Integration of Spatial Markets

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Studies of spatial market integration draw their implications from a theory which assumes that there are no intraregional transport costs. An alternative theory is offered, based on the assumptions that buyers and sellers are spatially dispersed and intraregional transport costs are significant. This implies that the market is a linked oligopoly (or oligopsony) and that market integration tests are tests of alternative oligopoly price formation processes. For example, collusive basing-point pricing produces results typically assumed to imply efficiently integrated markets, while competitive FOB pricing does not. The theoretical implications are illustrated with an analysis of hog prices in Canada.

Key words: Canadian hog prices, spatial market integration, spatial oligopoly.

Spatial price relationships for agricultural and food commodities have been widely used to indicate market performance. For example, two generally accepted principles thought to underlie regional price differences are (Tomek and Robinson, p. 151): (a) price differences between any two regions (or markets) that trade with each other will just equal transfer costs; (b) price differences between any two regions (or markets) that do not engage in trade with each other will be less than or equal to transfer costs.

The seminal book by Takayama and Judge provides the necessary theoretical justification for these principles, given certain explicit assumptions. Of particular interest here is the assumption that all transactions within a region occur at a point; that is, no intraregional transportation costs apply (effectively, all buyers and sellers are located at a single point). Although some applied studies of spatial market integration directly acknowledge the importance of the Takayama and Judge formulation (e.g., Ravallion), others do not (Harriss, Jones).

A direct application of the two principles listed above is to test statistically whether price differences between regions (markets) are greater than, less than, or equal to transfer costs. Prices can also be compared to those which might exist under a "perfect" economic system. In practice, this has been done by solving a Takayama-Judge spatial equilibrium model for theoretical prices or price differences between regions (Leath and Blakley). 1

A less direct application of the Takayama-Judge model, employing price responses between various regions or markets, has also been developed. If two sites trade with each other, price changes in one should lead to identical price responses in the other. Thus, Monke and Petzel (p. 482) define integrated markets as "markets in which prices of differentiated products do not behave independently." In the case of spatial markets, identical products are assumed to be differentiated by location, and statistical tests of interdependence between prices at different locations are employed to indicate the degree of market integration. Bivariate correlations of price series between pairs of markets that approach a value of 1.0 infer market integration (Jones, Stigler and Sherwin, Neal). Taken together, available studies using price correlation comparisons suggest that market integration is often quite low, although the markets appear to operate competitively. Problems with this statistical test have led researchers to advocate the

1 Although it is widely known that a spatial equilibrium model can be solved to compute equilibrium price or price differences between regions, this is not often done. One problem is that actual transfer costs are determined in a market with supply and demand conditions, but a supply/demand component for transfer services is generally not included as one part of an empirical spatial equilibrium model (Seaver, p. 1370). In addition, the findings of Wallace suggest that actual and predicted price levels and differences are not closely correlated when a linear programming model is used to determine "predicted" prices.
use of statistical procedures that include lagged responses and/or consideration of normal seasonal fluctuations (Blyn, Harriss, Ravallion, Delgado).

In this paper we suggest a revised structural view of intermarket price interdependence by realistically assuming that buyers and sellers are both spatially dispersed and intraregional transport costs exist—an obvious characteristic of agricultural and food markets. This approach alters theoretical expectations of price relationships in spatial markets and, therefore, alters the interpretation of market integration tests proposed by Ravallion. The next section examines relevant aspects of spatial price theory. This is followed by a section which delineates the Ravallion tests and suggests possible modifications in their interpretation. An application is then made to hog prices in Canada.

**Price Relationships in a Spatial Market**

A large literature deals with spatial competition in agricultural and food markets. The least-cost approach, based upon the location theory of Weber and Isard, examines the trade-offs between the costs of assembling inputs and distributing outputs. The relative costs of nontransferable inputs across potential sites, the cost of transporting transferable inputs to possible locations, and the cost of shipping finished products from these sites to markets are of primary concern. Spatial equilibrium models, based on linear or quadratic programming, have this theoretical base (e.g., Takayama and Judge, chap. 3).

Central to the solution of these models, and therefore predictions regarding price equilibrium conditions, is the assumption that a geographic area can be partitioned into a discrete number of regions in which all intraregional transfer costs are zero. Intraregional competition and trade can be characterized by the perfect competition model, and regional boundaries are assumed fixed.

A second spatial approach emphasizes locational interdependence, based upon the early writings of Hotelling and Smithies (e.g., Greenhut 1971). In markets where sellers and buyers are spatially distributed, transfer costs affect the net price received or paid. In food markets, consumers generally consider only those retailers who are located nearby even though many more retail outlets may exist in the economic market (Benson and Faminow). Similarly, in agricultural product markets, even when large numbers of buyers are located across a geographic area, farmers typically compare the prices in several proximate locations because of intraregional transport costs. That is, farmers differentiate between buyers on the basis of location. This suggests a second characteristic of spatial competition. Even when many sellers (buyers) are located in a geographic area, each considers only nearest rivals as major competitors, so linked oligopolistic (oligopsonistic) competition characterizes food retail (agricultural product) markets where expected pricing responses of rivals—conjectural variations—also determine pricing policy. Thus, spatial markets where both buyers and sellers are dispersed and transport costs are significant should not be characterized as perfectly competitive (Greenhut 1971). Furthermore, regional boundaries become a function of relative prices and do not remain fixed as prices change.

Market integration, that is, the process by which price interdependence occurs, can be directly deduced by developing a model of spatial oligopolistic (or oligopsonistic) competition. This model allows illustration of price reaction functions which form the theoretical basis for price interdependence (i.e., integration) in spatial markets.

In keeping with the spatial literature, the model given below is couched in terms of a few firms selling to spatially dispersed consumers located on a linear market (oligopoly). The theoretical example developed here will assume three spatially separated sellers, $X$, $Y$, and $Z$ in figure 1, with consumers evenly distributed between $X$ and $Z$. However, the results generalize to much larger numbers of sellers located at either the same sites ($X$, $Y$, and $Z$) or at numerous other sites, to unevenly distributed buyers and/or sellers, and to a two-dimensional space, although with increased mathematical complexity (magnitudes change but not comparative statics). In addition, they easily generalize to a market with relatively few buyers (e.g., at $X$, $Y$, and $Z$) and large numbers of spatially distributed sellers—oligopsony rather than oligopoly. This is an important point because some stages of the vertically linked series of markets which transform agricultural products into consumer goods (e.g., producer to processor markets) involve a few relatively widely dispersed buyers and much more numerous and more ubiquitously located sellers. Other stages, such as food retailing, readily lend themselves to spatial oligopoly modeling, however (Benson and Faminow). Therefore, the theoretical pre-
Figure 1. FOB pricing

presentation focuses on oligopoly in order to emphasize the generality of the market interdependence implications of spatial competition and to establish clearly these implications in the context of an extensive existing literature.

**Spatial Competition under FOB Pricing**

Assume identical consumers are evenly and continuously distributed between $X$ and $Z$ in figure 1. Let demand at each buying point for the physically homogenous product be of the form

$$\tilde{P} = a - (b/v) q^v,$$

where $\tilde{P}$ represents delivered price, $q$ denotes quantity demanded, $a$ and $b$ are positive constants, and $v$ is a constant parameter which can be positive or negative but greater than $-1$.\(^2\) Delivered price, $\tilde{P}$, consists of the price actually set by a firm, $p$, and transport costs. Assume for simplicity that a constant transport rate equal to unity exists for hauling the good one unit of distance. Thus, the delivered price from a selling site to any buying point is

$$\tilde{P} = p + u,$$

where $u$ represents the units of distance to that point from the relevant seller’s location. Combining (1) and (2) are solving for $q$ yields

$$q = \left[ \frac{v}{b (a - p - u)} \right]^{1/v}.$$

Assume that each of the firms faces production costs consisting of a fixed cost component, $F$, and a variable cost which involves a constant marginal cost, $c$:

$$C_i = F_i + c_i Q_i, i = x, y, z.$$

The $x$, $y$, and $z$ subscripts denote the three firms, while $Q$ represents a firm’s output. In a spatial world these fixed and marginal cost values need not be identical for survival of geographically separated firms. In fact, they are assumed to differ here in order to explore potential relationships between the three firms’ prices. In particular, assume $c = c_x = c_y$, but $c_z > c$. Thus, $z$ is a relatively high-cost producer. The schedules

\(^2\)This functional form has been used extensively in the spatial literature, e.g., Greenhut and Greenhut, Benson (1980, 1984), Benson and Hartigan. Note that $v$ must be greater than $-1$ in the FOB model which follows because we assume a constant marginal cost, and $v < -1$ implies an upsloping marginal revenue.
In order to determine the profit-maximizing FOB mill price, the individual demands from equation (3) within each firm’s service area must be aggregated:

\[
Q_x = \int_0^D \left[ \frac{v}{b} (a - p_x - u) \right]^{1/v} \, du = \frac{b}{v + 1} \left[ \frac{v}{b} (a - p_x D + G) \right]^{(v + 1)/v} - \left( \frac{v}{b} (a - p_x - u) \right)^{(v + 1)/v},
\]

\[
Q_y = \int_0^{D-G} \left[ \frac{v}{b} (a - p_y - u) \right]^{1/v} \, du + \int_0^{D-H} \left[ \frac{v}{b} (a - p_y - u) \right]^{1/v} \, du
\]

\[
= \frac{b}{v + 1} \left[ \frac{v}{b} (a - p_y - D + H) \right]^{(v + 1)/v} - \left( \frac{v}{b} (a - p_y - u) \right)^{(v + 1)/v},
\]

\[
Q_z = \int_0^H \left[ \frac{v}{b} (a - p_z - u) \right]^{1/v} \, du = \frac{b}{v + 1} \left[ \frac{v}{b} (a - p_z - u) \right]^{(v + 1)/v} - \left( \frac{v}{b} (a - p_z - H) \right)^{(v + 1)/v}.
\]

The \( Q_i \) represent the aggregate demand functions relevant to the FOB pricing firms, while \( G \) and \( H \) are distances over which \( X \) and \( Z \), respectively, sell.

Profit for each firm is

\[
\pi_i = (p_i - c_i) Q_i - F_i,
\]

so profits are maximized when \( d\pi_i/dp_i = 0 \). Thus, for example, firm \( X \)'s profit-maximizing decision is represented by

\[
d\pi_x = \left[ \frac{v}{b} (a - p_x) \right]^{(v + 1)/v} - \left( \frac{v}{b} (a - p_x - G) \right)^{(v + 1)/v} \left( 1 + \frac{dG}{dp_x} \right) - \frac{v}{b} (a - p_x) \right]^{(v + 1)/v} = 0.
\]

\[
p_x = p_x \left( a, b, v, c_x, G, \frac{dG}{dp_x} \right).
\]

Of course, \( G \), given in equation (11), is a function of \( p_x \) and \( p_z \); so, through \( G \), the price set by the firm at \( X \) depends on the price set by the firm at \( Y \). Furthermore,

\[
H = \frac{1}{2} (p_y - p_z + D),
\]

\[
p_z = p_z \left( a, b, v, c_z, H, \frac{dH}{dp_z} \right), \text{ and}
\]

\[
p_y = p_y \left( a, b, v, c_y, G, H, \frac{dG}{dp_y}, \frac{dH}{dp_y} \right).
\]

Assumption of specific parameter values and conjectures allows simultaneous solution of equations (11), (13), (14), (15), and (16) for equilibrium prices, such as \( p_x \), \( p_y \), and \( p_z \) in figure 1. Thus, the price set by \( X \) is, through \( G \), \( p_y \) and \( H \), a function of the price set at \( Z \). In
fact, given \( v < 0 \) (if \( v > 0 \), price discrimination rather than FOB pricing is likely, as explained below) comparative statics analysis implies that

\[
\frac{dp_x}{dp_z} > 0.
\]

The actual comparative statics analysis of the integration process implied by this model is not presented here because the results are intuitively obvious (Benson 1980). If firm \( Z \) lowers price for some reason, \( H \) would expand \((D - H \text{ would shrink})\) prompting firm \( Y \) to lower price; \( G \) in turn would shrink \((D - G \text{ would expand})\), and firm \( X \) would lower its price. The price set by \( X \) is impacted by cost and demand conditions which \( Z \) faces (and vice versa). By the definition of geographic market integration used here, \( X, Y, \) and \( Z \) are all in the same market because each firm's price depends on the prices set by the other two.

However, this integration likely represents a dynamic process if spatial oligopolistic competition underlies the price formation process. Initial price reactions and their feedbacks can lead to additional price changes as the market adjusts toward a new equilibrium for comparative statics analysis. Reaction functions such as equations (13), (15), and (16) imply a sequence of reactions and re-reactions. The full price adjustments can take time. In addition, as already noted, the fully adjusted equilibrium prices need not be equal or differ exactly by transport costs (recall the discussion of fig. 1). Indeed, given \( c_z > c_x, p_x > p_z, \) but \( p_x + u_z = p_x (u_z \text{ represents the distance from } X \text{ to } Z) \). Prices may be highly interdependent in a spatial setting without net price uniformity (price less transportation costs) rising. Arbitrage only guarantees that prices at different spatial buying sites will not differ by more than the transport cost of shipping the product from one site to another. It does not imply that prices net of transfer costs will be the same; indeed, they can differ for many reasons in a spatially interdependent market.

The magnitude of price responses need not be identical. Consider firm \( Y \)'s response to firm \( X \)'s original price change. Firm \( Y \) may wish to regain its lost geographic market share by exactly matching \( X \)'s price change, but such a response will also generate a price reaction by \( Z \) (as well as further price changes by \( X \)). If \( Y \) does not fully match \( X \)'s price change, then \( Y \) serves as a buffer between \( X \) and \( Z \). The larger the number of intermediate selling sites between two specific sellers, the weaker the price linkage.

Mulligan and Fik (1988, 1989) demonstrate mathematically that a distance-decay effect occurs in spatial competition models. More distant located competitors are linked indirectly and, ceteris paribus, the price response will be weaker.

**Spatial Price Discrimination**

The value of the parameter \( v \) in the demand function [equation (3)] is one important determinant of whether or not firms in the market can practice price discrimination. A spatial firm which faces no direct competition for customers at a particular buying point will set a profit-maximizing price at that point unless prevented from doing so (e.g., by consumer arbitrage or by legal/institutional constraints). For instance, firm \( X \) will set price for a customer located at \( X \) by equating marginal revenue and marginal cost:

\[
\hat{P}_x (1 - (1/e)) = c_x,
\]

where \( e \) is the own-price elasticity of demand. From equation (1), \( dP/dq = -bq^{-1} \) and \( bq^e = v (a - \bar{P}) \), so

\[
(19) \quad e = \frac{\bar{P}}{v(a - \bar{P})}.
\]

Substituting (19) into (18) provides

\[
(20) \quad \hat{P}_x (1 + v) - va = c_x.
\]

For consumers located at some distance from \( X \), transport costs are netted from marginal revenue or added to marginal cost

\[
(21) \quad \hat{P}_{sd} (1 + v) - va = c_x + u,
\]

where \( \hat{P}_{sd} \) represents delivered price from \( x \) to any point in the market. Solving equation (21) for \( \hat{P}_{sd} \) yields firm \( X \)'s discriminatory delivered price schedule.

\[
(22) \quad \hat{P}_{sd} = (1/(1 + v)) (va + c_x)
\]

\[+ (1/(1 + v)) u.]

The first term on the right-hand side of equation (22) is the price at point \( X \) [see equation (20)], while the slope of the delivered price schedule as \( u \) increases is \((1/(1 + v)) \). The slope of an FOB schedule is unity because the transport rate is assumed equal to one. Therefore, a delivered price schedule with a slope of less than one implies freight absorption and discrimination in favor of distant buyers (or against near buyers). A slope greater than one, implies phantom freight and discrimination in favor of near buyers (against
distant buyers). Thus, \( v > 0 \) means that freight absorption is profitable, while \( v < 0 \) implies that it is not.

Profitable consumer resale or arbitrage is not possible when freight is absorbed. However, arbitrage should prevent phantom freight and discrimination in favor of near buyers (see Benson 1984 for more detail). Thus, \( v < 0 \) implies that the best spatial firms can likely do is set FOB prices. As a consequence, the theoretical analysis of price discrimination was developed assuming \( v > 0 \) and FOB pricing assuming \( v < 0 \). Of course, FOB pricing may also arise when price discrimination is prevented even though \( v > 0 \) (e.g., legal sanctions may prevent spatial price discrimination, or consumers may pay the transport cost themselves by traveling to pick up the product).

Similar schedules to equation (22) can be derived for \( Y \) and \( Z \). Assuming the same parameters, discriminatory schedules would produce higher price intercepts and flatter schedules than the FOB schedules depicted in figure 1. Consumers would buy from the firm offering the lowest delivered price, so market boundaries occur where delivered price schedules are equal.

Because prices are set independently at each buyer site, interdependence only applies where delivered prices are equal. In the example developed here, this condition occurs at only one point between \( X \) and \( Y \) and between \( Y \) and \( Z \). Spatial price discrimination is not restricted to monopoly, and spatial competitors can discriminate in order to invade rival's markets, producing considerable market overlap (Greenhut and Greenhut). Thus, discrimination may break the linkage that implies extensive market integration, as under FOB pricing. A complete breakdown in market integration requires constant marginal costs.

When marginal costs are upsloping, the spatial price discriminator does not equate marginal cost to the net marginal revenue on sales at each buyer location. Instead, the relevant marginal cost is that which applies to the last unit of total sales over the firm's entire marketing area (Greenhut, Norman and Hung, pp. 180–96). Spatial markets consisting of price discriminatory oligopolists are interdependent because price changes in one firm affect its market fringe, moving neighboring firms down along their original marginal cost schedules. Thus, other firms lower profit-maximizing discriminatory prices to all buyer locations, firms consider rival responses to potential price adjustments, and lagged price adjustments and feedbacks characterize the adjustment to an equilibrium. Thus, market integration implications similar to those discussed above under oligopolistically competitive FOB pricing can arise under oligopolistically competitive spatial price discrimination, given nonconstant marginal costs.

**Basing-Point Pricing**

Basing-point pricing systems generally result from an organized oligopoly arrangement, either price leadership or collusion (Greenhut, Scherer). Under this system the mill or base price is set at a particular production site (sites under a multiple base-point system) or basing point, and the delivered price to any buyer location is the base price plus transportation costs.

In figure 2, site \( A \) is the basing point. The price at \( A \) (\( p_a \)) is set, perhaps jointly by several spatially dispersed firms or perhaps by the basing point firm (or firms) acting as a price leader. Firms located at other sites (for example, \( B \) and \( C \)) adopt the delivered price schedule from \( A \) (\( p_a + tu \)) for all sales. Thus, prices net of transport costs are equal. Sale to the left of \( B \) and \( C \)'s locations require freight absorption by the firms at those locations, while sales to the right involve "phantom freight" because they would normally charge a price below \( P_B \) and compete for market area such as in figure 1. If the price at \( A \) were to change for some reason, all other prices would change by the same amount. Furthermore, collusion or price leadership implies virtually instantaneous price adjustments with no feedbacks.

Clearly, prices are interdependent as the intuitive definition of market integration suggests. Moreover, any arbitrarily chosen regional boundaries established over this market (e.g., at political boundaries) would result in interregional trade because the prices charged by all firms are exactly the same at all locations. Consumers do not differentiate among sellers by location. Thus, the firm at \( A \) probably sells through the \( AC \) space and firms at \( B \) and \( C \) may sell all the way back to \( A \) if freight absorption is not too great. Under an effective single basing-point system, prices will differ exactly by transportation costs.

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3 The constant marginal cost assumption also influences comparative statics under FOB pricing, given \( v > 0 \) (thus assuming some legal or institutional constraint prevents price discrimination). If \( v > 0 \) and marginal costs are constant, a seller may raise price as its market shrinks (Benson 1980, Benson and Hartigan, Capozza and Van Order); so equation (17) need not hold. However, an upsloping marginal cost will reestablish (17) even when \( v > 0 \).
Implications for Empirical Tests

Market integration studies have emphasized applications to food staples in developing countries, most notably Nigeria and India (see Harriss for a review of these studies). Different, but related, empirical techniques have been used to test spatial market integration. High price correlations are often taken to infer integration (e.g., Jones, Harriss, Uri and Rifkin, Blyn). In addition, price differences between markets, relative to transfer costs (Stout and Feltner, Hays and McCoy) or normal seasonal fluctuations (Delgado), provide other approaches to determining integration. However, these empirical tests of market integration are essentially tests to see which spatial pricing system underlies the price formation process.

The usual definition in the literature is that integrated markets are those where prices are determined interdependently. This has generally been assumed to mean that price changes in one market will be fully passed on to other markets (or the result has been derived from a Takayama-Judge model). In this context, Ravallion (p. 105) discusses both short- and long-run market integration. With short-run integration, price changes are fully and immediately passed on to other markets with no lagged effects. Long-run integration requires that a unit price change is fully passed on over time, but with the potential for lagged effects. In principle, however, the Ravallion approach is consistent in its general expectations with the price correlation and net spatial price difference approaches described earlier, which rely on all activity within a region taking place at a point.

Ravallion developed his market integration tests for a central urban market with interlinked local (rural) markets where trade with the central market was the dominant feature of the price formation process. This implies that the rural

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4 Systems like this have been characterized as "competitive" basing point systems (e.g., Haddock). In fact, base point pricing can conceivably arise without collusion or price leadership, but the necessary conditions are very limiting (Benson, Greenhut, and Norman). Thus, a more accurate characterization of such a system is that competitive FOB pricing exists between various central marketing points, and the rural markets are simply transshipment terminals. Alternatively, they may actually involve a price leadership basing point arrangement with the central market firm as the dominant firm price leader and the smaller rural firms as price takers. The following presentation suggests a statistical procedure for determining whether such a system is competitively or cooperatively produced.
markets are relatively minor. However, extension to a linked framework, as developed above, is straightforward by evaluating all bivariate price relationships in the spatial area under consideration. Consider the model

\[ X_i = \sum_{j=1}^{n} a_{j} X_{i-j} + \sum_{k=0}^{m} b_{k} Z_{i-k} + E_i, \]

where \( X_i \) and \( Z_i \) are the prices in location \( X \) and \( Z \) at time \( t \), \( E_i \) is the error process, and the fixed parameters are \( a_{j} \) and \( b_{k} \). In this simplified version of the Ravallion model the market integration tests remain as

(a) independence:

\[ b_{k} = 0 \ (k = 0, 1, \ldots, m), \]

(b) short-run integration (strong form):

\[ b_{0} = 1; a_{j} = b_{k} = 0 \]

\( (j = 1, 2, \ldots, n; k = 1, 2, \ldots, m), \)

(c) short-run integration (weak form):

\[ b_{0} = 1; \sum_{j=1}^{n} a_{j} + \sum_{k=1}^{m} b_{k} = 0, \]

(d) long-run integration:

\[ \sum_{j=1}^{n} a_{j} + \sum_{k=0}^{m} b_{k} = 1. \]

Price interrelationships in the system can be evaluated by considering all market pair combinations.

The test of independence requires that the contemporaneous and lagged price effects at one location are independent of prices at another location \( (b_{k} = 0, \text{ all } k) \). If consumers and producers are spatially distributed, this possibility is predicted by spatial price discrimination with constant marginal costs. Under the other spatial pricing systems described above, \( b_{k} \neq 0 \) is expected to hold.

The strong form of short-run integration requires basing-point pricing if consumers and producers are not concentrated at single points and prices differ by transportation costs. In this case price adjustments are fully reflected in the same time period \( (b_{0} = 1) \) with no lagged effects \( (a_{j} = b_{k} = 0; j, k \neq 0) \). An effective basing-point system is the only theoretical spatial model which produces this expectation, given spatially distributed buyers and sellers, and significant intraregional transport costs.

The other widely used spatial models (competitive FOB oligopoly and spatial price discrimination) do not produce these same expectations. Basing-point systems generally arise out of a noncompetitive institutional structure and are not usually considered desirable.\(^5\) (They are frequently attacked under the antitrust laws.) This suggests that concerns about the lack of market integration in some empirical studies should be discounted; their expectations are not based on a model which is expected to generate desirable results if buyers and sellers are spatially dispersed in the market being examined. Under such circumstances, the evidence (previously interpreted as a lack of market integration) suggests that cartelization, in the form of a perfect basing-point pricing system, is not generally observed. Strikingly, the typical conclusion that highly integrated markets (that is, markets in which price movements are highly correlated and prices differ exactly by transport costs) are caused by competition and imply an efficient market is reversed: such markets are caused by collusive basing-point pricing and tend to be relatively inefficient.

The weak version of the short-run integration test requires that the lagged effects vanish on average \((\sum_{j=1}^{n} a_{j} + \sum_{k=1}^{m} b_{k} = 0)\); this result is consistent with a less than perfect basing-point system. For instance, if this test applies for all the relevant marketing points, then a tacitly collusive arrangement may exist and time is required to search for the new equilibrium price. If, on the other hand, the result applies for a subset of the interdependent marketing points, then an incomplete cartel may be in operation. Price adjustments set in motion within the base point system cause competitive reactions by firms outside the basing-point arrangement which feed back into the base point price determination process, and vice versa. Thus, lags and feedbacks are evident between firms in the basing-point arrangement and those outside it.

The two short-run integration tests constitute tests of an underlying basing-point system. Along with the Takayama and Judge criterion of equal spatial prices (net of transfer costs) over time, these tests allow examination of the underlying market behavior in spatial price generation.

In the long-run integration test, all contemporaneous and lagged effects sum to one. In effect, price changes in one region net out, in a dynamic fashion, to exactly equal price changes in the other. Because each short-run test implies

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\(^5\) Such a system might be competitively produced, but the necessary conditions are quite limiting. See footnote 4 for related discussion.
long-run integration (Ravallion), this test is a feature of a basing-point system. However, the short-run tests may be rejected and the long-run test accepted. This would be consistent with price reactions equal to one for the competitive FOB oligopoly and perhaps for increasing marginal cost price discriminatory models. However, exact price matching over the longer term is not a requirement of these models, only an empirical possibility.

An Empirical Example: Hog Prices in Canada

Weekly hog prices for five Canadian cities (Edmonton, Calgary, Saskatoon, Winnipeg, and Toronto) were taken from the Livestock and Meat Trade Report for the period 9 January 1965 to 20 December 1975. Data for Montreal, the other major hog market in Canada, were not published subsequent to July 1970, so this city is excluded from the analysis. In total, 572 weekly observations of average prices were available. From 9 January 1965 to 28 December 1968, Grade A dressed hog prices were used, and for the remaining time Dressed Index 100 hog prices were analyzed. This eleven-year period includes the time period when electronic exchanges were introduced for marketing hogs; thus, it represents a potential readjustment in the price formulation process in Canada. Therefore, the ability of the empirical tests to detect changes in pricing systems could be evaluated. In addition, this general time period has had considerable scrutiny. Concerns about market pricing efficiency resulted in a major price study (Canadian Pork Council) and in a major anticompete case. Both buyers and sellers are spatially dispersed, and transportation costs are significant; so these data are particularly well suited for evaluation of spatial prices and the form of the pricing system which is implicit in the market integration tests. Generally, hog production is dispersed across Canada, although not always evenly, and slaughtering occurs at the major cities included in the analysis. Hog production in each province was relatively constant during the 1965–69 time period. However, during the 1970–75 period, production trended slightly upward in Saskatchewan and Manitoba, decreased somewhat in Ontario, and fluctuated around the historical average in Alberta (Canada Pork Council). A substantial exported surplus developed in Saskatchewan and Manitoba, and the price differential in these provinces fell relative to U.S. prices. In addition, during this time Ontario moved from a position of self-sufficiency to a pork deficit.

Other institutional changes were occurring during the early 1970s. In Alberta (1969), Saskatchewan (1973) and Manitoba (1971) marketing boards for hogs were formed, and the pricing system changed. Electronic exchanges for selling hogs were instituted in Alberta and Manitoba, while Saskatchewan developed a formula pricing system for sales from the marketing board to packers. Finally, substantial rationalization of the packing industry occurred. In response to low levels of capacity utilization (estimated at about 30% by Canada West Foundation) a large number of plants either closed or ceased to slaughter hogs.

The price data were first differenced in order to represent price changes from period to period. This allowed the data analysis in a manner consistent with the theoretical models. Price levels were highly volatile during the latter half of the data set, and the transformation to price differences allows the empirical evaluation to focus on the interdependence of price changes rather than price levels. This is consistent with the theoretical model development, and interactions of price changes between different locations should not be seriously affected by volatile overall price levels. Additionally, based upon inspection of the estimated autocorrelation functions, differencing transformed the data into stationary series.

The empirical tests are based on estimated OLS versions of equation (23) for all combinations of market pairs for the five cities (20 regressions per time period). This exhaustive evaluation of price response equations allows the evaluation of the form (or forms) of spatial pricing for hogs. A simultaneous approach would evaluate the generalized version of equation (23) using vector autoregression. However, beyond the well-known tendency of severe multicollinearity using this approach, there is an additional cost. Weaker price responses, caused by the linked interdependence of spatial oligopoly pricing systems, should be observed in the $R^2$'s resulting from the OLS estimates of equation (23) for each market pair. With more intermediary markets the price response is less direct. This information would be lost by using vector autoregression.

The data were divided into two time periods for analysis. The first coincides with the period

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5 Reason for Judgment in Her Majesty the Queen v. Canada Packers Inc. and Intercontinental Packers Ltd.
of relative stability in the market (9 Jan. 1965 to 25 July 1970), while the second represents a period with considerable institutional change (1 Aug. 1970 to 20 Dec. 1975). The criterion for determining the break point is arbitrary. However, it coincides with the date after which prices for Montreal ceased to be publicly reported by Agriculture Canada, and it allows evaluation of any differences in pricing systems during the two periods. Therefore, the sensitivity of the empirical procedure to structural and institutional factors can be evaluated.

The correct dynamic process given in equation (23) cannot be determined theoretically. Mechanical procedures can be applied (Bessler and Brandt) when a priori information is not available. In all cases, the Ljung-Box $Q$-statistic of the unrestricted regressions implied that autocorrelation was not a problem when eight lags were specified.\(^7\) Therefore, the empirical tests

\(7\) Initial testing with four lags resulted in rejection of the null hypothesis of no autocorrelation. In addition, although choice of lag is by nature a difficult issue, eight weeks was a sufficient number to allow for interactive pricing between competing regions to run its course. "Hannan’s Criterion" (Hannan) was suggested by a reviewer as an alternative ad hoc procedure. "Long-run" in these types of tests should be interpreted with caution because long-run in the normal economics sense is not being tested.

**Table 1. F-Statistics for Pricing Behavior Tests—Jan. 65—July 70**

<table>
<thead>
<tr>
<th>Dependent Variable(^a)</th>
<th>Independent Variable(^b)</th>
<th>Independence(^b)</th>
<th>Perfect Basing-Point Pricing(^c)</th>
<th>Incomplete Basing-Point Pricing(^c)</th>
<th>Long-Run Price Matching(^c)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>11.91*</td>
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\(a\) CAL, Calgary; EDM, Edmonton; SAS, Saskatoon; WIN, Winnipeg; TOR, Toronto.  
\(b\) F(9, 263).  
\(c\) F(17, 263).  
\(d\) F(2, 263).  
\(e\) F(1, 263).  
\(f\) Single asterisk indicates rejected at 95% level of confidence.

Evaluation of the market integration or spatial pricing tests involved $F$-tests of the regressions implied by equation (23) with the tests imposed as constraints, combined with analysis of spatial price differences. Tables 1 and 2 show the $F$-statistics for the two time periods and table 3 reports means and standard deviations of price differences between Toronto and the other markets.

**Price differences.** Price differences between Toronto and the other markets display different results for the two time periods. In period 1, price differences generally correspond to differences in transfer costs. For example, the average Toronto—Calgary difference is $3.52, while the Toronto—Saskatoon difference is $2.74. The Toronto—Edmonton price difference is roughly equivalent to transfer costs reported by the Canadian Pork Council. During the second period, the relationship between Toronto prices and the other markets changes considerably. Not only are price differences greater in all cases (probably reflective of general price inflation during the period), but they tend towards equality. Thus,
Table 2. F-Statistics for Pricing Behavior Tests—Aug./70–Dec./75

<table>
<thead>
<tr>
<th>Dependent Variable*</th>
<th>Independent Variable*</th>
<th>Independence*</th>
<th>Perfect Basing-Point Pricing*</th>
<th>Incomplete Basing-Point Pricing*</th>
<th>Long-Run Price Matching*</th>
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a CAL, Calgary; EDM, Edmonton; SAS, Saskatoon; WIN, Winnipeg; TOR, Toronto.
b $F(9, 255)$.
c $F(17, 255)$.
d $F(2, 255)$.
e $F(1, 255)$.
f Single asterisk indicates rejected at 95% level of confidence.

in period 2 relative prices across markets no longer reflect differences in transfer costs to other markets.

Independence. In all cases the null hypothesis of independence is rejected. Thus, no evidence of price discrimination is found under conditions of constant marginal costs in either period.

Perfect basing-point pricing. The strong version of short-run integration is rejected in all cases. Thus, there is no evidence of a perfectly functioning basing-point pricing system during either period. In several cases inspection of the individual regression coefficients indicated that $b_0 = 1$, but lagged effects were significant.

Incomplete basing-point pricing. In period 1, the weak form of the short-run integration test is not rejected in six cases. Prices in the three western markets appear to be interrelated by a loose form of basing-point pricing where Calgary is the basing point. The evidence suggests an unidirectional system where (a) Edmonton bases on Calgary; (b) Saskatoon bases on Edmonton and Calgary; (c) Winnipeg bases on Saskatoon, Edmonton, and Calgary. This western basing-point system is apparently competitively linked with Toronto, however, and this may explain the observed lags and feedbacks.

In period 2 the results are considerably different; in only one case do we fail to reject the weak-form constraint. In the second period, prices in Edmonton continue to be based on Calgary prices.

The evidence from this test is striking. The data indicate that the more widespread basing-
point system evident in period 1 broke down. This result contrasts with the anticombines case, cited earlier, which alleged price fixing by the Alberta-based packers throughout the entire eleven-year period.

Long-run price matching. In period 1, the restriction of exact, but lagged, price matching is rejected in ten cases. In Calgary and Edmonton, price changes in one market are fully reflected in the other, but neither fully reflects changes in the other three markets. The intermediate cities, Saskatoon and Winnipeg, fully reflect other markets, while this test is always rejected for Toronto.

The results are considerably different for period 2. In all cases this restriction is not rejected for Calgary and Edmonton, while it is only accepted for Saskatoon and Winnipeg when Toronto prices are used as independent variables. Once the basing-point pricing system broke down, the magnitude of price interactions and responses between markets changed substantially. In particular, lagged responses became more important for the two Alberta markets.

Distance decay effects. The unrestricted $R^2$'s for the two periods are given in tables 4 and 5. The distance-decay feature of spatial competition is evident in both periods. The $R^2$-values decline with distance and/or the number of intermediate points, reflecting the linked nature of the price reaction functions given above. However, differences between the two time periods are evident. In particular, the increased pricing interdependence associated with the disappearance of the basing-point system is evident in the $R^2$-values. The relative importance of Saskatoon and Winnipeg price changes as predictors of Calgary and Edmonton price changes is diminished. In general, $R^2$-values are lower for all markets in period 2. Because of the increased competition associated with the breaking down of the basing-point system, the $R^2$'s of the paired market price responses are reduced. This is caused by a more rivalrous price determination process where price changes in additional markets must be considered. Thus, a lower level of correlation between any pair of price series should be expected.

Market efficiency. The marketing boards established in Alberta, Saskatchewan, and Manitoba were initially proposed to create more equitable and efficient markets for slaughter hogs. The electronic marketing systems implemented in Alberta and Manitoba were designed to create more competitive bidding by packers. In Saskatchewan, a formula pricing arrangement was developed to link provincial prices more closely to other markets. In all three cases, the primary emphasis was on designing pricing systems that facilitated exchange and reflected underlying

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>CAL</th>
<th>EDM</th>
<th>SAS</th>
<th>WIN</th>
<th>TOR</th>
</tr>
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<table>
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</table>
supply and demand conditions. None of the marketing boards was given authority to manipulate prices through supply management.

The disintegration of the basking-point system and movement to a more competitive FOB system roughly coincided with the introduction of these marketing innovations. However, other institutional changes (interregional supply/demand balances and rationalization of the packing industry in western Canada) were also occurring, so it is difficult to clearly establish a direct causal link. Adamowicz, Baah, and Hawkins suggest that shifts in market interdependency between Alberta and other major markets may have been caused by institutional changes instituted by the marketing board in Alberta. However, given the theoretical arguments presented above, the implications for market efficiency would be interpreted somewhat differently. High levels of price interdependence, in conjunction with price differences between hog buying locations that reflect transportation costs, is symptomatic of a collusive (overt or tacit) pricing system.

Conclusions

Studies of integration for spatial markets have explicitly or implicitly drawn their implications from a theory of market price formation which assumes no intraregional transport costs. Such studies have primarily relied upon price correlations and regressions that analyze the dynamic price adjustment patterns. Rarely, if ever, have prices been found to be highly correlated and differ between two points by transportation costs, thus indicating that the markets under study are not highly integrated and perhaps that they are not very efficient. An alternative theoretical interpretation for such results is suggested here, based on the assumptions that both buyers and sellers are spatially dispersed and intraregional transport costs are significant. These assumptions imply that the market is a linked oligopoly (or oligopolyson). The implications of this alternative theory are illustrated by focusing on market integration tests proposed by Ravallion which allow certain predictions of various spatial pricing systems that may underly oligopoly (oligopolyson) market price formation to be examined. For example, when combined with the criterion that prices between two points should differ by transportation costs, short-run integration standards are effectively tests of basking-point pricing.

To illustrate the implications of the theoretical analysis, the Ravallion methodology was applied to hog prices in Canada. Noncompetitive pricing, in the form of a basking-point pricing system for hogs, was detected for a subgroup of Canadian hog markets between 1965 and 1970. The tests were sensitive to institutional characteristics of the market. The results suggest that this pricing system disintegrated during the 1970-75 period, a time when substantial changes in the Canadian hog market occurred, and was replaced by a more competitive FOB pricing system.

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References


Greenhut, M. L. George Norman, and Chao-Shun Hung. The Economics of Imperfect Competitions: A Spatial


