USD terms (*wpusd* and *erusd*, respectively) to provide a comparison measure of pass-through:

$$px = \alpha wpusd + \alpha erusd + (1 - \alpha) cp. \quad (8)$$

Data on costs of production for variable *cp* are unfortunately not available for each commodity individually. Consequently, the indexes for all five commodities incorporate wages and material costs for the broader Food, Beverages and Tobacco industry classification (Australian and New Zealand Standard Industrial Classification (ANZSIC) Code 21). Although the indexes for each group are weighted by cost ratios as used specifically in the production of dairy products or meat products, respectively, the inclusion of the input costs of a wider range of products may limit the ability of this variable (*cp*) to accurately reflect movements in production costs for the individual commodities estimated here.[12]

4. Empirical estimation

Cointegration techniques can be used to estimate the long-run pass-through relationship represented by equation (7), provided that the method chosen allows for the possible joint endogeneity of the variables that is implied by the theoretical analysis, as discussed in Section 2. The Johansen maximum likelihood procedure was selected for this reason, as the estimation is performed within a system of equations in which all variables are explicitly endogenous. It also provides parameter estimates for all the cointegrating, or long run, relationships that may exist between the variables, and allows hypothesis testing of the restrictions implied by the model on the coefficients of individual variables (Johansen 1988; Johansen 1991).

The system of equations estimated in the Johansen method is an error correction model (ECM) derived from a standard unrestricted vector autoregressive model (VAR) of lag length k, which can be written as:

$$\boldsymbol{z}_t = \boldsymbol{A}_1 \boldsymbol{z}_{t-1} + \ldots + \boldsymbol{A}_k \boldsymbol{z}_{t-k} + \boldsymbol{\mu} + \boldsymbol{\Psi} \boldsymbol{D}_t + \boldsymbol{\varepsilon}_t \quad t = 1, \ldots, T; \ \boldsymbol{\varepsilon}_t \sim niid(0, \Sigma) \quad (9)$$

[12] Available data on production costs also do not discriminate between costs specific to exporters and those of producers, so pass-through estimates generally assume that exporters' costs are similar to production costs within the industry generally. See Goldberg and Knetter (1997) for a discussion of the use of cost indexes in the published pass-through literature.

where $\boldsymbol{z}_t$ is the $p \times 1$ vector of stochastic variables, $\boldsymbol{\mu}$ is a vector of constants, and $\boldsymbol{D}_t$ a vector of other deterministic variables such as seasonal dummies or a time trend. The VAR system of equations can be algebraically re-arranged into an ECM, written as:

$$\Delta \boldsymbol{z}_t = \boldsymbol{\Gamma}_1 \Delta \boldsymbol{z}_{t-1} + \ldots + \boldsymbol{\Gamma}_{k-1} \Delta \boldsymbol{z}_{t-k+1} + \boldsymbol{\Pi} \boldsymbol{z}_{t-1} + \boldsymbol{\mu} + \boldsymbol{\Psi} \boldsymbol{D}_t + \boldsymbol{\varepsilon}_t. \quad (10)$$

The first group of terms in the ECM represents the short-run effects of differences in the variables in $\boldsymbol{z}_t$, or $\Delta \boldsymbol{z}$, on each variable in the system. The next term, $\boldsymbol{\Pi} \boldsymbol{z}_{t-1}$, is the error correction term that represents the long-run cointegrating relationships between the levels of the variables in $\boldsymbol{z}$. If the variables are non-stationary, there may be up to $(p - 1)$ cointegrating relationships between them, with the number of cointegrating relationships indicated by the rank (r) of the matrix of long-run coefficients Π. If at least one cointegrating relationship exists, there will be $p \times r$ matrices γ and β such that $\Pi = \gamma\beta'$. The rows of matrix β' form the coefficients of the r cointegrating vectors and γ the coefficients of the error-correction term itself, so that γ can be interpreted as representing the speed of adjustment towards the long-run equilibrium (Johansen 1988; Johansen and Juselius 1990; Johansen 1991).

Johansen uses a canonical correlation technique, solved by calculating eigenvalues (λ_i), to provide a set of eigenvectors that form the maximum likelihood estimate of matrix β. Two likelihood ratio (LR) statistics, the trace statistic, and an alternative form called the Maximal Eigenvalue $(\lambda_{\max})$ statistic, are used to test the significance of the eigenvalues and therefore to determine the maximum number of statistically significant vectors (r) within β. The test statistics have asymptotic distributions that are functions of a $(p - r)$ dimensional Brownian motion, with critical values tabulated by simulation. LR statistics with the standard χ^2 asymptotic distribution can also be used to test linear hypotheses on both the cointegrating vectors (β) and the speed of adjustment coefficient (γ).

Stationarity testing of the variables was performed using Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, as well as the recursive and sequential approach of Banerjee *et al.* (1992). For all variables, test statistics showed little evidence for rejecting the null hypothesis of non-stationarity in levels, even after allowing for the possibility of a break in the series. Similarly, the combined test results for most variables in first differences indicate that they are non-stationary processes integrated of order one (I(1)). The only possible exception is the domestic export price variable *px* for beef. Here, the PP tests in first differences indicated that *px* is I(1), but the results of the ADF tests suggest that *px* may be I(2), or non-stationary in first differences.

Lag length for the Johansen estimation of all models was determined by LR tests of paired comparisons of different lag lengths in the original VAR system, as described in Enders (1995). An intercept or trend was included in the Johansen estimations where indicated by tests of the joint hypothesis of both the rank order and the deterministic components, following the Pantula principle, as described by Johansen (1992). Seasonal dummies were originally included in all models, but were retained only in those in which they proved significant. The stability of the system was confirmed after each estimation by an examination of the eigenvalues of the companion matrix, which should be less than or equal to unity in absolute value if the model converges in the long run. This procedure was also repeated after hypothesis testing of any restrictions imposed on the parameters, to ensure that the restricted system remained in agreement with the statistical model.

Table 3 shows the two test statistics for the number of cointegrating vectors (r) for each commodity. The results of the tests are not clear cut, as the asymptotic distributions are approximations to the true distributions, so that the critical values may be only indicative. Reimers (1992) suggests that the procedure tends to over reject the null when it is true, a result supported by Cheung and Lai (1993), who also report Monte Carlo results indicating that the trace test is more robust than the λ_{max} test to possible non-normality of the residuals.

For these reasons, greater weight was placed on the trace test results, as the λ_{max} statistic rejected the null more frequently, at higher values of r. The choice of r was also supported by recursive analysis of the time path of the trace statistic, where the cointegration rank corresponds to the number of test statistics that are above the 90 per cent quantile (Hansen and Juselius 1995). For example, in figure 1, only the trace statistic for the first vector in Model A for milk products is close to, or above, the 10 per cent significance level for most of the period. Using these criteria, the presence of only one equilibrium relationship ($r = 1$) was accepted for both models for milk products. For cheese, both test statistics are in agreement, indicating that the null hypothesis of a rank of one in Model A, and of two in Model B, cannot be rejected.

However, the examination of the eigenvalues of the companion matrix for both models for beef found that the modulus of the largest root was greater than unity in both cases (1.0262 and 1.0424 in Models 1 and 2, respectively). These results indicate that the ECM for both models for beef does not converge to the stable long run equilibrium relationship suggested by the theoretical model, for either destination market currencies or USD exchange rates. For sheepmeat and hides and skins, the test results for the number of cointegrating vectors shown in table 3 differs between the two alternative models. The null of $r = 0$ cannot be rejected for Model A for

Table 3 Tests for the number of cointegrating vectors

	Model A		90% critical values		Model B		90% critical values	
	λ_{max}	Trace	λ_{max}	Trace	λ_{max}	Trace	λ_{max}	Trace
Dairy products								
Milk Products								
H_0: $r = 0$	35.33*	66.57*	18.03	49.92	39.69*	68.75*	18.03	49.92
H_0: $r = 1$	19.08*	31.24	14.09	31.88	16.68*	29.05	14.09	31.88
H_0: $r = 2$	8.85	12.16	10.29	17.79	8.43	12.37	10.29	17.79
H_0: $r = 3$	3.31	3.31	7.50	7.50	3.94	3.94	7.50	7.50
Cheese								
H_0: $r = 0$	19.34*	45.88*	17.15	43.84	26.06*	69.29*	19.88	58.96
H_0: $r = 1$	13.09	26.54	13.39	26.70	20.68*	43.23*	16.13	39.08
H_0: $r = 2$	8.42	13.45	10.60	13.31	12.68*	22.55	12.39	22.95
H_0: $r = 3$	5.03	5.03	2.71	2.71	9.87	9.87	10.56	10.56
Livestock products								
Beef	System does not converge to a stable long-run equilibrium.				System does not converge to a stable long-run equilibrium.			
Sheepmeat								
H_0: $r = 0$	19.91*	41.67	17.15	43.84	32.34*	59.84*	18.03	49.92
H_0: $r = 1$	13.38	21.77	13.39	26.70	14.77*	27.50	14.09	31.88
H_0: $r = 2$	6.80	8.39	10.60	13.31	7.15	12.73	10.29	17.79
H_0: $r = 3$	1.59	1.59	2.71	2.71	5.58	5.58	7.50	7.50
Hides and Skins								
H_0: $r = 0$	20.89*	41.19	17.15	43.84	33.20*	64.49*	18.03	49.92
H_0: $r = 1$	10.09	20.30	13.39	26.70	16.93*	31.29	14.09	31.88
H_0: $r = 2$	5.78	10.21	10.60	13.31	10.19	14.36	10.29	17.79
H_0: $r = 3$	4.43	4.43	2.71	2.71	4.17	4.17	7.50	7.50

* significant at 10% level.

both sheepmeat and hides and skins, using the trace statistic and recursive analysis as before. Conversely, for Model B for both commodities, the results show that there is one cointegrating vector between the variables. These results indicate that there is no long run relationship between Australian export prices and destination market currencies for these commodities, but a cointegrating relationship does exist for the bilateral USD exchange rate.

The estimated coefficients of the cointegrating vectors are shown in table 4, normalised on the coefficient of px to correspond to the form of the long-run relationships in equations (7) and (8). Restrictions derived from the theoretical framework were then tested on the coefficients of the cointegrating vectors. The first hypothesis tested was that all coefficients satisfy the restricted model of complete pass-through in a perfectly competitive world market, that is, ($\alpha = 0$) on all coefficients in equation (7) or (8). If this hypothesis

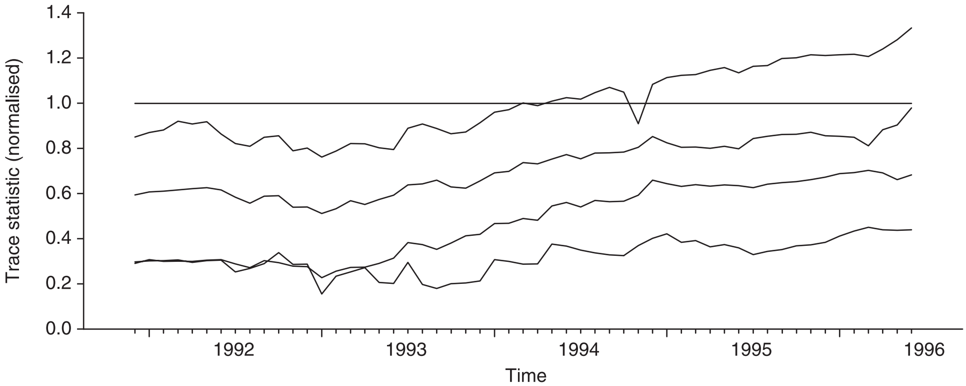

Figure 1 Milk products (Model A): time path of the trace statistics for each vector, obtained by recursive estimation (1.0 represents the 10% significance level).

Table 4 Coefficients of the cointegrating vectors (normalised on *px*)

	Model A				Model B			
	px	*wp*	*er*	*cp*	*px*	*wpusd*	*erusd*	*cp*
Dairy products								
Milk Products								
Vector 1:	1	0.20	0.29	2.00	1	0.02	0.33	2.08
Cheese								
Vector 1:	1	–0.29	0.22	2.16	1	0.98	–1.05	–1.94
Vector 2:	1				1	–0.39	0.91	2.64
Livestock products								
Beef	System does not converge to a stable long-run equilibrium.				System does not converge to a stable long-run equilibrium.			
Sheepmeat								
Vector 1:	No cointegrating vectors found.				1	–0.83	0.41	1.82
Hides and Skins								
Vector 1:	No cointegrating vectors found.				1	1.27	2.28	0.98

was rejected for a particular model, the restrictions were progressively loosened by permitting the coefficients on firstly *cp*, and then *wp* or *wpusd*, to be unrestricted. This sequence of testing allows for variations in the responses of exporters to different influences, while retaining the hypothesis that pass-through is complete for exchange rate changes, that is, the restriction that ($\alpha = 0$) in the coefficient on *er* and *erusd*.

In addition, the weak exogeneity of variables for the system was tested by combined hypotheses that included restrictions on the speed of adjustment coefficients (γ) on the cointegrating vectors in each equation of the system. This coefficient represents the rate at which each variable adjusts to the long run or cointegrating equilibrium. If γ is equal to zero in the equation for *px*, for example, then the cointegrating vector is not a significant determinant of changes in the variable *px*, and *px* is said to be weakly exogenous to the system.

If these combined hypotheses were not rejected, the model was conditioned on the weakly exogenous variables, and the partial system re-estimated to improve stochastic properties. The presence of serial correlation was rejected in all final models, using Lagrange-Multiplier tests at the 5 per cent significance level. There was, however, some evidence of non-normality in some equations, although this appeared to be as a result of kurtosis, which Johansen (1995, p. 29) notes is a less serious problem as the 'asymptotic properties of the methods only depend on the i.i.d. assumption of the errors.' Table 5 presents the final results of hypothesis testing of the identified models, including the speed of adjustment coefficients for each vector in the equation for domestic currency export prices (*px*).

5. Results

The tests of restrictions shown in table 5 give results that are very similar for milk products and cheese. The restricted model of complete pass-through represented by equation (8), that is, ($\alpha = 0$) on all coefficients, was accepted in its entirety in the first vector of Model B for cheese and was the most strongly supported hypothesis, with a *p*-value of 0.82. Although a second cointegrating vector was found here, the low *t*-value (0.50) on the speed of adjustment coefficient in the equation for *px* indicates that this second long-run relationship is not a significant determinant for Australian export prices. The hypothesis of the complete pass-through of exchange rates and world prices, that is ($\alpha = 0$) in the coefficients on *er*/*erusd* and *wp*/*wpusd*, was also accepted for the single cointegrating vectors in Model A for cheese, and in both models for milk products.

All of the estimated models therefore demonstrate the full pass-through of exchange rates changes expected in perfectly competitive market structures. These results support the view that, unlike the major destination markets from which they are largely excluded, the non-quota markets in which Australian dairy products are sold are 'subject to global competition' (Industry Commission 1991, p. 24). The similarity of results between Model A and Model B for both commodities also reflects the importance of the USD as the contract currency for dairy products, with around 70 per cent of Australian exports currently invoiced in USD (ABS 2003).

The stability of the parameters was investigated by recursive estimation over the second half of the period, commencing in December 1991, with

Table 5 Tests of restrictions on cointegrating vectors

	Model A					Model B				
	Coefficients under restriction (β)				Speed of adjustment	Coefficients under restriction (β)				Speed of adjustment
	px	*wp*	*er*	*cp*		*px*	*wp*	*erusd*	*cp*	
Dairy products										
Milk Products										
Vector 1:	1	0	0	1.98	–0.22 (–5.85)**	1	0	0	1.96	–0.23 (–5.71)**
	LR test of restrictions on β: *p*-value = 0.16†					LR test of restrictions on β: *p*-value = 0.09†				
Cheese										
Vector 1:	1	0	0	2.07	–0.14 (–4.32)**	1	0	0	1	–0.18 (–4.18)**
Vector 2:						1	–0.67	1	3.27	0.02 (0.50)
	LR test of restrictions on β: *p*-value = 0.63‡					LR test of joint restrictions on β in Vector 1 and Vector 2: *p*-value = 0.82§				
Livestock products										
Beef	System does not converge to a stable long-run equilibrium.					System does not converge to a stable long-run equilibrium.				
Sheepmeat										
Vector 1:	No cointegrating vectors found.					1	–0.80	0	1.71	–0.07 (–1.93)
						LR test of joint restrictions on β and weak exogeneity of *px*: *p*-value = 0.10§				
Hides and skins										
Vector 1:	No cointegrating vectors found.					1	1	1	1.19	0.01 (0.28)
						LR test of joint restrictions on β and weak exogeneity of *px*: *p*-value = 0.82§				

Numbers in brackets are *t*-values: ** significant at 1% level, * significant at 5% level. † In partial model conditioned on variable *cp* as weakly exogenous; ‡ in partial model conditioned on variables *er* and *cp* as weakly exogenous; § in full model.

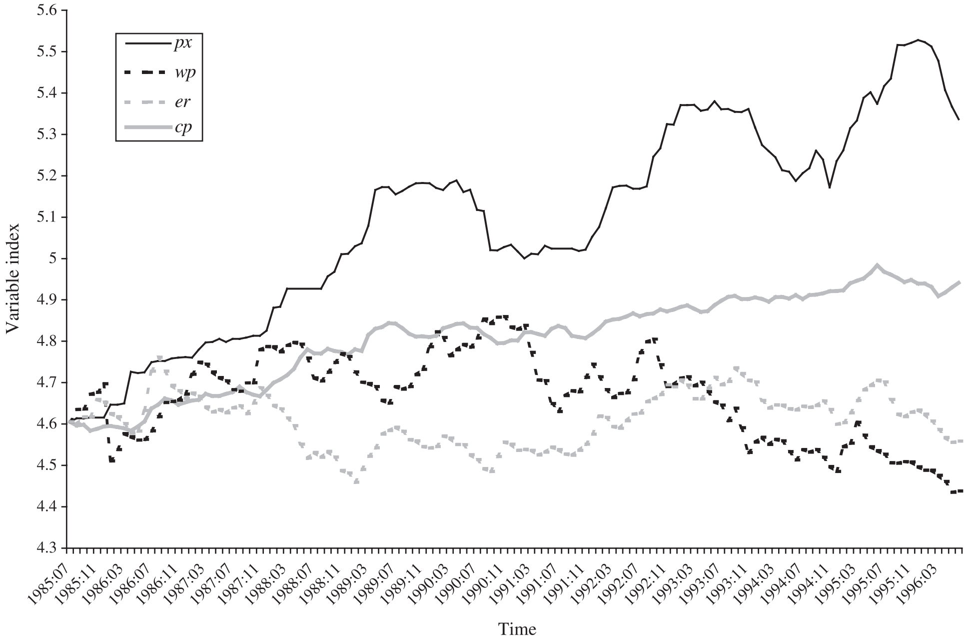

Figure 2 Milk products (Model A): all variables (ln form), indexed on the start of period.

the first half of the sample used as the base period. Tests of the hypothesis that the full sample estimate of the restricted cointegrating vectors is within the cointegration space for each subsample were accepted at the 5 per cent significance level for all models, indicating that the parameters for both commodities have remained constant over the period (Hansen and Juselius 1995). There is therefore no evidence of dynamic effects on the exchange rate relationship, either through strategic behaviour by imperfectly competitive exporters, or through the effects of NTB. For these dairy exports then, an exchange rate change, such as a 5 per cent depreciation, for example, would be expected to result in a 5 per cent decrease in foreign currency prices and a concomitant increase in demand.

The large coefficients on the cost of production variables in most models, however, are difficult to explain, but may reflect the lack of sufficiently disaggregated data to act as proxies for input costs for individual commodities, as discussed previously. (The long run relationship between *px* and *cp* can also be demonstrated graphically. For example, the variables in Model A of milk products, shown in figure 2, seem to be in keeping with the coefficient of around two found in the cointegrating vector.). Alternatively, they may be the result of other influences on the models, such as changing product attributes, or the introduction of new technology and microeconomic reforms that may have improved the relative cost efficiency of the domestic

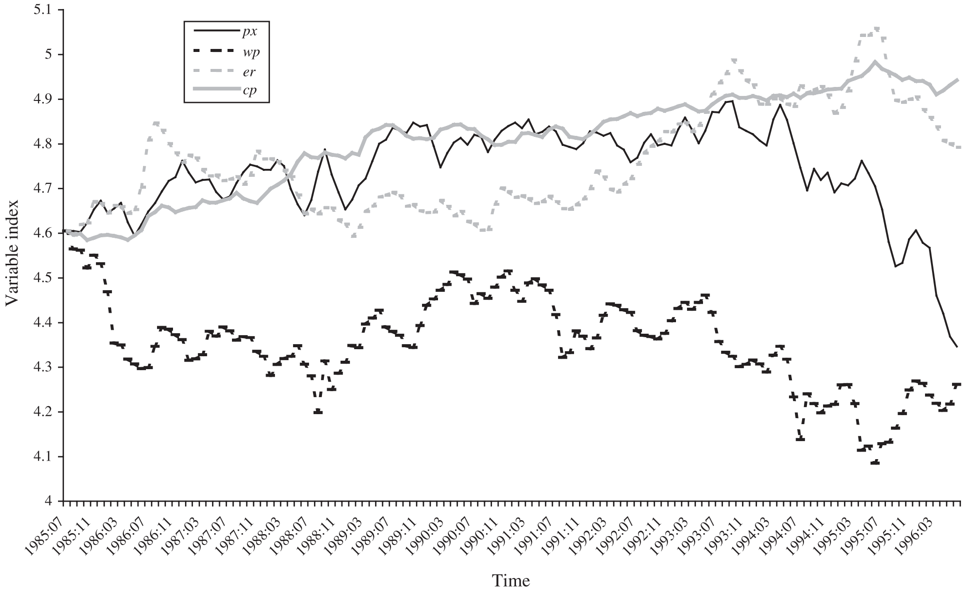

Figure 3 Beef (Model A): all variables (ln form), indexed on the start of period.

industry over the period (Industry Commission 1991). The production cost variable was also found to be weakly exogenous in most models, indicating that there are no exchange rate induced effects on input costs, or any feedback effects from export prices to costs.

The results for the three commodities in the livestock products group in table 5 are very different from those of the dairy products group. None of the livestock-based commodities, beef, sheepmeat or hides and skins, shows the stable long-run pass-through relationship that is expected in a perfectly competitive market. (Graphs of the variables, for example those of Model A for beef in figure 3, also show little indication of a consistent or stationary long run relationship between the variables over the period). For beef, a possible explanation for the failure of the model to converge to a long run equilibrium may lie in the conflicting results of the stationarity tests for variable *px*, as discussed previously. The assumption underlying the ECM model is that all variables are integrated of the same order, that is, I(1). If variable *px* is I(2), as indicated by the results of the ADF tests, its inclusion is likely to generate an explosive data process instead of converging to a stationary long-run equilibrium. In this case, a stationary long-run relationship could exist only if the export price variable (*px*) were included in first differenced form, which conflicts with the specification of the theoretical models of pass-through currently found in the published literature. As the main focus of the present paper has been to determine whether the long run pass-through relationship predicted by the theoretical models is present for these commodities, this issue has not been investigated further here.

Previous studies for beef have reported similar econometric and data problems, for example, poor explanatory power, persistent serial correlation, and inconsistent signs on coefficients (Jabara and Schwartz 1987; Alston *et al*. 1992; Patterson *et al*. 1996). The authors have suggested that their results indicate the importance of other factors specific to the beef market, particularly import quotas and differences in product quality. Although these past studies did not take account of the possible non-stationarity of the data, the instability found in the long run relationship here does appear consistent with the effects expected from the presence of NTB.

For sheepmeat and hides and skins, the only long-run relationships found were the single cointegrating vectors in Model B. For both commodities, however, the low *t*-values on the loadings in the cointegrating vectors in the equation for *px* suggest that *px* is weakly exogenous for these relationships. This conclusion was confirmed in both cases by the LR test of the joint restrictions on the cointegrating vectors and the speed of adjustment coefficients. These results indicate that the long-run cointegrating vector is not a significant determinant of changes in domestic currency export prices for either commodity. Domestic currency export prices are then influenced solely by the short-run dynamics in the system, that is, the lagged differenced variables in equation (10). The short-run exchange rate effects are significant for only one lag for both models of sheepmeat, but persist longer, for two lags and six lags for Model A and Model B, respectively, for hides and skins.[13]

As for beef, the absence of a significant long run pass-through relationship between exchange rates and export prices is consistent with the effects expected from the presence of NTB in the markets for these commodities. Restricted access to international markets has been considered one of the major impediments to the development of markets for these products. International trade represents only a small proportion of world production, so that changes in access restraints can have pronounced effects on both volume and prices in world trade. Although Australia is a major exporting nation, its reliance on a few major destination markets renders these products particularly vulnerable to such changes in market arrangements. For example, prior to 1992, the USA was the largest single market for Australian beef, and the second largest for sheepmeat. This trade was reduced by

[13] The full results of the econometric estimations are available from the author on request. As the primary purpose of the present study is to test for the existence of the linear long run pass-through relationship predicted by the theoretical models, other possible forms of cointegration, such as non-linear relationships, were not investigated.

20 per cent in the early 1990s by successive tightening of restrictions under the US Meat Import Law. Similarly, quotas have also limited exports into the major destination markets of Canada, Korea and the EU (Industry Commission 1994).

Data limitations have prevented the extension of the period of estimation in the present study beyond the end of 1996. However, an examination of the effects of subsequent trade reforms may throw some light on possible changes in exchange rate pass-through for the dairy and livestock industries since 1997. The Uruguay Round Agreement on Agriculture aimed to improve market access by the conversion of NTB to tariff equivalents or tariff rate quotas (TRQ), operating through a small in-quota tariff and a higher above-quota tariff. These tariffs were then to be progressively reduced over time. For the dairy industry, the reduction in import barriers has been minimal. Access allowed to major markets under tariff-quotas remains small compared to consumption in these countries, and above-quota tariff rates are so high that the agreed reductions in rates have had little impact (Andrews 2001). In these circumstances, it seems unlikely that there would have been any significant change in the pass-through relationship for milk products and cheese.

For the other livestock products, experiences have been mixed. The Meat Import Law in the USA was replaced by a TRQ in 1994, but the quota for beef was set so high that it became a constraint only after December 2001 when the bovine spongiform encephalopathy (BSE) outbreak reduced demand in the Japanese market (Riley *et al.* 2002). Conversely, the TRQ on lamb imports introduced by the USA in 1999 has been set at levels that are expected to substantially reduce growth into what had been Australia's fastest growing export market (Shaw 1999). The removal of quotas and the subsequent reductions in tariffs to Japan have allowed significant expansion of this market, but quotas on livestock products into other countries, particularly the large markets of the EU, have been largely unaffected (Rose and Gleeson 2000). Concern has also been raised over the increasing use of non-quota barriers such as quarantine and inspection requirements and restrictive administrative arrangements (Roberts *et al.* 2002). While some improvement would be expected in the markets in which access has been liberalised, many restrictions that have the potential to disrupt the long-run pass-through relationship still remain.

The conversion of NTB to TRQ under the Uruguay Round agreements has begun the process of dismantling trade barriers for these commodities. However, the results obtained here indicate that the further reduction in the tariffs imposed under TRQ and the removal of other non-quota restrictions proposed under the current Doha multilateral trade round have the potential to not only increase the volume of trade, but also to ensure that countries receive the full benefits of the changes in relative prices that should occur under flexible exchange rate regimes. In practice, this means that countries whose currencies have been appreciating over the last few years, such as the USA, should benefit from cheaper imports, while countries whose currencies have been depreciating, such as Australia, should experience increased demand for their exports. The full and uninterrupted pass-through of exchange rate changes is vital in ensuring that changes in relative prices, and the resulting trade flows, accurately reflect relative costs of production. Removing the impediments that hinder this process will enable both importing and exporting countries to gain benefits both from an increase in trade, and from the production of the goods in which each has a comparative advantage.

The main focus of the present paper has been on testing for the existence of the long run relationship predicted by the published theoretical literature on exchange rate pass-through. However, the absence of the expected continuous long run pass-through relationship for the livestock commodities is only indicative of the influence that NTB have on exchange rate effects in these markets. Other factors specific to these commodities, such as the differences in product quality and availability raised by Jabara and Schwartz (1987) and Patterson *et al*. (1996) may also lead to discontinuities in the relationship between exchange rates and export prices. For Australia, Chang and Griffith (1998) have also suggested that some participants in domestic beef markets practice price levelling, or the maintenance of relatively stable wholesale and retail prices in the face of changing procurement costs. If this practice extends to the stabilisation of export prices against volatile exchange rate changes, it too could result in a discontinuous long-run relationship. Further research is needed to more precisely identify the influences on exchange rate pass-through for these commodities, particularly in the areas of the effects of NTB in individual destination markets, effects on other stages of the price transmission process and at higher levels of commodity disaggregation, and relationships involving alternate forms of stationarity of the variables.

6. Conclusion

The present study examined the pass-through of exchange rate changes to the foreign currency and USD prices of five Australian agricultural exports: milk products, cheese, beef, sheepmeat, and hides and skins, from 1985 to 1996. For the two dairy products, a long run cointegrating relationship representing the complete pass-through of exchange rate changes was found in all models, indicating that an exchange rate change would result in an equiproportionate change in the foreign currency prices of these products, and a subsequent change in demand. The results support both the competitive nature of the non-quota markets in which Australian dairy products are sold, and the importance of the USD as the trading currency for dairy exports.

None of the models for the three livestock products, beef, sheepmeat or hides and skins, was found to have a stable long-term relationship that was significant for Australian export prices. However, all of these commodities have been severely affected by quotas and other NTB in major destination markets over the period. In the presence of access restraints such as these, previous theoretical models have shown that pass-through is expected to vary over time to generate a discontinuous relationship similar to that found here. The effects of exchange rate changes for these products will be dependent on the size of the exchange rate change and the level and nature of the trade barriers in each destination market. Since the end of the estimation period, some liberalisation of significant markets has occurred as a result of the Uruguay Round agreements, raising the hope that further improvements under the current Doha Round may result in a return to the complete exchange rate pass-through expected in a perfectly competitive market.

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Data appendix

All variables are monthly, seasonally unadjusted, indexes in logarithmic form, constructed using 1989/1990 period averages as the base value, covering the period from July 1985 to June 1996 inclusive.

px (Domestic Export Prices in Australian dollars (AUD)): These indexes represent the export-weighted average price in AUD received by Australian exporters from all Australian export markets for each commodity. The indexes for each commodity are compiled by the Australian Bureau of Statistics (ABS) using the following Standard International Trade Classification (SITC) codes:

Milk products: SITC 022 (concentrated milk and cream products, mainly powdered milk);

Cheese: SITC 024 (mainly hard and semihard cheeses, e.g., cheddar);

Beef: SITC 011(.11-.22) (mainly chilled or frozen boneless beef);

Sheepmeat: SITC 012(.11-.13) (mainly chilled or frozen sheepmeat);

Hides and skins: SITC 211(.11-.13, .20) (mainly raw hides and skins, fresh).

Source: ABS., Catalogue no. 6405.0 (unpublished data). Further details of the calculation of the export price indexes and commodity descriptions are available in, ABS (1995) and ABS (1989), respectively.

erusd (Nominal Exchange Rate in units of AUD per US dollar (USD))

er (Nominal Effective Exchange Rate): Export weighted index of the bilateral destination market exchange rates for each commodity, expressed in units of AUD per unit of foreign currency. The export-weighted exchange rate index for commodity i in period t is calculated as:

$$er_{it} = \ln \sum_{j=1}^{n} \left(\frac{e_{jt}}{e_{j0}} \times \frac{\omega_{ij}}{\omega_{iT}} \right) \tag{11}$$

where e_{jt} is the nominal bilateral exchange rate in terms of AUD per currency unit of country j in period t, e_{j0} is the same exchange rate in base period 0 (here represented by the 1989/1990 period average), ω_{ij} is the value of Australian exports of commodity i to country j in period t, and ω_{iT} is the total value (T) of Australian exports of commodity i to all n countries in period t (Lipsey *et al*. 1991). The indexes use annual weights based on the share of Australian exports of each commodity for 41 countries, so that each index represents as far as possible the export-weighed average exchange rate for all Australian export markets, as used to calculate the export price indexes for each commodity above.

Sources: IMF International Financial Statistics (series rf); RBA Bulletin table F.9 (New Taiwan dollar only); ABS, Catalogue nos. 5410.0, 5422.0, 5423.0, and 5424.0 (including some unpublished data).

wpusd (World or Competitors' Prices in USD): Movements in world prices are represented by indicator market prices from the United Nations or IMF commodity price indexes for each commodity that correspond most closely to the commodity types included in the export price indexes. The indexes are all derived from specific price quotations denominated in USD for representative grades of the commodity in countries that are recognised as major world traders of that commodity. For milk products and cheese, individual prices for several representative grades of the commodity are weighted by share in the value of total world exports of the commodity in 1980 (United Nations 1991).

Source: UN Monthly Bulletin of Statistics Primary Commodity Price Index for milk and milk products, and cheese; IMF International Financial Statistics Commodity Prices, Series 76k, 76pf and 76p, for beef, sheep meat and hides and skins respectively.

wp (World or Competitors' Prices in destination currencies): World price indexes calculated above (*wpusd*) are converted to a destination currency index for each commodity using monthly average exchange rates in units of national currency per USD. These indexes use the same countries and weights as for *er* above because they are designed to represent movements in world or competitor prices in domestic currency terms in all the Australian export markets for each commodity.

cp (Domestic Cost of Production in AUD): Weighted average of award rates of pay index (weekly: fulltime adult employees) and price index of materials used for ANZSIC code 21 (Food, Beverages and Tobacco). Weights are calculated as the average of input-output weights for 1986/1987, 1989/1990 and 1992/1993 for IOIC Codes 2102 Dairy products (wages 0.1118, materials 0.8882) and 2101 Meat products (wages 0.1382, materials 0.8618).

Sources: ABS, Catalogue nos. 5209.0, 6312.0, and 6411.0.