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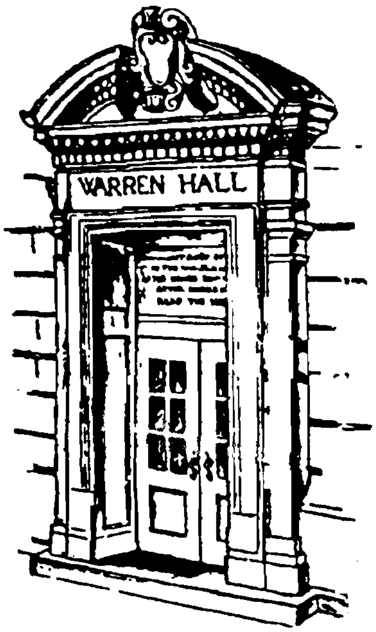

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FACTOR AND PRODUCT MARKET TRADABILITY AND EQUILIBRIUM IN PACIFIC RIM PORK INDUSTRIES

Abstract: This paper uses a new market analysis methodology to examine price and trade relationships in eight Pacific Rim factor and product markets central to the Canadian and U.S. pork industries. The new method enables direct estimation of the frequency with which a variety of market conditions occur, including competitive equilibrium, tradability, and segmented equilibrium. While extraordinary profit opportunities emerge episodically in a few niche markets, the vast majority of the markets studied are highly competitive – exhibiting zero marginal profits to spatial arbitrage at monthly frequency – and internationally contestable. In spite of continued high international transfer costs, the Pacific Rim is effectively a single market for pork producers and processors today.

Keywords: corn, feed, hogs, international trade, law of one price, market integration, meats, soybean meal, spatial equilibrium

Ongoing structural shifts in the North American pork industry raise important questions regarding the nature of international hog and feed factor markets and pork product markets. Canadian and United States pork production and processing are both increasingly industrialized, and each nation is now a net pork exporter. Since the gains in international competitiveness for Canadian and U.S. pork producers and processors seem increasingly likely to come from lowering unit costs through exploitation of emerging economies of scale, the definition and development of accessible factor and product markets is central to the long-term health of the industry in both countries. And because the biggest pork markets and the fastest growth in consumption and trade are found in the Pacific Rim countries of Asia and North America, this region is of particular interest to Canadian and U.S. suppliers. Both countries have seen significant expansion of processing capacity in the west, based largely on plans to expand exports to Pacific Rim markets. In this paper, we therefore study price and trade relationships in pork factor and product markets among the major Pacific pork economies.

Prevailing market integration testing methods – e.g., correlation coefficients, Granger causality, cointegration, error correction mechanisms – are unreliable under a variety of conditions because they rely solely on price data and make strong, often unrealistic assumptions about trading behavior and costs. These level I methods[1] fail when trade is discontinuous or bidirectional, and when transactions costs are considerable or nonstationary (Dahlgran and Blank 1992, Barrett 1996, McNew 1996, Baulch 1997, McNew and Fackler 1997, Fackler and Goodwin forthcoming). Such conditions are common in the face of intraindustry trade due to economies of scale and product differentiation, seasonality in demand and supply, and trade policy reforms and technological change in shipping, storage and communications. As we demonstrate below, such conditions prevail in the

Pacific Rim markets we study.

Baulch (1997), introducing his parity bounds model (PBM), shows that the use of both price and shipping cost data (level II analysis), combined with maximum likelihood estimation methods that relax many untenable assumptions about the nature of intermarket price relationships, can eliminate many of the biases of traditional price analysis (level I) methods. But as Barrett (1996) argues, failure to take advantage of the information available in trade flow data still limits the inferential capacity of level II methods.

Li and Barrett (1999) introduce what appears to be the first level III method, one that uses the information in price, trade, and marketing cost data. The Li-Barrett method (LBM) permits distinction between *market integration*, reflecting the tradability of products between spatially distinct markets – equivalent to contestability between markets – irrespective of the existence or absence of spatial market equilibrium, and *competitive market equilibrium*, in which extraordinary marginal profits are exhausted by competitive pressures to yield socially efficient allocations, regardless of whether this results in physical trade flows between markets. This paper applies the LBM to a new, rich data set on factor and product markets for the pork industries of several Pacific Rim economies.

Estimating Market Condition Frequencies

The core virtue of the LBM lies in its capacity to use the information from multiple, interrelated data sources to distinguish between interrelated but distinct concepts of market equilibrium and market integration. The two are not synonymous in spite of current praxis. A good definition of market integration is the influence of one market by another through the

Walrasian transfer of excess demand. When two markets are integrated, supply and demand in the one market affect the price and/or transactions volume in the other. This definition of integration is closely related to the concepts of tradability or contestability (Baumol 1982). By this definition, markets can be (imperfectly) integrated even when imperfectly competitive or inefficiently restricted by trade barriers or collusion, whether or not physical flows occur between the markets, and whether or not price in one market responds (especially one-for-one) to shocks in the other.

This more practical and intuitive defintion of market integration-cum-tradability does not equate to competitive equilibrium. Following the familiar logic of spatial equilibrium models, two markets, i and j, are in long-run competitive equilibrium, meaning that marginal profits to intermarket arbitrage equal zero, when $P_{it} \leq \tau(P_{it}, P_{jt}, c_{ijt}) + P_{jt}$, with P_{it} the price at location i in time t, and τ the transactions costs of spatial arbitrage, which may be a function of prices (e.g., in the case of *ad valorem* or variable rate tariffs or insurance) and the exogenous costs of transport between the two locations at time t, c_{ijt}. The equilibrium condition binds with equality when trade occurs. But when trade does not occur, the constraint may be slack so there may be no correlation among market prices in spite of the existence of competitive equilibrium.[2] When two markets are both integrated and in long-run competitive equilibrium, they may be classified as "perfectly integrated," the special case on which the existing market integration literature focuses, as shown by Goldberg and Knetter's (1997) recent review. Tests of the law of one price (LOP), for example, are a test of the perfect integration hypothesis, not a test of (perhaps imperfect) integration or of (perhaps segmented) competitive equilibrium.

The LBM builds on switching regimes models, notably Baulch's (1997) parity bounds model (PBM), that compare observed intermarket price differentials against observed costs of intermarket transport, thereby estimating the probability that markets are in competitive equilibrium (Spiller and Huang 1986, Sexton, Kling, and Carman 1991, Baulch 1997). This approach hurdles the problems of discontinuous trade, and time-varying and potentially nonstationary transactions costs that bedevil pure price analysis methods. But absent trade flows data, it still conflates the concepts of equilibrium and integration. Price differentials less than transfer costs are identified as "integration" even when there is no flow of product and no transmission of price shocks between the two markets. Conversely, markets are classified as "segmented" whenever price differentials exceed transfer costs, regardless of whether there are observed trade flows.

Since we can never observe all possible transactions costs involved in trade (e.g., subjective risk premia, discount rates, quasi-option values), trade flow information can offer indirect evidence of the effects of unobservable or omitted transactions costs, thereby providing fuller information with which to analyze market relationships. It is common, for example, to find that trade does (not) occur even when price differentials exceed (are less than) transfer costs – defined as the observable portion of transactions costs – implying that some unobservable effects (e.g., trade barriers, unmeasured transactions costs, information gaps) exist and influence intermarket trade. If markets are imperfectly competitive, there may be positive rents associated with arbitrage in equilibrium and if one or both markets experience shocks, arbitrage conditions may be violated during market disequilibrium. In short, if traders are rational profit-maximizers, trade flow data convey additional information about market integration beyond that offered by observable price and transfer cost data. So it makes sense to exploit such data in markets analysis.

The LBM interprets the observed distribution of market prices as a mixture of observations drawn from different distributional regimes corresponding to distinct market conditions. This mixture distribution estimation approach is well suited to time-varying market conditions, such as exist for most international agricultural markets. There exist six distinct market regimes. Trade is either observed (odd numbered regimes) or not (even numbered regimes). Price differentials may equal transfer costs (regimes 1 and 2), implying binding arbitrage conditions and tradability, regardless of whether trade occurs or not. Or price differentials may exceed transfer costs (regimes 3 and 4), implying the existence of positive profits to intermarket arbitrage. Finally, when price differentials do not fully cover transfer costs (regimes 5 and 6), trade brings negative profit to arbitrageurs. Letting P^i and P^j be the prices in locations *i* and *j*, respectively, T_{ji} be the observable transfer costs from *j* to *i*, and $\Sigma_i\lambda_i=1$, the six regimes are summarized in Table 1.

In estimating the probability of observing the i^{th} regime (λ_i), we have only partial information: the binary observation of trade or no trade. So we estimate a mixture model, maximizing the likelihood associated with the regime frequencies found in sample, conditional on knowing whether trade occurs or not and the distribution assumption made about the errors associated with each regime. We assume all regimes are subject to iid normal sampling and measurement error, v_t, with zero mean and variance σ^2_v. Regimes 3-6 also include a one-sided error, u_t, that is independent of v_t and is iid half-normal with variance σ^2_u. The half-normal error is added to (subtracted from) $T_{ji} + v_t$ for regimes 3 and 4 (5 and 6). Using the density of the sum of a normal random variable and a truncated normal random variable (Weinstein 1964), the distribution functions for the observations in each regime are:

$$f_t^1 = f_t^2 = \frac{1}{\sigma_v}\phi\left[\frac{Y_t - T_t}{\sigma_v}\right] \tag{1}$$

$$f_t^3 = f_t^4 = \left[\frac{2}{(\sigma_u^2+\sigma_v^2)^{1/2}}\right]\cdot\phi\left[\frac{Y_t - T_t}{(\sigma_u^2+\sigma_v^2)^{1/2}}\right]\left[1-\Phi\left[\frac{-(Y_t - T_t)\sigma_u/\sigma_v}{(\sigma_u^2+\sigma_v^2)^{1/2}}\right]\right] \tag{2}$$

$$f_t^5 = f_t^6 = \left[\frac{2}{(\sigma_u^2+\sigma_v^2)^{1/2}}\right]\cdot\phi\left[\frac{Y_t - T_t}{(\sigma_u^2+\sigma_v^2)^{1/2}}\right]\left[1-\Phi\left[\frac{(Y_t - T_t)\sigma_u/\sigma_v}{(\sigma_u^2+\sigma_v^2)^{1/2}}\right]\right] \tag{3}$$

where T_t and Y_t are intermarket transfer costs and price differentials, respectively, at time t, ϕ is the standard normal density function and Φ is the standard normal cumulative distribution function. The likelihood of observing the sample price, transfer cost, and trade data can therefore be written:

$$L = \prod_{t=1}^{T}\left\{A\cdot[\lambda_1 f_t^1 + \lambda_3 f_t^3 + \lambda_5 f_t^5] + (1-A)\cdot[\lambda_2 f_t^2 + \lambda_4 f_t^4 + \lambda_6 f_t^6]\right\} \tag{4}$$

where A is a dummy variable for the occurrence of trade: A=1 if trade is observed and A=0 otherwise. The probabilities of each regime and the variances σ^2_u and σ^2_v can be estimated by maximizing the logarithm of equation (4), subject to the constraints that $\lambda_k \geq 0\ \forall k$, and $\Sigma_k \lambda_k = 1$.[3]

This method permits construction of several useful indicators of the frequency with which particular market conditions prevail. *Intermarket tradability* ($\lambda_1+\lambda_2+\lambda_3+\lambda_5$) occurs whenever trade is observed or the intermarket arbitrage condition is binding, so that traders are indifferent between trading or not. *Competitive equilibrium* ($\lambda_1+\lambda_2+\lambda_6$) occurs whenever the intermarket arbitrage (zero marginal trader profit) condition holds. Two markets are thus *perfectly integrated* with frequency ($\lambda_1+\lambda_2$), *inefficiently integrated* with frequency ($\lambda_3+\lambda_5$), in *segmented equilibrium* with frequency λ_6, and in *segmented disequilibirium* (neither integrated nor in long-run competitive equilibrium) with frequency λ_4. These conditions describe essentially all market conditions of interest to economists and their business and trade policy clients.

The regimes of most concern to economists are typically those reflecting violations of long-run competitive equilibrium. In regime 3, trade occurs and appears to earn positive marginal profits. This implies either (1) insufficient market arbitrage, due either to formal or informal nontariff trade barriers or to temporary disequilibria (e.g., due to informational or contracting lags) that generate rents, or (2) the existence of significant unobservable transactions costs that fill in the gap between the price differential and observable transfer costs. In regime 4, apparent positive profits go wholly unexploited by traders. The plausible explanations for this observation are the same as for regime 3, but the behavioral effect is extremal. Parallel logic holds in regime 5, where transfer costs exceed price differentials yet trade occurs despite negative estimated marginal profits. This is either due to temporary disequilibria (e.g., due to information and contracting lags) or to the existence of significant unobservable transactions benefits (e.g., first mover advantages) accruing to traders.

While price differentials are symmetric (in absolute value) between any two markets, intermarket transfer costs, T_t, commonly depend on the direction of trade since tariffs vary across countries and backhaul freight rates are sometimes lower than the standard freight rates going the opposite direction. Asymmetric transfer costs implies the need to estimate direction-specific regime probabilities, i.e., one vector λ^{ij} related to product moving from market i to market j and a second vector, λ^{ji}, related to movements in the opposite direction. In general, $\lambda^{ij}-\lambda^{ji}\neq\mathbf{0}$, meaning there will not be a unique probability vector describing integration and equilibrium between two distinct markets since direction-specific regime probabilities may differ. This is not a problem for measures of tradability, which is inherently a unidirectional concept. A product is tradable between two markets when it can or does flow from either one to the other. Bidirectional tradability is unnecessary for there to be transmission of Walrasian excess demand between markets. By contrast, equilibrium is an omnidirectional concept, in which the spatial equilibrium conditions should prevail in both directions (e.g., a segmented equilibrium one direction, and perfect integration the other). When only one of the two markets employs nontariff barriers to trade, equilibrium may hold in only one of two directions. By these criteria, we use the maximal direction-specific values of intermarket tradability and perfect integration in describing those market conditions between two (prospective) trading partners.[4] By contrast, we use the bounds created by the two direction-specific results in describing the frequency of spatial market equilibrium. The width of that band is itself suggestive of the underlying efficiency of arbitrage between the markets.

Pacific Rim Pork Industry Factor and Product Markets

We assembled comparable monthly time series data on prices, trade flows, and the costs of intermarket arbitrage over the years 1990-1996 for eight commodities — feedgrains (corn and soybean meal), slaughter hogs, chilled carcass and chilled pork cuts (bellies, hams, loins, ribs)[5] — from eight countries — Australia, Canada, Japan, Korea, Mexico, the Philippines, Taiwan, and the United States.[6] We are unaware of any other study that uses either such comprehensive time series data on the costs of commerce or trade data combined with price and transfer cost data. Data are not available for precisely the same periods across countries or commodities.

Indeed, data are not available on some commodities for some countries. So the number of observations vary across commodity-specific country pairs and the number of country pairs available differ among commodities in the estimation results that follow.

Because we want to account carefully for transfer costs — the observable costs of trading between locations — we have tried to identify precisely the spatial location from which price data are gathered and to include in our transfer cost series those domestic transport costs associated with moving product from interior price reporting locations to or from port, as well as the international c.i.f. and tariff costs associated with moving product from one country's port to another's.[7] Data on transfer costs were not publicly available, so we constructed these series, somewhat painstakingly, from U.S. Customs data, national commodity-specific tariff schedules, and domestic transport cost series available from national statistical agencies. As analysts increasingly recognize the importance of incorporating data on transfer costs in market analysis, we hope that government statistical agencies will begin to make series on transfer costs more readily available. At present, the cost of gathering reliable, complete transactions costs time series poses a serious obstacle to using improved, level II or III markets analysis methods.

The inferential failings of conventional price analysis methods (including correlation coefficients, Granger causality, cointegration testing, error correction mechanisms) arise from characteristics of the underlying (and usually ignored) transfer costs or trade flows (Barrett 1996, McNew 1996, Baulch 1997, McNew and Fackler 1997). The data show that the factor and product markets of the Pacific Rim pork industries frequently violate assumptions on which existing, linear price analysis techniques depend. For example, trade discontinuity implies a nonlinear or piecewise linear relationship between price series and bidirectional trade implies variation in direction of flow – implying a non-constant sign of τ, the transactions cost term in the linear spatial equilibrium model implicitly estimated – product differentiation, or both. Yet continuous, unidirectional trade characterizes less than six percent of the commodity-specific market pairs for which we gathered data; this assumption holds only for trade in primal pork cuts between Japan and Taiwan. And since we could not collect reliable transfer cost series between Japan and Taiwan, not one of the 88 commodity-specific market pairs to which we apply LBM fully satisfies the trade flow and transfer cost assumptions on which conventional methods rest. Hence the rationale for using LBM to obviate the statistical hazards of traditional price analysis techniques.

Discontinuous trade or trade flow reversals frequently arise due to perturbations in the costs of market arbitrage, including trade policy reforms. Our data show that transfer costs are time-varying and nonadditive, meaning there is some multiplicative component attributable to ad valorem tariffs or graduated insurance or freight schedules. Moreover, they are frequently substantial, nonstationary or both. Figures 1 and 2 present histograms depicting the frequency distribution of mean transfer cost to export country domestic price ratios for direction- and commodity-specific market pairs. These ratios represent the period mean proportional markup necessary to break even on shipments from the exporting country to the importing country. Transfer costs tend to be greatest as a proportion of price for low value-to-weight commodities (i.e., feedgrains) and for longer distances traveled. Mean transfer costs were only 1.8 percent of export country domestic price for intra-North American trade in chilled pork products, but averaged 221.0 percent of export country domestic price for trans-Pacific trade in feedgrains. What is perhaps most striking is that the direction of trade often matters too. Mean transfer costs are considerably higher going from North America to Asia than vice versa (Figure 2), almost entirely due to differences in tariff rates. For example, Japanese tariffs alone on live slaughter hogs averaged 39 percent of the U.S. domestic price. Similarly, while transfer costs for loins averaged but 1.4 percent of export price going from Canada to the United States or vice versa, and only 6.0 (6.1) percent from Japan to Canada (the U.S.), transfer costs averaged 121.6 (192.5) percent of export price going the opposite direction across the Pacific, from Canada (the United States) to Japan![8] Trade policy clearly matters as much as transport costs, yet has been largely ignored in the market integration studies we have found.

Given secular trends toward liberalized trade through permanently lower tariff rates, it is intuitive that many international transfer cost time series should be nonstationary.[9] Indeed, augmented Dickey-Fuller tests find that 12 of 14 feedgrains' transfer cost series are nonstationary, more precisely, that one cannot reject the null hypothesis of nonstationarity at the 90 percent significance level.[10] Transfer costs from North America to Japan are nonstationary for *each* commodity over the 1990-96 period. Transfer costs for meat and live hogs were more commonly stationary than those for feedgrains, probably due to the relatively smaller role of tariff reduction in these commodities since many animal product trade restrictions are nontariff technical barriers that have been less subject to liberalization to date (Hillman 1991, Thilmany and Barrett 1997). With agricultural trade liberalization likely to feature prominently in the next round of multilateral WTO negotiations, this issue is unlikely to disappear any time soon, so market analysts must adopt methods better suited to the underlying conditions of international trade and its associated costs.

Table 2 presents the LBM estimation results. Several results stand out. First, lossmaking trade (λ_5) is extremely uncommon, occurring at ten percent or greater frequency in only 3/88 cases, all in soybean meal trade involving Japan. When price differentials are insufficient to cover observable market intermediation costs, as in just over one-quarter of all these commodity-, direction-, and period-specific observations, segmented equilibrium (λ_6) prevails 91.5 percent of the time.[11] Recall from Figures 1 and 2 that transfer costs are often considerably greater than the f.o.b. export price. Segmented equilibrium is to be expected in the face of large wedges driven between markets' prices by tariffs and shipping costs. While comparative disadvantage manifest as segmented equilibrium never occurs with positive and statistically significant probability for either US or Canadian producers of these eight commodities, it occurs for half the primal cuts from Taiwan, two-thirds from Mexico, and all the meat (cuts and carcass) from Japan. In general, the comparative disadvantage of Japan, Korea, Mexico, the Philippines and Taiwan in feed grains, hogs, and pork is apparent from the asymmetric frequency with which those source markets are in segmented equilibrium from the Canadian and United States markets.

Second, segmented disequilibrium (λ_4), where no trade occurs in spite of the apparent existence of positive profits, likewise appears rarely, only three percent of the time overall, and with five or greater percent frequency in only three cases: bellies and loins from the U.S. into Taiwan, and slaughter hogs from the U.S. into Canada. This likely reflects the fact that trade in higher value-added products and live animals tends to be most subject to nontariff trade barriers, but few such barriers bind completely (Hillman 1991). The observation that unprofitable trade or segmented disequilibrium occurs only five percent of the time is strong empirical confirmation of the profit-making behavior of international traders operating in these markets.

Segmented disequilibrium and inefficient integration with positive apparent profits, λ_3, are most likely the consequence of nontariff barriers to trade (e.g., quotas, sanitary and phytosanitary restrictions, and private or public technical barriers) that create positive rents to trade by restricting the free flow of commodities between nations. Such rents exist about 11 percent of the time overall in these markets, but with more than 22 percent frequency in the case of primal cuts (bellies, hams, loins, and spareribs). Part of this is likely attributable to subtle noncomparability of cuts that make intermarket price comparison difficult. But this likely also reflects the relatively greater propensity for nontariff barriers to apply to higher-value-added products, like chilled meats, than to raw commodities, like corn, for which $\lambda_3+\lambda_5$ occurred with only 1.5 percent frequency.

In several cases the λ_2 estimates – for the no trade equilibrium within the parity bounds – appear rather high. This seems attributable to large standard errors (σ_u) on those particular estimates, and probably comes at the cost of lower estimates of λ_6, the segmented equilibrium. We therefore suspect the estimates reported here understate the frequency with which Canadian and U.S. producers and processors exhibit comparative advantage over their counterparts in the other six economies and, correspondingly, overstates the frequency with which eastward (i.e., from Asia to North America) intermarket tradability holds.

Tables 3-5 offers summary descriptions of the estimated frequencies of particular market conditions prevailing. The most striking result is that intermarket tradability is effectively ubiquitous, occuring with at least 99 percent frequency in 42/44 commodity-specific market pairs. There is no question that the factor and product markets of Pacific Rim pork industries are integrated in the sense of tradability. The LBM estimation results also underscore the distinction between tradability and equilibrium. While equilibrium prevails with at least 96 percent frequency in 43/44 commodity-*and*-direction-specific market pairs (i.e., the upper bound on market equilibrium is at least 96 percent), many links suffer disequilibrium in one direction. We take this as an indication of nontariff (formal or informal) trade barriers, all of which involve Japan, the United States, or both. Market equilibrium nonetheless prevails at least two-thirds of the time in all products, and effectively continuously in carcass, corn, and ham markets. The intersection of tradability and equilibrium, constant perfect market integration ($\lambda_1+\lambda_2=1$) – for which existing methods implicitly test when studying either the absolute or relative versions of the law of one price – holds in only 17/44 market pairs. Hence the need to disentangle market integration-cum-tradability from spatial market equilibrium, as we can using the Li-Barrett method.

The dynamics of intermarket relationships merits some discussion at this point. The LBM, like Baulch's (1997) parity bounds model and other switching regime models (Spiller and Huang 1986, Sexton et al. 1991), does not estimate the dynamics of price or intermarket relationships, and so is not well suited to answering questions surrounding the speed with which market prices converge on equilibrium. This should serve as a caution against applying LBM to high frequency data. Yet, for moderate-to-low frequency data, like the monthly series we use here, this method seems well-suited. For example, it takes just over two weeks, including non-transport time, to ship chilled pork cuts from a processing plant in North Carolina by refrigerated truck to Seattle and then by ship to Japan. If prices between the United States and Japan are not in equilibrium on a monthly basis when it takes only a half-month to move product between the most distant points, that information alone is quite informative.

Conclusions

This paper applies a new approach – the Li-Barrett method (LBM) – to the study of spatial market relationships using maximum likelihood estimation of a mixture distribution model incorporating price, transfer cost, and trade flow data. This method generates intuitive and useful indicators of the frequency of intermarket tradability, competitive market equilibrium, perfect market integration (a tradable competitive equilibrium), segmented equilibrium, and segmented disequilibrium. This enables useful distinction between *market integration*, reflecting the tradability of products between spatially distinct markets, irrespective of the existence or absence of spatial market equilibrium, and *competitive market equilibrium*, in which extraordinary profits are exhausted by competitive pressures to yield socially efficient allocations, regardless of whether this results in physical trade flows between markets. In addition, this method is robust to time-varying, nonstationary or nonadditive transfer costs and discontinuous or bidirectional trade, conditions that commonly prevail in the eight Pacific Rim commodity markets we study.

The LBM estimation results yield a number of clear findings with respect to the factor and product markets of Pacific Rim pork industries. First, these products are highly tradable among the eight economies we study. Second, spatial equilibrium holds significantly more often than not, although there remain a number of niches where the marginal profits to spatial arbitrage remain positive, largely reflecting binding nontariff barriers to trade, particularly those imposed by Asian meat importing countries. Third, while spatial equilibrium is commonplace, in many cases that is attributable to large intermarket transfer costs that drive a substantial wedge between market prices. Continued tariff reduction, whether unilaterally or in the context of regional or multilateral accords, would no doubt increase trade – although not the frequency of intermarket tradability or spatial market equilibrium – and reduce deadweight losses associated with trade restrictions.

Table 1. The Six Intermarket Regimes

	$P_i - P_j = T_{ji}$	$P_i - P_j > T_{ji}$	$P_i - P_j < T_{ji}$
Trade	λ_1	λ_3	λ_5
No trade	λ_2	λ_4	λ_6

Table 2. LBM Testing Results

Direction of Trade	Trade			No Trade				
	λ_1	λ_3	λ_5	λ_2	λ_4	λ_6	σ_u	σ_v
Bellies								
US - CA	1.00*	0.00	0.00	0.00	0.00	0.00	1.158	0.986
CA - US	0.99*	0.01	0.00	0.00	0.00	0.00	0.121	1.236
US - TW	0.00	0.00	0.00	0.01	0.98*	0.00	1.264	0.039
TW - US	0.00	0.00	0.00	0.01	0.01	0.98*	4.202	0.465
US - MX	0.01*	0.98*	0.00	0.01	0.00	0.00	3.095	0.469
MX - US	0.01*	0.01*	0.00	0.01	0.00	0.97*	3.114	0.496
CA - TW	0.00	0.00	0.00	0.99*	0.00	0.00	0.427	0.492
TW - CA	0.00	0.00	0.00	0.01	0.01	0.97*	2.105	3.140
Hams								
US - CA	0.98*	0.01*	0.01	0.00	0.00	0.00	0.517	0.055
CA - US	0.89*	0.04	0.01	0.05	0.01	0.00	0.284	0.024
US - TW	0.00	0.00	0.00	0.99*	0.01	0.00	0.996	1.004
TW - US	0.01	0.00	0.00	0.00	0.01	0.99*	1.785	1.495
PH - US	0.01	0.00	0.00	0.98*	0.00	0.00	0.002	0.847
US - PH	0.01	0.00	0.00	0.99*	0.00	0.00	0.053	0.737
CA - TW	0.01	0.00	0.00	0.99*	0.00	0.00	1.347	0.769
TW - CA	0.00	0.00	0.00	0.01	0.01	0.98*	0.381	0.646
Loins								
US - CA	0.99*	0.00	0.01*	0.00	0.00	0.00	0.058	0.681
CA - US	0.99*	0.00	0.01*	0.00	0.00	0.00	0.677	0.665
JP - US	0.00	0.00	0.00	0.00	0.00	0.99*	0.179	1.944
US - JP	0.01*	0.98*	0.00	0.01	0.00	0.00	1.217	1.540
CA - TW	0.01*	0.00	0.00	0.99*	0.00	0.00	1.107	1.221
TW - CA	0.01	0.00	0.00	0.99*	0.00	0.00	1.726	2.094
JP - CA	0.00	0.00	0.00	0.01	0.01	0.98*	1.734	0.393
CA - JP	0.01	0.98*	0.00	0.00	0.01	0.00	1.193	0.244

US → MX	0.01*	0.98*	0.00	0.01	0.00	0.00	0.448	0.290
MX → US	0.01	0.00	0.00	0.01	0.00	0.98*	0.451	0.445
US → TW	0.01	0.21*	0.00	0.01	0.77*	0.00	1.554	0.168
TW → US	0.01	0.01	0.00	0.97*	0.00	0.00	4.554	1.748
Spareribs								
US → CA	0.10	0.89*	0.00	0.01	0.00	0.00	0.265	0.083
CA → US	0.41*	0.02	0.00	0.56*	0.01	0.00	0.000	0.466
CA → TW	0.01	0.00	0.00	0.99*	0.00	0.00	0.000	0.585
TW → CA	0.01	0.01	0.00	0.98*	0.00	0.00	0.778	2.524
US → MX	0.01	0.98*	0.01	0.00	0.00	0.00	0.934	0.588
MX → US	0.01*	0.01	0.00	0.99	0.00	0.00	0.482	1.130
US → TW	0.20*	0.01*	0.00	0.78*	0.01	0.00	0.000	0.504
TW → US	0.01	0.01	0.00	0.97*	0.00	0.00	0.005	0.279
Carcasses								
US → CA	0.14*	0.00	0.00	0.86*	0.00	0.00	0.578	0.330
CA → US	0.98*	0.01*	0.00	0.01	0.00	0.00	0.165	0.139
US → JP	0.79*	0.01*	0.00	0.20*	0.00	0.00	0.000	1.308
JP → US	0.01	0.01	0.00	0.01	0.01	0.95*	0.404	0.699
US → AU	0.01	0.00	0.00	0.99*	0.00	0.00	0.000	1.203
AU → US	0.01	0.00	0.00	0.99*	0.00	0.00	0.711	1.485
US → KO	0.01*	0.00	0.00	0.97*	0.01	0.00	1.015	0.038
KO → US	0.01	0.01	0.00	0.97*	0.01	0.00	0.000	2.934
CA → JP	0.14*	0.01	0.00	0.84*	0.01	0.01	0.001	1.356
JP → CA	0.00	0.00	0.00	0.01	0.01	0.97*	0.423	0.662
Slaughter hogs								
US → CA	0.01	0.18*	0.01*	0.30	0.50*	0.00	0.123	0.121
CA → US	0.99*	0.01	0.00	0.00	0.00	0.00	0.030	0.315
CA → TW	0.00	0.00	0.00	0.99*	0.00	0.00	1.358	0.954
TW → CA	0.00	0.00	0.00	0.02	0.00	0.97*	0.448	0.279
US → TW	0.00	0.00	0.00	0.99*	0.00	0.00	0.759	0.376

TW → US	0.01	0.00	0.00	0.00	0.00	0.99*	2.319	0.728
US → AU	0.00	0.00	0.00	0.98*	0.00	0.00	0.000	0.670
AU → US	0.01	0.00	0.00	0.99*	0.00	0.00	0.029	1.845
US → JP	0.32*	0.00	0.00	0.67*	0.01	0.00	0.638	0.456
JP → US	0.00	0.00	0.00	0.01	0.00	0.99*	3.214	2.986
CA → JP	0.04	0.00	0.01	0.95*	0.00	0.00	0.765	0.443
JP → CA	0.00	0.00	0.00	0.99*	0.00	0.00	0.000	2.728
US → KO	0.01	0.00	0.00	0.99*	0.00	0.00	0.412	0.577
KO → US	0.00	0.00	0.00	0.01	0.00	0.99*	0.001	2.178
CA → KO	0.02	0.01	0.00	0.97*	0.00	0.00	0.003	0.782
KO → CA	0.00	0.00	0.00	0.01	0.00	0.98*	0.004	1.956
US → PH	0.01	0.01	0.00	0.98*	0.00	0.00	0.000	2.038
PH → US	0.01	0.00	0.00	0.98*	0.01	0.00	0.016	1.636
CA → PH	0.01*	0.00	0.00	0.99*	0.00	0.00	2.173	0.370
PH → CA	0.01*	0.01*	0.03	0.01	0.00	0.93*	0.000	1.468
AU → CA	0.00	0.00	0.00	0.99*	0.00	0.00	0.427	1.599
CA → AU	0.01*	0.02	0.01	0.96*	0.01	0.00	1.892	0.338
Corn								
US → CA	0.96*	0.03	0.01	0.00	0.00	0.00	0.180	0.095
CA → US	0.65*	0.04	0.01	0.29*	0.01	0.00	0.000	0.103
US → TW	0.31*	0.01	0.00	0.67*	0.01	0.00	0.000	0.229
TW → US	0.01*	0.00	0.00	0.00	0.00	0.99*	0.458	0.431
US → PH	0.20*	0.00	0.00	0.80*	0.00	0.00	3.825	0.659
PH → US	0.01	0.00	0.00	0.00	0.00	0.98*	0.433	0.477
CA → TW	0.01	0.00	0.00	0.99*	0.00	0.00	4.611	0.230
TW → CA	0.00	0.00	0.00	0.97*	0.01	0.00	0.701	0.012
CA → PH	0.01	0.00	0.00	0.99*	0.00	0.00	0.000	0.853
PH → CA	0.01*	0.03	0.01	0.93*	0.02	0.00	0.299	0.082
Soybean Meal								
US → CA	0.91*	0.01	0.06*	0.00	0.00	0.00	0.195	0.018

CA - US	0.88*	0.00	0.00	0.12*	0.00	0.00	0.324	0.077
TW - CA	0.53*	0.02	0.01	0.41*	0.02	0.01	0.000	0.359
CA - TW	0.22*	0.00	0.00	0.78*	0.00	0.00	0.368	0.207
CA - JP	0.01	0.17	0.82*	0.00	0.00	0.00	0.013	0.088
JP - CA	0.77*	0.01*	0.01	0.01*	0.01*	0.19*	1.415	0.475
US - JP	0.14	0.33*	0.34*	0.18*	0.01	0.00	0.000	0.065
JP - US	0.01*	0.01	0.39*	0.01*	0.01	0.57*	0.000	0.513
US - TW	0.52*	0.00	0.00	0.48*	0.00	0.00	0.184	0.030
TW - US	0.01*	0.01*	0.09*	0.01	0.01*	0.87*	6.855	0.386

AU = Australia, CA= Canada, JP = Japan, KO = Korea, MX = Mexico, PH = Philippines, TW = Taiwan, US = United States

* statistically significantly different from zero at the 95% confidence level using standard errors computed using the Gallant-Holly method.

Due to rounding error, rows do not always sum to one.

Table 3. Estimates of Intermarket Condition Frequencies for Canada

		Perfect Market Integration	Intermarket Tradability	Market Equilibrium
Product	**Other Market**	$\lambda_1+\lambda_2$	$\lambda_1+\lambda_2+\lambda_3+\lambda_5$	$\lambda_1+\lambda_2+\lambda_6$
Bellies	Taiwan	0.99	0.99	(0.98, 0.99)
	United States	1.00	1.00	(0.99, 1.00)
Hams	Taiwan	1.00	1.00	(0.99, 1.00)
	United States	0.98	1.00	(0.94, 0.98)
Loins	Japan	0.01	0.99	(0.01, 0.99)
	Taiwan	1.00	1.00	(1.00,1.00)
	United States	0.99	1.00	(0.99, 0.99)
Spareribs	Taiwan	1.00	1.00	(0.99, 1.00)
	United States	0.97	1.00	(0.11, 0.97)
Carcasses	Japan	0.98	0.99	(0.98, 0.99)
	United States	1.00	1.00	(0.99, 1.00)
Slaughter Hogs	Australia	0.99	1.00	(0.97, 0.99)
	Korea	0.99	1.00	(0.99, 0.99)
	Philippines	1.00	1.00	(0.95, 1.00)
	Taiwan	0.99	0.99	(0.99, 0.99)
	United States	0.99	1.00	(0.31, 0.99)
Corn	Philippines	1.00	1.00	(0.94, 1.00)
	Taiwan	1.00	1.00	(0.97, 1.00)
	United States	0.96	0.99	(0.94, 0.96)
Soybean Meal	Japan	0.78	1.00	(0.01, 0.97)
	Taiwan	1.00	1.00	(0.95, 1.00)
	United States	1.00	1.00	(0.91, 1.00)

Table 4. Estimates of Intermarket Condition Frequencies for the United States

		Perfect Market Integration	Intermarket Tradability	Market Equilibrium
Product	**Other Market**	$\lambda_1+\lambda_2$	$\lambda_1+\lambda_2+\lambda_3+\lambda_5$	$\lambda_1+\lambda_2+\lambda_6$
Bellies	Canada	1.00	1.00	(0.99, 1.00)
	Mexico	0.02	1.00	(0.02, 0.99)
	Taiwan	0.01	0.01	(0.01, 0.99)
Hams	Canada	0.98	1.00	(0.94, 0.98)
	Philippines	1.00	1.00	(0.99, 1.00)
	Taiwan	0.99	0.99	(0.99, 1.00)
Loins	Canada	0.99	1.00	(0.99, 0.99)
	Japan	0.02	1.00	(0.02, 0.99)
	Mexico	0.02	1.00	(0.02, 1.00)
	Taiwan	0.98	0.99	(0.02, 0.98)
Spareribs	Canada	0.97	1.00	(0.11, 0.97)
	Mexico	1.00	1.00	(0.01, 1.00)
	Taiwan	0.98	0.99	(0.98, 0.98)
Carcasses	Australia	1.00	1.00	(1.00, 1.00)
	Canada	1.00	1.00	(0.99, 1.00)
	Japan	0.99	1.00	(0.97, 0.99)
	Korea	0.98	0.99	(0.98, 0.98)
Slaughter Hogs	Australia	1.00	1.00	(0.98, 1.00)
	Canada	0.99	1.00	(0.31, 0.99)
	Korea	1.00	1.00	(1.00, 1.00)
	Philippines	0.99	1.00	(0.99, 0.99)
	Taiwan	0.99	0.99	(0.99, 0.99)
Corn	Canada	0.96	0.99	(0.94, 0.96)
	Philippines	1.00	1.00	(0.99, 1.00)
	Taiwan	0.98	0.99	(0.98, 1.00)
Soybean Meal	Canada	1.00	1.00	(0.91, 1.00)
	Japan	0.32	0.99	(0.32, 0.59)
	Taiwan	1.00	1.00	(0.89, 1.00)

Table 5. Mean Estimates of Intermarket Condition Frequencies by Product

Product	Perfect Market Integration $\lambda_1+\lambda_2$	Intermarket Tradability $\lambda_1+\lambda_2+\lambda_3+\lambda_5$	Market Equilibrium $\lambda_1+\lambda_2+\lambda_6$
Bellies	0.50	0.75	0.75
Hams	0.99	1.00	0.99
Loins	0.50	0.99	0.67
Spareribs	0.99	1.00	0.76
Carcasses	0.99	1.00	0.99
Slaughter Hogs	0.98	1.00	0.94
Corn	0.99	1.00	0.98
Soybean Meal	0.82	1.00	0.76

The first two columns are the unweighted arithmetic means of the maximal direction-specific estimate from each country pair. The last column is the unweighted arithmetic mean of the direction-specific estimates.

Figure 1: Transfer cost proportions by commodity type

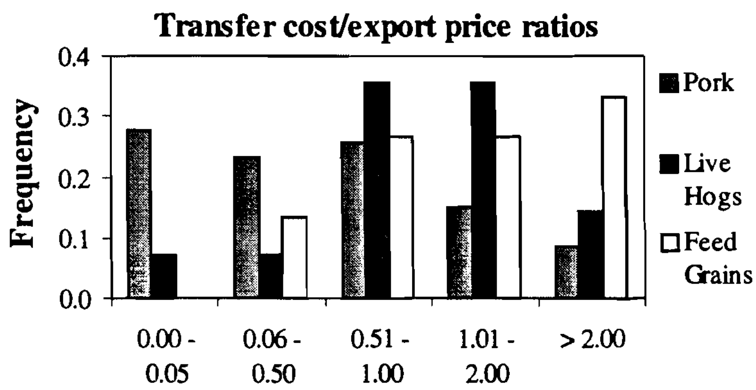
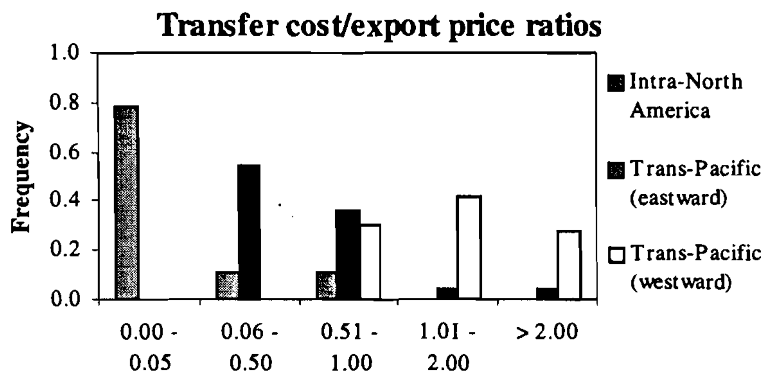


Figure 2: Transfer cost proportions by geography of trade



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Notes

1. Barrett (1996) presents a hierarchical classification of markets analysis methods based on the nature of the data used. Level I methods use only price data and are most susceptible to specification error. Level II methods combine price and transactions cost data. Level II methods are relatively recent innovations and represent the current frontier. Level III methods, combining price, transactions cost and trade flows data, were predicted to offer greater flexibility and inference.

2. Goldberg and Knetter (1997: 1245), reflecting the bulk of the literature, claim that "[a]ny perfectly competitive market is characterized by the condition that price equals marginal cost. Therefore a perfectly competitive market must be integrated." The claim in the second sentence relies on the assumption of an interior solution, i.e., continuous tradability. When corner solutions occur – as manifest by no trade – segmented equilibria are possible. Since trade can also occur without perfect competition – as in the case of binding quotas – equilibrium is neither necessary nor sufficient for integration, nor vice versa.

3. Baulch's (1997) PBM is a special case of our model that applies when there is no variation in trading status (i.e., A=1 all periods or A=0 all periods), in which case the only available information comes from price and transfer cost data.

4. Equivalently, the minima are the most appropriate estimates for market segmentation between a pair of markets ($\lambda_4+\lambda_6$).

5. Since the mid-1980s, chilled meats have overtaken frozen meats in international commerce, apparently because consumers prefer the quality of chilled over frozen meat.

6. Different countries' authorities define and report data on these products slightly differently. Although we have taken pains to ensure reasonable comparability among the series, these are surely not perfectly homogeneous commodities across all the countries. Details on all the data series are available in Barrett et al. (1997).

7. Note that the cif costs include more than just transport costs. Thus our series tend to be somewhat higher and more comprehensive than the International Wheat Council's freight rate series for heavy grains, which has occasionally been used by researchers, or the *Ocean Freight Rate Report* series available from the USDA's Agricultural Marketing Service.

8. During the period 1990-96, Canada imposed no tariffs on imported pork or slaughter hogs. The United States imposed a specific duty of 2.2 cents per kilogram on primal pork cuts, but no duty on carcasses or slaughter hogs. Pork from Canada to the United States became duty free under the North American Free Trade Agreement, which was effective January 1994 by Presidential Proclamation 6641 of December 15, 1993. Taiwan imposed a 15% (10%) ad valorem duty on pork and carcasses (on slaughter hogs). Japan employed a more complex variable rate schedule under which specific duties apply over some ranges, ad valorem tariffs over others, all tied to variable trigger prices.

9. There is also evidence that macroeconomic shocks may also add to international trade costs through their effects on the incidence of sea piracy, which occurs disproportionately in Asian waters and has risen sharply in the wake of the east Asian crisis (Sullivan and Jordan 1999).

10. Detailed test results are available from the authors by request.

11. This comparison is made by dividing the point estimate by the sum of the estimates across a category (e.g., $\lambda_5/(\lambda_5+\lambda_6)$.

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