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# Influence of Trade Policies on Price Integration in the World Beef Market

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## Abstract

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The article develops three hypotheses about how policy interventions in major trading nations influence price integration in the world beef market. Simple correlation coefficients, tests for significant differences between coefficients, and Granger causality tests are used to test the hypotheses. First, segmentation between prices in Foot and Mouth Disease (FMD)-free and FMD-endemic countries is found, but it is much less than previously assumed. Second, European Community policies that closed the E.C. import market have isolated prices in the E.C. from other markets. These policies also led to greater integration among prices in FMD-free and FMD-endemic market segments by forcing exporters from both segments to compete directly in new import markets. Third, the U.S.A. is found to be the price leader in world beef markets, due not only to market size, but also to U.S. policies that allow transmission of price information from the U.S. market to the world market but not vice versa.

## Introduction

It is widely recognized that certain kinds of trade policies can increase instability in world prices (Bale and Lutz, 1979; Sarris and Freebairn, 1983; Monke and Salam, 1986), but the influence of trade policies on border price integration in an international market has received less attention.[1] Policy interventions of major trading nations can create a segmented or thin international market which can raise transactions costs and thereby reduce price in-

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[1]An exception is Petzel and Monke's (1979-80) study of the world rice market.

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tegration. The extent to which one international price series can substitute for another is a concern for researchers who need a 'world' price to model a commodity market and for policy makers who need an indicator of the social opportunity cost of domestic production.

This article examines how policy interventions in the major trading nations influence the process of price formation in the world beef market. It is frequently assumed that restrictions on trade from countries where Foot and Mouth Disease (FMD) is endemic have split the world beef market into two segments. Yet past studies have examined only price transmission in the FMD-free beef trade between the United States of America and Australia (Houck, 1974; Hinchy, 1978; Roberts and Martin, 1985). There has been no evaluation of overall price integration in the world beef market.

In addition to phytosanitary restrictions, trade policies in the two largest importers also shape the pattern of price discovery in the world beef market. The U.S.A. is the world's largest domestic and import market for beef. Because of its size, Simpson (1979) hypothesized that the U.S.A. is the world price leader. It will be demonstrated below that the U.S. is the world price leader not only due to market size, but also because U.S. policies allow transmission of price signals from the U.S. domestic market to the world market, but not vice versa.

As a result of trade protection, the European Community shifted from the world's second largest net importer of beef in the early 1970s to the world's largest exporter of beef in 1985. The E.C. was the major FMD-endemic importer. The closing of the E.C. market should have brought about greater integration between the FMD-free and FMD-endemic segments of the world market by forcing FMD-endemic exporters to compete more directly with FMD-free exporters in new markets.

Simple correlation coefficients, tests for significant differences between coefficients, and Granger (1969) causality tests will be estimated with first-differenced price data to test the above hypotheses concerning price integration in the world beef market. The degree of FMD segmentation will be tested by examining the difference in integration across segments compared to within segments, and the time lag in transmission of price information across segments. The effect of growing E.C. protection of domestic beef production is tested by comparing patterns of price integration before and after 1974. This year is chosen because a major beef importer, the United Kingdom, joined the E.C. in 1973, and because the E.C. was no longer a net importer of beef after 1974. Finally, the price leadership role of the U.S. will be tested directly with Geweke's (1984) model of Granger causality. The article begins with a review of the literature on policy interventions in the world beef trade in order to develop the price integration hypotheses.

## Structure of the world beef market and price integration hypotheses

The U.S.A., the E.C. and Japan are three of the four largest importers of beef in the world, and all restrict imports to sharply below free trade levels (Simpson and Farris, 1982). These trade restrictions are one reason why world trade in beef is a small proportion of world production. If the intra-EC beef trade that takes place behind the variable levy system is subtracted, then the world beef market is thinner than the world market for any other major commodity except rice (Table 1). This relatively thin market can mean higher transactions costs for buyers and sellers, and hence, less rapid price transmission than in most commodity markets.

In addition to being relatively thin, until recently the world beef market was segmented into two major trade flows. In the 1960s, Argentina and Australia sold about half of total world beef exports, while the U.K. and the U.S. bought about half of world beef imports (Table 2). The pattern of trade flows was largely determined by health and sanitary restrictions on imports of fresh, chilled, and frozen beef from countries where FMD is endemic. Exports of fresh or frozen beef from FMD-endemic Argentina are not allowed into the U.S., which is FMD-free. Therefore most Argentine beef exports went to the U.K. and other European countries that are also FMD-endemic. Australia is FMD-free, so most Australian exports went to the U.S. Some Australian exports also went to the U.K., as FMD-free beef can move into FMD-endemic markets, but not vice versa. This segmentation of the market into two major flows, Argentina to Europe, and Australia to the U.S., led most observers to

TABLE 1

World commodity trade 'thinness' comparison (1982–85 average)

| Commodity | Exports (MMT) | Production (MMT) | Exports as a percent of production |
|---|---|---|---|
| Soybean meal | 22.3 | 57.9 | 38.5 |
| Soybeans | 26.7 | 89.9 | 29.7 |
| Wheat | 102.5 | 495.3 | 20.7 |
| Sorghum | 12.5 | 63.4 | 19.8 |
| Corn | 63.6 | 413.9 | 15.4 |
| Beef | 4.7 | 41.7 | 11.2 |
| Pork | 3.2 | 50.5 | 6.4 |
| Beef[a] | 2.6 | 41.7 | 6.2 |
| Rice | 12.0 | 446.6 | 2.7 |

MMT, million metric tonne.
Source: USDA-FAS: Foreign Agriculture Circulars, Grains; Oilseeds and Products; Livestock and Poultry Situation (various issues).
[a]Excludes intra-E.C. trade.

TABLE 2

Trade shares of the major beef trading nations (percent)

| | 1961-63 | 1970-74 | 1976-80 | 1978-82 | 1983-86 |
|---|---|---|---|---|---|
| *Exporters*[a] | | | | | |
| Argentina | 29 | 18 | 19 | 17 | 8 |
| Australia | 19 | 21 | 31 | 29 | 20 |
| Brazil | 2 | 5 | 5 | 6 | 12 |
| E.C. | - | - | 11 | 12 | 22 |
| Central America | - | - | 4 | 3 | 2 |
| New Zealand | 9 | 9 | 11 | 10 | 9 |
| Uruguay | 4 | 4 | 4 | 4 | 5 |
| United States | - | - | 2 | 3 | 5 |
| *Importers* | | | | | |
| Brazil | - | 0 | 2 | 2 | 3 |
| Canada | 1 | 3 | 3 | 2 | 3 |
| E.C.[b] | - | - | 15 | 17 | 15 |
| Egypt | - | - | 2 | 2 | 4 |
| France | 1 | 5 | 6 | 7 | 8 |
| Italy | 8 | 12 | 9 | 10 | 12 |
| Japan | - | 4 | 4 | 5 | 6 |
| United Kingdom | 28 | 15 | 13 | 11 | 8 |
| United States | 35 | 30 | 27 | 25 | 23 |
| U.S.S.R. | 2 | 3 | 7 | 8 | 11 |
| West Germany | 5 | 9 | 7 | 7 | 7 |

[a]The last three columns above are percentages of total beef exports excluding intra-E.C. trade, whereas the first two columns are percentages of total beef trade. Separate data are not available on intra-E.C. trade before 1976.
[b]E.C. import percentage is excluding intra-E.C. trade in both numerator and denominator, whereas all other percentages are based on figures that include intra-E.C. trade in the denominator.
Source: USDA-FAS: Foreign Agriculture Circular, Livestock and Poultry (various issues).

hypothesize that the world beef market was segmented into FMD-free and FMD-endemic trade (Simpson and Farris, 1982; Jarvis, 1986). Changes in supply and demand in one segment would affect the other segment only slowly and prices in the two segments were not expected to move closely together.

During the mid-1970s the structure of the world beef market changed. The enlargement of the E.C. to include the U.K. (among others) in 1973, and the growing level of protection for beef production within the E.C. (discussed below) cut off the major Argentine market. As a result, Argentina's share of world exports fell to only 8% in the early 1980s (Table 2). Argentina was forced to seek out new markets in FMD-endemic North Africa and the Middle East. As protected production grew within the E.C., the Community began to subsidize exports of beef to reduce stocks, and the E.C. share of world exports grew rapidly in the 1980s (Table 2). During the late 1970s and the early 1980s, there

was also growth in demand for beef imports in East Asia, the Middle East, North Africa, and the Soviet Union. As a result of these changes, world beef trade, and import demand in particular, became much less concentrated in the 1970s and early 1980s (Table 2).

The closing of the E.C. market and the growth in new import markets caused the two traditional exporters, Australia and Argentina, to compete more directly in new markets. This should have reduced the traditional split of trade between FMD segments, and should also have increased price integration between the two major exporters, Argentina and Australia.

In addition to health and sanitary restrictions, tariffs and quotas in the two major import markets also influence price integration in the world beef market. The U.S., the largest beef importer, has a quota on beef imports. A fixed quota would insulate world prices from domestic price movements, and vice versa. However, in practice U.S. imports have varied inversely with the size of domestic production (Reeves and Longmire, 1982). The meat import law in force from 1964 to 1979 gave discretionary power to implement the quota, and it was not enforced in years of high prices. Since 1979, the import quota is based on a formula that is 'countercyclical', i.e. imports increase when domestic production falls.[2] Changes in the quota will transmit some price information to the world market by changing the size of import demand.

Furthermore, exporters to the U.S. voluntarily restrain their exports in order to capture the implicit rent from the quota (Reeves and Longmire, 1982; Allen et al., 1983).[3] For example, Australia, the major exporter to the U.S., voluntarily restrains its exports through export licensing. This allows Australian exporters to obtain higher prices for exports to the U.S. market. These higher prices are in turn reflected in domestic Australian prices (Hinchy, 1978; Reeves and Longmire, 1982). Changes in the quota and the transfer of quota

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[2]From 1964 to 1979 the law defined the quota as a percentage of domestic production, and therefore it tended to grow with the size of the domestic market. However, the quota was not binding from 1965 to 1967. Furthermore, it was lifted entirely during the high beef price years 1972 through 1975. See Allen et al. (1983) for further details of the 1964 law.

Since 1979 the import quota has been determined by a formula that adjusts a basic fixed quota for variations in domestic production and cow slaughter. The quota increases with long run growth in production and declines when cow slaughter increases. The latter adjustment tends to reduce imports during periods of herd liquidation and low prices. See Simpson (1982) for further details of the 1979 law.

[3]These references do not clarify how the two major exporters to the U.S., Australia and New Zealand, divide the U.S. market. Allen et al. (1983) refer to the export supply side of the U.S. market as a duopoly but do not elaborate on how it functions.

VERs might also be expected to have an influence on supply and prices offered to importers other than the U.S. Reeves and Longmire (1982) show that the effect of the VER on prices in other markets is indeterminate. We cannot test these effects because we did not obtain a quarterly Japanese beef import price series.

rents to exporting countries transmits price information from the domestic market in the U.S. to exporting countries.

As the U.S. is the world's largest beef importer, Simpson (1979) has hypothesized that the U.S. cattle cycle is the leading indicator of world price changes. Size of market, however, is not the only reason the U.S. may be the price leader rather than a price taker. The way in which the U.S. beef import quota is administered allows price information to be transmitted from the U.S. to the world market, but not from the world market to the domestic U.S. market. An increase in U.S. demand has been reflected in an increase in the quota and in prices received in Australia. But an increase in Australian supply does not alter the quota or reduce prices in the U.S.

As mentioned above, policies in the E.C. have had a major impact on world beef trade. The Community began in 1968 to implement a set of policies designed to completely isolate the domestic market for beef from the world market. A 'guide' price is set that is well above world prices and any beef imports into the E.C. are subject to a variable levy equal to the difference between the guide price and the border price. An intervention price is also set at some percentage of the guide price, and the E.C. purchases beef when market prices fall below the intervention price.[4] As a result of high, stable prices, E.C. beef production grew and reached self-sufficiency in 1974. Growth in Community beef supply led to an increasing divergence between market prices and the intervention price in many Community countries in the 1980s.[5] To reduce the supply of beef, exports are subsidized by the E.C., and exports grew rapidly from 1980 to 1987.

As a result of E.C. policies, beef prices within the Community have become increasingly isolated from world prices over time. However, the growth in subsidized beef exports increases world export supply, thus transferring some of the influence of the growth in supply and fall in Community market prices onto the world market.

In summary, the trade restrictions in the world beef market lead to three major hypotheses concerning the integration of beef prices in major trading countries. First, prices in the FMD-free and FMD-endemic segments of the international market are not expected to move closely together. The second hypothesis is that changes in the structure of the world market as the E.C.

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[4]The intervention (or buy-in) price has usually been 90 percent of the guide price. Intervention between 1972 and 1986 occurred in a particular country whenever the E.C. market price was below 98% of the guide price and market prices in the country were below the intervention price.

[5]In recognition of the growing difficulty of defending the intervention price, the procedure for setting the intervention price changed in 1986. It is now a lower percentage of the guide price, particularly in countries with an oversupply of beef. Intervention operates in any one country only if the average E.C. market price is less than 91% of the intervention price, and if the market price in that country is lower than 87% of the intervention price. However, the variable levy is still set with respect to the guide price.

shifted from a net importer to a net exporter of beef altered the pattern of price integration. Specifically, E.C. policies should have isolated internal E.C. prices from world prices, and brought about greater integration between the FMD-free and FMD-endemic segments of the market by forcing Argentina to compete more directly with Australia in new markets. Third, the U.S. is hypothesized to be the world price leader, because it is the largest beef importer and its trade policies allow transmission of price signals from the U.S. domestic market to the world market, but not vice versa.

## Methodology and data

In order to test the above hypotheses, two different methodologies are used. First, simple Pearson correlation coefficients are estimated for first-differenced quarterly price series from the major beef trading nations. The usefulness of correlation coefficients is limited by the underspecification of the relationship between the two prices (Harriss, 1981; Petzel and Monke, 1979–80), but they give a reasonable first approximation of price relationships. To correct for non-stationarity in the time-series price data, first differences of the original data are used in the analysis. Correlograms of the first differenced data showed little or no evidence of any remaining non-stationarity.

The correlation coefficients are tested for significant differences between FMD-free and FMD-endemic portions of the market, using the following statistic (Anderson, 1984, p. 122–124):

$$V=\frac{|z_1-z_2|}{\sqrt{1/(N_1-3)+1/(N_2-3)}} \tag{1}$$

where $z=1/2\ \log[1+r/(1-r)]$, $N$ is the number of observations, and $r$ the correlation coefficient. If $V$ is greater than 1.96, then the two correlation coefficients are significantly different from each other at the 5% level. Correlation coefficients are also compared for the time periods 1962–1973 and 1974–1985 to discover changes in price integration over time.

The direct Granger approach suggested by Geweke (1984) is also used to test for leads and lags in the process of price discovery. While this methodology has been widely employed to test 'causality' between economic variables, it is not used here to infer causality. Rather, the tests of lead/lag relationships give insight into delays in the process of price transmission and also test whether the U.S. market is a price leader.

The direct Granger approach uses ordinary least squares regression to estimate the relationship between economic time series. To test for Granger causality running from $X$ to $Y$ the following models are specified (1969):

$$Y_t = a_{10} + \sum_{j=1}^{p} a_{1j} Y_{t-j} + u_{1t} \tag{2}$$

$$Y_t = a_{20} + \sum_{j=1}^{p} a_{2j} Y_{t-j} + \sum_{k=1}^{q} b_{2k} X_{t-k} + u_{2t} \tag{3}$$

where $u_{1t}$ and $u_{2t}$ are white noise residuals, $a_{1t}$ and $a_{2t}$ are parameters relating $Y_t$ and its lagged values, and $b_{2k}$ are parameters relating $Y_t$ and the past values of $X_t$.

The following hypothesis is tested with equations 2 and 3:

$$b_{21} = b_{22} = \ldots = b_{2q} = 0$$

by using the following $F$ statistic:

$$F^* = \frac{\dfrac{\mathrm{SSE}_1 - \mathrm{SSE}_2}{q}}{\dfrac{\mathrm{SSE}_2}{N-p-q-1}} \tag{4}$$

where $\mathrm{SSE}_1$ and $\mathrm{SSE}_2$ refer to the sum of squared errors from the OLS regressions indicated in equations (1) and (2), $N$ is the number of observations in the time series $Y_t$, and $F^*$ is distributed $F$ with $(q, N-p-q-1)$ degrees of freedom. If $F^*$ is sufficiently larger, then the null hypothesis that $X$ does not cause $Y$ is rejected, and unidirectional causality from $X$ to $Y$ is indicated; $X$ and $Y$ are reversed in equations (1) and (2) to test for causality running from $Y$ to $X$. If the null hypothesis is rejected in both cases, a feedback relationship exists.

Schwarz's Bayesian Information Criterion (BIC) is used to select the value of $q$ in equation (3), and for convenience, all $p=q$. The BIC selects the appropriate AR order as follows:

$$\mathrm{BIC(p)} = \min \{\mathrm{BIC}(k) \mid k=0, 1, \ldots, q\} \tag{6}$$

$$\mathrm{BIC(k)} = \ln \mid \hat{\Sigma}_k \mid + \frac{d^2 k \ln T}{T} \tag{7}$$

where $p$ is the order estimate which is the value $k$ at minimum, $\mathrm{E}\, u_t u_t' = \Sigma_k$, $\hat{\Sigma}_k$ is the maximum likelihood estimate of $\Sigma_k$ computed under the assumption that an AR $(k)$ is the true model, $T$ is the number of observations in the time series; $d$ is the dimension of the model, and $q$ is a chosen upper bound for the AR process.

The lag structure selected by the BIC did not always remove serial correlation from the residuals, as indicated by a significant Ljung-Box Q test for white noise in the residuals. Serial correlation in the residuals renders the $F$ test for causality unreliable. For price pairs where significant serial correlation remained, additional lagged variables were added one at a time until the serial

correlation was removed, and then this ad hoc model was tested for causality. Most of the causality results were the same for the BIC and the ad hoc models; only two were not the same. Conclusions regarding price relationships are drawn only for the cases where the causality results were the same for both models.

Contemporaneous cross-equation correlation of the errors of equation (2) specified twice (once with $Y_t$ and once with $X_t$ as the dependent variable) is an indicator of the importance of instantaneous causality (Bailey and Brorsen, 1985). High contemporaneous correlation between the errors of these two structures indicates a high level of price integration within the sampling interval. The correlation of contemporaneous errors can confirm the pattern of price integration revealed by the simple correlation of the first-differenced data series.

Eight quarterly international beef price series, published in three sources and roughly covering the time period of the early 1960s through 1986, were

TABLE 3

Quarterly international beef price series

| Price series | Period | Abbreviation |
|---|---|---|
| Australian exports (cif in U.S. ports)[a] | 1961-1984(III) | AUS1 |
| Australian saleyard wholesale beef[a] | 1961-1984 | AUS2 |
| German domestic wholesale beef[b] | 1966-1985 | GER |
| French domestic wholesale beef[b] | 1966-1985(II) | FRA |
| Irish exports of beef (London market)[b] | 1972(II)-1987(I) | IRE |
| Unit values of Argentine frozen beef exports[c] | 1962-1984 | ARG1 |
| U.S. domestic wholesale beef[c] | 1961-1987(II) | US1 |
| U.S. imports of beef (cif port of entry from all origins)[c] | 1963-1987(II) | US2 |

Sources:
[a]Bureau of Agricultural Economics, Canberra, Australia: Meat Situation and Outlook (various issues).
[b]FAO, The Livestock and Meat Market, Geneva: Economic Commission for Europe (various issues).
[c]IMF: International Financial Statistics (various issues).

selected for the analysis (Table 3).[6] These include prices from the U.S., Australia, Argentina, Germany, France, and Ireland. To establish a common numeraire, all of the price series are expressed in U.S. dollars per 100 kg of beef.

## Results and Analysis

Table 4 presents the simple Pearson correlation coefficients. The standard errors are shown in parentheses underneath each coefficient, and the coefficients significantly different from zero at the 5% level are noted with an asterisk. The underlined correlations in Table 4 are the best indicators of the effect of FMD market segmentation, because correlation between these prices is free of the effects of E.C. policy intervention.

The correlation coefficients between Australian or U.S. prices and Argentine export prices show how closely prices move together across the FMD-free

TABLE 4

Whole period correlations of world beef prices[a]

| | AUS1 | AUS2 | GER | FRA | IRE | ARG | US1 | US2 |
|---|---|---|---|---|---|---|---|---|
| AUS1 | 1.00 | 0.60* | 0.15 | 0.14 | −0.09 | 0.25* | 0.59* | 0.95* |
| | | (0.083) | (0.116) | (0.116) | (0.147) | (0.103) | (0.084) | (0.034) |
| AUS2 | | 1.00 | 0.05 | 0.16 | 0.05 | 0.14 | 0.42* | 0.56* |
| | | | (0.116) | (0.115) | (0.146) | (0.104) | (0.094) | (0.089) |
| GER | | | 1.00 | 0.64* | 0.48* | 0.19 | 0.29* | 0.11 |
| | | | | (0.088) | (0.123) | (0.114) | (0.108) | (0.113) |
| FRA | | | | 1.00 | 0.25 | 0.14 | 0.08 | 0.09 |
| | | | | | (0.136) | (0.115) | (0.114) | (0.114) |
| IRE | | | | | 1.00 | 0.15 | 0.11 | −0.02 |
| | | | | | | (0.144) | (0.133) | (0.134) |
| ARG | | | | | | 1.00 | 0.18 | 0.25* |
| | | | | | | | (0.104) | (0.104) |
| US1 | | | | | | | 1.00 | 0.54* |
| | | | | | | | | (0.086) |
| US2 | | | | | | | | 1.00 |

[a]All price series were first differenced, and examined for non-stationarity. Please see Table 3 for descriptions of the data series. Correlations were run for the longest possible joint time series in all cases.

*Indicates the coefficient is significantly different from zero in a $t$-test at the $\alpha = 0.05$ level.

[6]Unfortunately we were unable to obtain any E.C. border price series or any Japanese import price data on a quarterly basis. This limits our ability to test some hypotheses concerning world price integration.

and FMD-endemic market segments. These correlation coefficients can be compared to the correlations between Australian prices and U.S. prices, to see if prices are less integrated across segments than within one segment of the market. The following shows correlation pairs tested for significant differences and their respective $V$-statistics calculated from equation (1):

| Correlations tested for | | |
|---|---|---|
| Significant difference | | $V$-statistic |
| (AUS1 * US2 = 0.95) | (AUS1 * ARG = 0.25) | 10.333 |
| (AUS2 * US2 = 0.56) | (AUS2 * ARG = 0.14) | 2.753 |
| (US1 * AUS1 = 0.59) | (US1 * ARG = 0.18) | 2.742 |

As expected, the $V$ statistics show that the correlations within the FMD-free segment of the market are significantly greater than correlations across the FMD-free and FMD-endemic segments, indicating that the international beef market is segmented on the basis of FMD import restrictions. Yet the correlation coefficients of Argentine beef prices (ARG) with Australian export prices (AUS1) or U.S. import beef prices (US2) are both significantly greater than zero, indicating that there is some price transmission across segments.

Comparison of correlation coefficients before 1974 with those from 1974 forward reveals whether the change in the structure of the world beef market due the enlargement of the E.C. and increased E.C. protection altered the pattern of integration. The coefficients of interest are those between the German and French domestic wholesale beef prices (GER and FRA) and the Argentine and Australian export price series (ARG and AUS1). In the matrix of pre-1974 correlations (Table 5), seven out of eight of the correlation coefficients relating German and French domestic prices with the Australian and U.S. domestic and border prices are significantly different than zero. In the post-1974 matrix (Table 6), none of these coefficients are significantly different from zero. It is also interesting to note that the French and German domestic wholesale beef prices are almost as well correlated with the U.S. and Australian beef price series as they are with each other prior to 1974, and this is clearly not the case in the later period.[7]

[7]In spite of the CAP, prices are not perfectly integrated within the E.C. for two reasons. First, market prices have been allowed to deviate from the guide and intervention prices (see footnotes 4 and 5). Second, the use of 'green' exchange rates and the corresponding Monetary Compensatory Amounts (MCAs) for intra-E.C. beef trade has also allowed prices in individual countries to vary. MCAs were originally instituted to protect German farmers from the effects of the 1969 revaluation of the Deutsche Mark. They function as taxes or subsidies on traded quantities within the E.C. MCAs have led to higher market prices (denominated in U.S. dollars) for beef in Germany than in France or Ireland. MCAs on beef traded between Germany and France have been small, but MCAs on beef exports from Ireland to the U.K. have been large (AgraEurope, 1988) and probably account for the lack of significant positive correlation between French and Irish beef prices.

TABLE 5

Pre-1974 correlations of world beef prices[a]

| | AUS1 | AUS2 | GER | FRA | IRE | ARG | US1 | US2 |
|---|---|---|---|---|---|---|---|---|
| AUS1 | 1.00 | 0.41* | 0.39* | 0.54* | - | −0.16 | 0.69* | 0.92* |
| | | (0.130) | (0.171) | (0.156) | | (0.147) | (0.103) | (0.061) |
| AUS2 | | 1.00 | 0.21 | 0.35* | - | 0.14 | 0.37* | 0.31* |
| | | | (0.182) | (0.174) | | (0.148) | (0.133) | (0.148) |
| GER | | | 1.00 | 0.57* | - | 0.12 | 0.66* | 0.40* |
| | | | | (0.153) | | (0.184) | (0.139) | (0.170) |
| FRA | | | | 1.00 | - | 0.21 | 0.63* | 0.48* |
| | | | | | | (0.181) | (0.144) | (0.163) |
| IRE[b] | | | | | - | - | - | - |
| ARG | | | | | | 1.00 | 0.11 | −0.21 |
| | | | | | | | (0.148) | (0.153) |
| US1 | | | | | | | 1.00 | 0.66* |
| | | | | | | | | (0.117) |
| US2 | | | | | | | | 1.00 |

[a]All price series were first differenced, and examined for non-stationarity.
[b]The Irish price series started in 1972, which did not provide enough observations for pre-1974 correlations.
*Indicates the coefficient is significantly different from zero in a $t$-test at the $\alpha = 0.05$ level.

The results in Tables 5 and 6 show that price integration between the E.C. domestic market and the U.S./Oceania segment of the international beef market decreased substantially after 1974. Prior to 1974, the E.C. competed with the U.S. market to attract Oceania beef exports in years of scarce international supply. After 1974, the E.C. was no longer a net importer due to growing protection of domestic production, and the E.C. market became isolated from the world market.[8]

The effect of E.C. policies on the integration between Argentine export prices and European prices is unclear. The correlations between German and French prices and the Argentine price are very low both before and after 1974, and none are significantly different from zero. It may be that Argentina primarily exported beef to the U.K. before 1974, and that German and French prices did not move closely with British prices.

However, the hypothesis concerning the change in relationship between Argentine prices and U.S. or Australian prices before and after 1974 is confirmed. Before 1974, Argentine prices were not significantly correlated with U.S. or

[8]Although beef imports into the E.C. continue, these are primarily under special bi-lateral agreements, and are not in response to changes in demand within the Community.

TABLE 6

Post-1974 correlations of world beef prices[a]

| | AUS1 | AUS2 | GER | FRA | IRE | ARG | US1 | US2 |
|---|---|---|---|---|---|---|---|---|
| AUS1 | 1.00 | 0.62* (0.121) | 0.09 (0.154) | 0.03 (0.154) | −0.13 (0.153) | 0.31* (0.147) | 0.59* (0.125) | 0.95* (0.048) |
| AUS2 | | 1.00 | −0.00 (0.152) | 0.07 (0.152) | 0.02 (0.152) | 0.16 (0.151) | 0.46* (0.135) | 0.59* (0.123) |
| GER | | | 1.00 | 0.65* (0.113) | 0.46* (0.130) | 0.20 (0.149) | 0.23 (0.142) | 0.03 (0.146) |
| FRA | | | | 1.00 | 0.24 (0.145) | 0.16) (0.151) | 0.01 (0.149) | −0.04 (0.149) |
| IRE | | | | | 1.00 | 0.15 (0.151) | 0.06 (0.140) | −0.05 (0.140) |
| ARG | | | | | | 1.00 | 0.19 (0.150) | 0.32* (0.144) |
| US1 | | | | | | | 1.00 | 0.54* (0.116) |
| US2 | | | | | | | | 1.00 |

[a]All price series were first differenced, and examined for non-stationarity.
*Indicates the coefficient is significantly different from zero in a $t$-test at the $\alpha = 0.05$ level.

Australian prices, but after 1974 they are significantly correlated. $V$-statistics indicate that the increase in correlation after 1974 was significant:

| Correlation pairs tested for | |
|---|---|
| Significant difference | $V$-statistic |
| ARG*AUS1 | |
| Pre-1974 = −0.16; Post-1974 = 0.31 | 2.218 |
| ARG*US2 | |
| Pre-1974 = −0.21; Post-1974 = 0.32 | 2.467 |

Argentine beef prices became significantly better integrated with the U.S./Australia or FMD-free segment of the international beef market following the loss of the European market in the mid-1970s. Increased competition with Australia in the non-traditional importing markets strengthened price integration across market segments.

The tests of lead/lag relationships confirm the results of the simple correlation analysis. Table 7 shows the contemporaneous coefficients of the errors from estimation of equation (2). Significant coefficients indicate instanta-

TABLE 7

Contemporaneous correlations between the error structures of the bivariate lead/lag models

| | AUS1 | AUS2 | GER | FRA | IRE | ARG | US1 | US2 |
|---|---|---|---|---|---|---|---|---|
| AUS1 | 1.00 | 0.60* | −0.03 | 0.13 | −0.02 | 0.25** | 0.54* | 0.96* |
| AUS2 | | 1.00 | −0.02 | 0.16 | 0.09 | 0.21** | 0.37 | 0.59* |
| GER | | | 1.00 | 0.73* | 0.39* | 0.16 | 0.20 | −0.05 |
| FRA | | | | 1.00 | 0.39* | 0.04 | 0.18 | 0.08 |
| IRE | | | | | 1.00 | 0.13 | −0.02 | 0.22 |
| ARG | | | | | | 1.00 | 0.37* | 0.32* |
| US1 | | | | | | | 1.00 | 0.49* |
| US2 | | | | | | | | 1.00 |

*Coefficient significant at the ($\alpha=0.01$) level, indicating instantaneous causality.
**Coefficient significant at the ($\alpha=0.05$) level, indicating instantaneous causality.

TABLE 8

Summary of lead/lag price relationships based on Granger tests

| Nation 1 | Nation 2 | | | | | | |
|---|---|---|---|---|---|---|---|
| | AUS2 | GER | FRA | IRE | ARG | US1 | US2 |
| AUS1 | ⟷ | ⟵ | ⟵ | ⟶ | ⟶ | – | – |
| AUS2 | | – | – | – | ⟶ | ⟵ | ⟷ |
| GER | | | ⟶ | – | – | – | ⟶ |
| FRA | | | | – | – | – | – |
| IRE | | | | | ⟵ | – | ⟵ |
| ARG | | | | | | ⟵ | ⟵ |
| US1 | | | | | | | – |

The arrows denote lagged flows that were significant at the 5% level. The arrow ⟶ represents a flow of price information from Nation 1 to Nation 2, the ⟵ arrow represents a flow from Nation 2 to Nation 1, the ⟷ arrow represents feedback, and — means that no significant lagged causal information flow exists.

neous 'causality' between the two prices. The magnitude and significance of the correlations of contemporaneous errors are very similar to the simple correlation coefficients in Table 4.

Tests for leads and lags also reveal more about the process of price discovery. Table 8 summarizes the results. The two Australian price series exhibit a lagged feedback relationship, as do Australian domestic wholesale prices and the U.S. import price from all origins. The U.S. domestic price also leads the Australian domestic price. Furthermore, there is instantaneous causality between all three of these price pairs (Table 7). In sum, the U.S. and Australian beef prices are closely integrated, with domestic wholesale beef prices in the U.S. playing a leadership role.

There is no instantaneous causality between the domestic E.C. beef prices and any other international beef price series. The German domestic price series leads both the U.S. import price from all origins (US2) and the Australian export series to the U.S. (AUS1). The French domestic beef prices also lead the AUS1 series. These results are rather surprising, as the results of the correlation analysis found little or no instantaneous relationship between E.C. prices and the U.S. or Australian prices in the second half of the sample after 1974. The causality tests were run with the whole sample. Before 1974, Europe and the U.S. competed for supply in years of scarcity. After 1980 weakening prices in the E.C. domestic beef market may have been transmitted to world markets through subsidized exports. These E.C. beef exports may have depressed other world prices after a time lag. Thus the lagged price relationship could reflect the influence of European demand on U.S./Australia prices before 1974 and the influence of european export supply after 1980.

E.C. beef prices are expected to lead the Argentine price series, but there is no relationship between Argentine prices and either the German or French price (Table 8). The Argentine price leads the Irish beef export price, possibly due to the influence of Argentine beef in the U.K. market until 1974, where Argentina and Ireland were competitors. The lack of any significant relationship between Argentine prices and E.C. prices in either the correlations before 1974 or the causality tests is surprising. It may be that prices in the Argentine–U.K. trade before the U.K. joined the E.C. in 1973 were independent of prices in Europe.

The Argentine export price is instantaneously related to all of the Australian and U.S. prices, and is also led by all four series. This confirms and reinforces the results of the whole period and post-1974 correlation analysis showing significant correlation between the FMD-free and FMD-endemic segments of the market. The causality tests show that more price information is transmitted between the market segments after more than one calendar quarter. The results also suggests that Argentina is a price taker, receiving prices that are first determined in the FMD-free segment of the market.

## Conclusions

This paper examined three hypotheses concerning price integration in the world beef market. First, the existence of market segmentation due to restrictions on trade from FMD-endemic countries was tested. The correlation between prices in Australia and the U.S. is significantly greater than correlation between prices in Australia and Argentina. However, the correlation between Australian and Argentine export prices is significantly different from zero. Furthermore, the tests for price leadership reveal that Argentine prices are led by U.S. and Australian prices. These results indicate that market segmenta-

tion exists, but is by no means absolute and the degree of segmentation declines as more time is allowed for price transmission.

The second hypothesis is that changes in the structure of the world beef market following the closing of the E.C. import market altered the pattern of integration. Two changes were apparent in the price data tested here. First, domestic German and French prices were integrated with U.S. prices before 1974, but not integrated within one calendar quarter with any other series after 1974. E.C. policies insulate domestic prices from world prices. However, the causality tests suggest that the E.C.'s growing subsidized exports of beef may be depressing world prices.

A second effect of the changing structure of the world market is that Argentine export prices became much more highly integrated with U.S.–Australia prices after 1974. The loss of the E.C. market caused Argentina to compete more directly with Australia in new markets, and because of the close linkage between U.S. and Australian prices, U.S. prices indirectly influence Argentine prices.

Finally, the hypothesis that the U.S. is a price leader in the world beef market was tested. The U.S. domestic price was found to lead prices in the major exporting countries. The international beef price series that most nearly represents a 'world' price of beef is the import price of Australian beef in the U.S. (AUS1), as it has some type of lead/lag or instantaneous relationship with all of the other beef price series. This import price series provides a good indicator of price movements in the world market, and would be a useful series for econometric models of the world market. It would not be a correct indicator of the social opportunity cost of beef production in countries other than Australia and New Zealand, however, because this price includes a quota rent.

The U.S. price leadership role arises not only because it is the world's largest domestic market and importer of beef, but also from the nature of U.S. and E.C. policies. The combination of the U.S. import quota that varies with domestic production and voluntary export restraints which transfer the quota rent to exporters allows transmission of price information from the U.S. domestic to the world market, but not vice versa. E.C. policies that have restricted imports have made the U.S. price leadership role even more important.

The results in this paper demonstrate that trade policies of the major market actors have strongly influenced price integration in the world beef market. The overall level of price integration seems to be fairly high, however, in spite of the thin and segmented nature of world beef trade. Thus there does seem to be a functioning world beef market that equates export supply and import demand. Countries trading small amounts of beef in the international market can use border prices as good indicators of the social opportunity cost of beef production or as the reference price for calculations of the producer subsidy equivalent.

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