Spatial Price Analysis: A Methodological Review

by

Paul L. Fackler

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Empirical methods of dynamic spatial price analysis are reviewed. Emphasis is given to interpreting these methods in the context of economic models of price determination, including both point-location and agents-on-links models. This focus calls into question or sheds new light on a number of standard practices, including the market integration criteria of Ravallion and Timmer, the use of impulse analysis and Granger-causality.

Introduction

Many economically important commodities are costly to transport and the spatial aspects of markets for such commodities cannot be ignored. Spatial patterns of marketing give rise to a complex web of relationships among prices throughout a market. Spatial price analysts attempt to study that price behavior in order to gain insight into the workings of the market and to test whether it is performing well.

In addition, spatial transformations (transportation) are also representative of production processes characterized by fixed input/output ratios, arguably the most simple input/output relationship. An understanding of spatial markets therefore increases understanding of price relationships in vertical marketing chains as well. Spatial differentiation can also be viewed as a metaphor for more general kinds of product differentiation and therefore the study of spatial markets can shed light on more general competitive processes.

Spatial prices have been used to address a variety of economic issues. Anti-trust economists have been interested in market definition (the extent of the market) in order to determine whether particular firms are subject to effective competition. Also of interest to students of industrial organization is nature of competition among spatially separated firms, particularly those that possess some degree of local market power. Agricultural and development economists have been interested in the degree to which regions are economically efficient and integrated. Among the questions raised in this regard are whether the market moves commodities towards their highest value users, whether it is able to absorb large shocks (abundant or failed harvests, large swings in international prices, etc.) without breakdown, and whether it is sufficiently integrated to foster development through specialization. In a number of cases, economists have used spatial price analysis to gain insights into the organization of markets, examining, for example, whether different regions display dominant/satellite relationships and how prices adjust dynamically to economic

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shocks.[2]

In spite of the wide variety of issues that students of spatial markets have asked, the repertoire of empirical methodologies is fairly limited. For the most part price data are used because they are the data most readily available and reliable. Typically time series of prices at different spatial locations are analyzed using correlation analysis or some form of vector time series analysis.

This review attempts to develop a common framework for spatial price analysis in order to shed light on what conclusions can be drawn about spatial markets. It attempts to carefully distinguish between the economic model of price determination and the statistical techniques used to analyze price behavior. The paper first discusses alternative models of spatial price formation; these models provide a basis on which empirical analysis can be interpreted. Two commonly used models are discussed, both of which model space in terms of a network, with prices observed at the network nodes. They are distinguished by what occurs on the links between nodes, with one using the links only to transport the commodity and the other using links both for transport and for production (or consumption).

Empirical studies of spatial prices of a homogenous good are generally conducted within the context of a dynamic regression model of prices. Many studies of spatial prices express hypotheses about market efficiency and integration in terms of restrictions on the regression parameters. A very simple economic model is used to provide a better understanding of these restrictions and the conditions under which they are appropriate.

Tests that can be justified in the context of the simple model should be though of as joint tests of market efficiency, market integration and the equilibrium model. Presuming the model is correct, failure to pass these tests can be due either to a breakdown in the integration of the market or to some form of market inefficiency. One problem with tests based on dynamic regressions is that the nature of the alternative is not clear, making the interpretation of test failure difficult. Models that attempt to make explicit the nature of the alternative to well integrated, efficient markets have been developed but suffer from problems of their own.

It is also possible that the model used to interpret empirical results does not adequately capture important features of the market being examined. Unfortunately, many of the methods that can be rigorously justified within the context of a simple model of spatial price formation cannot be supported when the assumptions of the model are relaxed.

The paper begins with a discussion of alternative economic models of spatial price determination. Then the most commonly used econometric framework, the dynamic regression model, is discussed. A simple economic model that results in a dynamic regression in prices is then outlined and several approaches to testing for market efficiency and integration are examined in light of this model. Alternative econometric approaches that attempt to nest reasonable alternatives to perfect integration or efficiency are then examined, followed by a discussion of the implications of alternative models of price determination that do not support the tests based on the simple model. Long-run equilibrium concepts and cointegration models are then discussed, followed by concluding comments.

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2. Another question not covered in this review concerns whether goods produced in different regions are perfect substitutes. Monke and Petzel address this market integration issue by examining the behavior at a single location of similar goods imported from different regions.

The conclusions drawn are mixed. Some of the interpretations placed on empirical results do not seem to have a firm economic foundations. Others can be justified within the context of simple models of spatial price determination but are not robust to key assumptions about the nature of the market.

Economic Models of Price Determination

Given the variety of issues that have been addressed by spatial price analysts, there has been relatively little attention paid to the linkages between well defined theoretical models and econometric methods. The most commonly used theoretical models have a network structure consisting of nodes at which prices are observed and linkages among the nodes along which the commodity is transported. Typically such models fall into one of two categories: point-location and agents-on-links models.

The simpler of the two, the point-location model, treats the network links as simply routes over which transportation occurs. Enke and Samuelson first discussed models of this type and they were extensively developed by Takayama and Judge. Point-location models are appropriate for markets in which the nodes represent major collection, processing or distribution centers which deal directly with one another. For example, the grain market in the United States includes a system of terminal elevator locations on major water and rail links. A study of prices at these locations (as opposed to a study at country elevator sites) would appropriately be modeled with a point-location model.

The agents-on-links model has economic activity occurring at both the nodes and along the links. Generally, there are agents at nodes that sell to or buy from the agents on the links. For example, the links might represent spatially dispersed farmers and the nodes represent city or town market (demand) centers. Agents-on-links models are often used to model imperfectly competitive situations in which a single agent exists at a node and exerts local market power (Benson, Faminow and associates discuss this type of model).

In either model an important issue concerns dynamic linkages. Linkages in commodity markets over time occur for a variety of reasons including storage, investment, seasonality (in production and consumption), demographic shifts, preference shifts, etc. With the exception of storage and (possibly) investment, price analysts will generally treat these factors as exogenous and represent them as shifts in regional demand and supply functions. There have been some attempts to incorporate storage activities into dynamic spatial models (e.g., Chapter 7 of Williams and Wright) but this adds considerable complexity to the model.

An alternative is to use a sequential equilibrium model in which the market is modeled as a sequence of static equilibria. In a sequential equilibrium model the dynamic linkages are all taken to be exogenous to the model. For example, consider a simple two location spatial model in which location 1 exports its surplus to location 2. Suppose that, at time t, the location i excess demand function is

$$q_{ti}=E(p_{ti},a_{ti}),$$

where q_{ti} is the net imports (exports if negative), p_{ti} is the price and a_{ti} is an exogenous shock that shifts excess demand. Also, suppose that the per unit transport cost from 1 to 2, denoted by r_t, is exogenous (i.e., supply of transport is perfectly elastic).

The equilibrium conditions for such a model are that

$$-E(p_{t1},a_{t1})=E(p_{t2},a_{t2})$$

and

$$p_{t2}-p_{t1} = r_t.$$

The first of these is a material balance equation, the second is the spatial arbitrage condition. Taken together these define a functional relationship between the three exogenous forces (a_{t1},a_{t2}, and r_t) and the two prices. A sequential equilibrium model imposes the two static equilibrium conditions at each period.

Serial correlation in sequential equilibrium models arise from the exogenous serial correlation of the driving variables. If these driving variables are serially independent then prices will be as well. Generally, however, these variables will exhibit significant serial correlation; indeed they may exhibit long-run persistence (unit roots).

The natural occurrence of serial correlation in the shocks implies that the kind of informational efficiency tests developed for speculative asset markets are improperly applied to commodity prices. Informational efficiency tests are based on the lack of intertemporal arbitrage opportunities. They are useful applied to excess returns on speculative assets, which should be essentially unpredictable in an informationally efficient market: predictable excess returns would imply the existence of expected excess profits. Serial correlation in commodity prices, on the other hand, does not imply excess expected profits so long as there are real dynamic links. For example, intertemporal arbitrage in storable commodity markets ensures prices are expected to rise enough to cover storage costs, implying a high degree of serial correlation in prices (Williams and Wright). Indeed, the lack of serial correlation would be a sign of a malfunctioning market.

Dynamic Regression Models

A connection running through much of the recent work on spatial price analysis is the use of dynamic regression models.[3] A set of statistical tools based on dynamic regressions have been used to analyze a variety of issues related to spatial prices. The basic framework involves a system of simultaneous equations with current prices as the endogenous variables and lagged prices and possibly some deterministic variables (constant term, time trend, regime shifters, seasonal terms) as the predetermined variables.[4]

The basic dynamic regression model can be expressed as a structural vector autoregression (SVAR)

$$A_0 p_t = \sum_{k=1}^{m} A_k p_{t-k} + Bx_t + e_t,$$

where p_t is a p-vector of observations on a set of spatial prices at time t, x_t is a vector of deterministic variables such as constants, time trends and seasonals, e_t is a vector of exogenous shocks and the A_k are $n \times n$ matrices of coefficients and B is $n \times p$. Often VARs are estimated in reduced form, in which case A_0 is an order-n identity matrix.

Ravallion and Timmer have both proposed market integration criteria that can be expressed as restrictions on the coefficients of this regression model. A number of analysts

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3. There is a large literature that uses static regression models of the form

$$p_{1t} = a_0 + a_1 p_{2t} + e_t$$

and variants thereof. These approaches will not be discussed here.

4. A few studies include other variables in the model. Mjelde and Paggi, for example, include prices of closely related commodities and stock level data.

have used this model as a basis for understanding the dynamic aspects of price determination, especially through the use of impulse analysis.

The use of a simultaneous equation model requires that careful attention be paid to model identification. This issue will be discussed in some detail in what follows. Many studies have not addressed the identification issue directly but have made implicit choices that need to be examined. In the end, much of the believability of the results will depend on the believability of the explicit or implicit identification assumptions made.

There are some approaches that do not depend on identifying assumptions. Granger-causality tests of spatial efficiency use the reduced form model:

$$p_t = \sum_{k=1}^{m} R_k p_{t-k} + \tilde{B}x_t + v_t$$

$$= \sum_{k=1}^{m} A_0^{-1} A_k p_{t-k} + A_0^{-1} Bx_t + A_0^{-1} e_t.$$

The null hypothesis of no Granger-causality is a zero-restriction on off-diagonal elements of the R_k. Price j fails to Granger-cause price i if the ijth elements of all of the R_k $(k>0)$ equal zero.

Cointegration techniques also make use of reduced form parameter restrictions. Cointegration concerns long run tendencies of a dynamic system and has been used to define the notion of a long-run equilibrium. Intuitively, cointegration models the situation in which prices are nonstationary but there are linear combinations among them that are stationary. There has been some debate concerning what kinds of cointegration relationships should be expected in spatial prices. It is often claimed that bivariate cointegration is a necessary condition in efficient and integrated markets. Others have argued that the stronger condition that price differences are stationary (that a one-to-one long-run relationship be maintained) is also necessary. Furthermore, in a system of n prices, the number of cointegration relationships present has been taken to be an indication of the degree of integration in the market as a whole. The following section examines these methods in light of a very simple point-location model of spatial price determination.

Table 1 lists a large number of studies using dynamic models of spatial prices and indicates the main diagnostic tool used to interpret empirical results.

Dynamic Regression Models Based on a Point-Location Model

To make dynamic regressions models of spatial prices economically interpretable it is desirable to have an explicit economic model that results in this form. One economic model that meets this criterion is a point-location model with linear excess demand functions:

$$q_{it} = b_i(a_{it} - p_{it}).$$

The equilibrium conditions for the two location model in which location 1 always exports to location 2 can be written in matrix form as the linear equations:[5]

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5. The model formulated here is expressed in terms of price levels and assumes that transport costs are absolute (not dependent on the commodity price). Many analysts use log price specifications, which can be justified if transport rates are expressed in percentage terms. Transport rates could also be a mixture of these (e.g., insurance may be a percentage of the

$$\begin{bmatrix} b_1 & b_2 \\ -1 & 1 \end{bmatrix} \begin{bmatrix} p_{1t} \\ p_{2t} \end{bmatrix} = \begin{bmatrix} b_1 a_{1t} + b_2 a_{2t} \\ r_t \end{bmatrix}$$

Notice that, although there are three forcing variables, two of them always appear together. Suppose the forcing variables can be written as a VAR:[6]

$$x_t = \sum_{k=1}^{m} B_k x_{t-k} + v_t,$$

where $x_{1t} = b_1 a_{1t} + b_2 a_{2t}$ and $x_{2t} = r_t$. Eliminating the forcing variables results in a VAR in prices:

$$\begin{bmatrix} b_1 & b_2 \\ -1 & 1 \end{bmatrix} p_t = \sum_{k=1}^{m} \begin{bmatrix} B_{11k} & B_{12k} \\ B_{21k} & B_{22k} \end{bmatrix} \begin{bmatrix} b_1 & b_2 \\ -1 & 1 \end{bmatrix} p_{t-k} + v_t$$

$$= \sum_{k=1}^{m} \begin{bmatrix} B_{11k} b_1 - B_{12k} & B_{11k} b_2 + B_{12k} \\ B_{21k} b_1 - B_{22k} & B_{21k} b_2 + B_{22k} \end{bmatrix} p_{t-k} + v_t$$

At issue is what restrictions, if any, spatial equilibrium imposes on the coefficients of this model. Four approaches to spatial price analysis using the basic dynamic regression model are discussed in this section, Ravallion's market integration criteria, Timmer's market integration criteria, impulse analysis based approaches and Granger-causality tests of efficiency and market dominance. Cointegration approaches are discussed at the end of the paper. Table 1 contains a summary of a number of studies that use dynamic regression models to analyze spatial commodity prices.[7]

Ravallion's Integration Criteria

Ravallion suggests three sets of restrictions to test for market integration, which he applied to Bangladesh rice markets. Ravallion considered the case in which a set of hinterland markets interact with a central or reference market (a radial market structure). An econometric specification of the hinterland price, p_{1t}, can be written:[8]

$$p_{1t} = c_0 p_{2t} + \sum_{k=1}^{m} \left(c_{1k} p_{1t-k} + c_{2k} p_{2t-k} \right) + v_{1t}.$$

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value of the shipment and freight rates are per unit). In the mixed case, the model must be modified and a number of the results no longer hold.

6. Henceforth the deterministic variables are eliminated to avoid notational clutter; equivalently, the variables are expressed as deviations around a deterministic function.

7. A large literature exists dealing with market integration in other goods, especially in financial markets. This review concentrates on goods that are expensive to transport relative to their value.

8. There are a number of econometric issues in this approach involving stationarity and simultaneity, that have been addressed more or less successfully in the applications of Ravallion's criteria.

Ravallion suggested the following criteria:

1) $c_0=1,\ c_{1k}=c_{2k}=0$ for $k>0$

2) $c_0=1,\ \Sigma_k c_{1k}+c_{2k}=0$

3) $c_0+\Sigma_k c_{1k}+c_{2k}=1$

He called these criteria strong-form short-run, weak-form short-run and long-run, respectively.[9] Notice that (1) implies (2) which in turn implies (3). These criteria can be interpreted in terms of the arbitrage equation of economic model. In both of the short-run tests the restriction that $c_0=1$ comes directly from the economic model. Criterion 1 implies the additional restrictions that

$$B_{22k}-B_{21k}b_1 = -B_{22k}-B_{21k}b_2 = 0 \text{ for all k.}$$

It is difficult to justify such a restriction. It is only true if $B_{21}=B_{22}=0$ for all k, implying that transport rates exhibit no persistence. It is not surprising that this condition is virtually always rejected (transport rates, like many prices, tend to exhibit serial correlation). As notes above, lagged price effects do not in themselves indicate market imperfections.

Ravallion's weak-form short-run restriction, written in terms of the economic model, implies that

$$\Sigma_k(B_{22k}-B_{21k}b_1-B_{22k}-B_{21k}b_2) = -(b_1+b_2)\Sigma_k B_{21k} = 0.$$

Given that b_1 and b_2 are positive (demand is not perfectly elastic), this restriction can be expressed as

$$\Sigma_k B_{21k} = 0.$$

The B_{21k} measure the effect on the transport rate of lagged excess demand shocks. This restriction can be interpreted to say that excess demand shocks have no long-run effect on the transport rate. To the extent that this is a reasonable assumption, the weak-form criterion can be derived in the context of this point-location economic model. I have argued elsewhere that an even stronger criterion may be justified if it is assumed that $B_{21k}=0$ for all k, which is the same as saying that excess demand shocks do not Granger-cause the transport rate. If such an assumption is valid then a revised strong-form short-run criterion is

1a) $c_0=1,\ c_{1k}+c_{2k}=0$ for all k.[10]

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9. Further discussion of the long-run test is deferred until the discussion of cointegration methods.

10. Ravallion's tests are expressed in terms of a simultaneous equation model, which requires that good instruments can be obtained to estimate the c_0 coefficient. It is possible to express the restrictions in terms of the reduced form parameters, however. Write the reduced form as

$$p_t = \sum_{k=1}^{m} \begin{bmatrix} R_{11k} & R_{12k} \\ R_{21k} & R_{22k} \end{bmatrix} p_{t-k}+u_t.$$

It can be shown that the weak form criteria is

$$\Sigma_k(R_{11k}+R_{12k}) = \Sigma_k(R_{21k}+R_{22k})$$

and the revised strong form criteria is

$$(R_{11k}+R_{12k}) = (R_{21k}+R_{22k}) \text{ for all k.}$$

It should also be noted that the reduced form tests do not depend on a radial market structure.

It should be noted that the weak form criterion does not imply a weaker equilibrium condition but rather a weaker identification assumption concerning the driving forces.[11]

Ravallion also proposed a test for market isolation or segmentation. In isolated markets prices are equal to the autarky prices (the a_i). As Harriss has noted, the autarky prices may be correlated contemporaneously. They should, however, fail to Granger-cause one another. In the two location model, isolated markets have the VAR structure

$$p_t=\sum_{k=1}^{m}\begin{bmatrix} R_{11k} & 0 \\ 0 & R_{22k} \end{bmatrix} p_{t-k}+v_t.$$

This leads to the testable restrictions that $R_{12k}=R_{21k}=0$ for all k, i.e., that prices fail to Granger-cause one another.[12]

Timmer's Index of Market Connectedness

Another approach to studying market integration using dynamic regressions was proposed by Timmer in a study of the Indonesian corn market. Timmer suggested an index of market connection (IMC) in the case that prices are described by a first order model. As in Ravallion's model, a reference location is chosen that represents the focal point of the price discovery process. The hinterland price equation of Ravallion's can be rearranged in the following way:[13]

$$p_{1t} = c_0(p_{2t}-p_{2t-1})+(c_0+c_{21})p_{2t-1} + c_{11}p_{1t-1}.$$

Timmer argued that, in the long run, price changes in the reference location should be fully reflected in the hinterland price and thus c_0 should equal 1.

He further argued that short run price relationships can be measured by assuming that the reference price is unchanged, in which case the hinterland price is a function of lagged own and reference prices. Timmer's index measures the relative effect of these two prices

$$\text{IMC} = c_{11}/(c_0+c_{21}).$$

Timmer argues that, in highly integrated markets, lagged own effects are small relative to current and lagged central market effects and hence the IMC should be close to 0.

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11. Ravallion also suggested that deterministic variables such as constants and seasonal terms should be zero in an integrated market. It is difficult to see how this assertion can be justified. A constant term in the arbitrage equation of the dynamic regression model should be present any time transport is costly. Furthermore, seasonality in transport rates, which is often present, will result in non-zero seasonal coefficients. Regime shift (dummy) variables and time trends can similarly be interpreted in terms of changes in transport rates.

12. Ravallion's criteria are not symmetric. His proposed market structure is one with a central market and hinterland markets. His market segmentation criteria is that the central market price fails to Granger-cause the hinterland price. In a segmented market situation, however, Granger-causality should not be present in either direction.

13. Timmer's notation is related to the coefficients of this expression in the following way:

$$c_0 = d_2$$
$$c_{11} = 1 + d_1$$
$$c_{21} = d_3-d_1-d_2.$$

A different interpretation emerges from considering the measure in terms of the parameters of the economic model in the fully integrated case:

$$IMC = (B_{22}-B_{21}b_1)/(1-B_{22}-B_{21}b_1).$$

If the identification restriction is imposed that $B_{21}=0$, the measure can be written as

$$IMC = B_{22}/(1-B_{22}).$$

Recall that B_{22} measures the autocorrelation coefficient on transport rates, which should lie on the [0,1] interval. This measure could therefore be interpreted as a measure of transport rate persistence; it is not clear how this relates to market integration.

Suppose, on the other hand, that the locations are actually isolated, so the reference price has no effect on the hinterland price, and

$$c_0 = c_{21} = 0.$$

In this case, Timmer's market integration index will correctly be large. This poses a dilemma. If the analyst calculates that the IMC is large, it may indicate that the locations are not integrated or it may indicate that they are integrated and that transport rates exhibit a high degree of persistence. On the other hand, if the IMC is low, it suggests that the markets are not isolated but it is unclear how connected they are. Timmer's IMC, like Ravallion's strong form criterion, is useful only if one has independent confirmation that transport rates are white noise processes.

<u>Impulse Analysis</u>

The Timmer measure relies on a view of markets in which causality in prices is unidirectional and can be determined a priori. In the Timmer model, large coefficients on the reference market price are interpreted as measuring the effect of that price on the hinterland prices. This sort of interpretation is common, especially in studies that use impulse analysis.

Impulse analysis converts the basic VAR model into moving average form[14]

$$p_t = \sum_{k=0}^{\infty} M_k e_{t-k},$$

which expresses the prices as functions of current and lagged shocks (impulses). Two measures of the influence of the shocks on prices are used. Impulse response functions trace the impact over time of shock j on price i: the ijth elements of the M_k expressed as a function of k. With n prices there are n^2 of these functions; it is generally preferable to plot these.

The other tool used to study the impact of the shocks on prices is the Forecast Error Variance Decomposition (FEVD). This measures the percentage of the forecast error at each forecast horizon accounted for by each shock. For this measure to be well defined it must be the case that the shocks are mutually uncorrelated, so the forecast error can be expressed as the sum of the effects attributed to each shock.[15]

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14. Again, deterministic terms are suppressed.

15. It is often incorrectly claimed that IRFs require mutually uncorrelated shocks. To give an example, suppose that two shocks are interpreted as excess demand shocks in two locations, which may be influenced by common factors. The IRF associated with the first shock can be viewed in this case as a thought experiment that measured the effect of a

Both the IRFs and the FEVD, to be meaningful, require that the shocks be given a economic interpretation. A standard practice is to assume that the shocks are uncorrelated and that A_0 is triangular for some ordering of the variables, implying that prices form a causally recursive system. The A_0 can then be estimated as the Choleski decomposition of the reduced form error covariance matrix. System recursivity, however, is a strong identifying assumption, implying a belief that shocks affecting some prices have no immediate impact on other prices. It is inherently untestable and, to be believable, must be justified on a priori grounds. This issue is often given less attention than it deserves.

Mjelde and Paggi, for example, assume that causality in U.S. corn prices runs from New Orleans to Illinois to Texas and not in the other direction. They follow a common practice of justifying this assumption in terms of the importance of the locations for the market as a whole: it is intuitively reasonable to expect that price shocks originating in a small relatively insignificant location cannot "cause" those in a major central location.

If one takes seriously the notion that prices are determined simultaneously, however, the idea that the central market price is causally prior to the hinterland prices is not justified. In a fully integrated and efficient market shocks originating in any location are transmitted to the other locations quickly and fully. This is not inconsistent with the idea that small submarkets should not have a large price impact. In the simple point-location model, the price impact of a given shock is determined by the relative size of the excess demand slope for that location (b_i). Relatively insignificant locations will have a small b_i because excess demand shocks have small quantity effects.

It is also often claimed that the use of a particular recursive ordering is irrelevant because the results are invariant to the ordering used. This argument is incorrect for several reasons. First, to actually be true it must be the case that the innovation covariance exhibit either zero correlation or exact correlation and, in the latter case, that some other highly restrictive conditions hold on the parameters of the reduced form moving average coefficients matrices and the innovation covariances. Even if these are approximately true, the results are not invariant to any possible identification assumption, but only to recursive ones (except in the case of uncorrelated innovation, which essentially never happens with spatial prices in integrated markets). As Leamer pointed out, it reflects a rather strange prior that one is concerned only about invariance within the class of recursive models. This is tantamount to the assumption that one is certain that causality only flows in one direction but uncertain of the direction of that flow (see also Cooley and Leroy).

There is another serious reason to interpret results based on a recursivity assumption with caution. In the context of a dynamic spatial price regression, recursivity amounts to imposing a particular kind of inefficiency on the model. Shocks that originate in one location, it is assumed, have no immediate effect on prices at some of the other locations, which can be interpreted as an informational inefficiency. If the intent is to study the efficiency of the market it is not a good practice to impose inefficiency on the market a priori.

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demand shift at location 1 that occurs independently of a shift at location 2. Thus, even though historically the demand shocks at these locations typically exhibit correlation, it is possible to conceive of meaningful economic events that shift demand at one location but not at the other (e.g., a consumption subsidy in location 1).

To my knowledge, no studies have been published that make use of non-recursive identifying assumptions in the context of a model of spatial prices. Indeed, I know of only one such application to agricultural markets: Myers, Piggott and Tomek. A useful discussion is contained in Tomek and Myers.

Finally, it should be noted that a number of analysts have interpreted impulse response functions as dynamic disequilibrium adjustments. The analysis based on the simple economic model suggests that they may instead be equilibrium adjustments to ongoing changes in economic fundamentals.

Granger-Causality Tests

In contrast to previous methods, Granger-causality involves tests on the reduced form of the model.[16] The reduced form, in terms of the economic model's parameters, can be expressed as

$$p_t = \frac{1}{b_1+b_2}\sum_{k=1}^{m}\begin{bmatrix}1 & -b_2\\ 1 & b_1\end{bmatrix}\begin{bmatrix}B_{11k} & B_{12k}\\ B_{21k} & B_{22k}\end{bmatrix}\begin{bmatrix}b_1 & b_2\\ -1 & 1\end{bmatrix}p_{t-k}+v_t$$

$$= \frac{1}{b_1+b_2}\sum_{k=1}^{m}\begin{bmatrix}B_{11k}b_1-B_{12k}-B_{21k}b_1b_2+B_{22k}b_2 & (B_{11k}-B_{22k}-B_{21k}b_2)b_2+B_{12k}\\ (B_{11k}-B_{22k}+B_{21k}b_1)b_1-B_{12k} & B_{11k}b_2+B_{12k}+B_{21k}b_1b_2+B_{22k}b_1\end{bmatrix}p_{t-k}+v_t$$

The hypothesis that p_1 fails to Granger-cause p_2 is the hypothesis that the lower left hand elements of the coefficient matrices are all zero:

$$(B_{11k}-B_{22k}+B_{21k}b_1)b_1 - B_{12k} = 0, \text{ for all k.}$$

This hypothesis would be accepted if both b_1 and B_{12k} are small enough. Similarly the hypothesis that p_2 fails to Granger-cause p_1 is

$$(B_{11k}-B_{22k}-B_{21k}b_2)b_2 + B_{12k} = 0,$$

which would be accepted if b_2 and B_{12k} were both small enough.

Gupta and Mueller argue that the failure of one price to be predictive of another when the second is predictive of the first (unidirectional causality) is an indication that the second price is not incorporating the price information from the first region. Unidirectional causality is, therefore, taken to indicate that a market is informationally inefficient. An alternative explanation for unidirectional causality is suggested by Brorsen et al.: "Supply/demand fluctuations in a location with a large volume of commodity trading represent a larger shift in aggregate supply/demand, thus these locations are expected to have a larger influence on prices in other locations" (p. 1).

This can be demonstrated by considering when the simple point-location model would produce such a result. B_{12k} will be small if lagged transport rates have little impact on excess demand shocks. This is not unreasonable and implies that one is likely to find that p_1 fails to Granger-cause p_2 when p_2 Granger-causes p_1 in a situation in which b_2 is much larger than b_1, i.e., when the amount demanded is far more sensitive to a given change in the absolute price level at location 2 than at location 1. This tends to happen when location 2 is a much larger market than is location 1. Thus, a sufficient condition for one-directional Granger-

16. One sometimes sees tests Granger-causality written in terms of a simultaneous system of prices. All of the parameters of such a system cannot be identified, however, and so tests on coefficients of such an equation will be problematic.

causality in prices is that a dominant/satellite market structure exists. Garbade and Silber used this kind of test to detect such market relationships and their approach was applied by Kootz, Garcia and Hudson to the market for U.S. cattle.

The results of Granger-causality tests should, therefore, be interpreted with caution. If one finds unidirectional causality in a market that should not exhibit dominant/satellite relationships, it would be an indication that the market should be analyzed carefully. At this stage, however, it would be premature to conclude that it indicates market inefficiency, as no convincing model of an inefficient market exhibiting this phenomenon has been developed.

Failures of Market Efficiency and Integration

Assuming that the point-location model with linear excess demand and per-unit transport rates presented in the previous section is a useful model of a market, it is instructive to ask why prices may fail to satisfy the tests derived from the model. There are two key assumptions, either of which may fail to hold. First, it is possible that the markets fail to equilibrate in each time period. This would lead to a failure of the law of one price in that it is possible that the arbitrage condition $(p_{2t}-p_{1t})=r_t$ is not exactly satisfied. Second, it is possible that the market equilibrates but that the trading pattern changes. Suppose that transport rates increased sharply resulting in a cessation of trade between the regions. In this case the regions would not be integrated at some periods and shocks to one location would fail to be transmitted to another.

Switching Regime Models

It is difficult to see how either of these two phenomena lead to a standard VAR model. When the market is imperfectly integrated it would be more appropriately modeled using a switching regime regression model. In a two location market, three regimes are possible:

1) location 1 ships to location 2 if $a_{2t}-a_{1t} > r_{12t}$
2) location 2 ships to location 1 if $a_{2t}-a_{1t} < -r_{21t}$
3) no trade occurs if $-r_{21t} \leq a_{2t}-a_{1t} \leq r_{12t}$,

where r_{ijt} is the transport rate for shipping the commodity from location i to j at time t (it is possible that $r_{12t} \neq r_{21t}$).

Spiller and Wood develop a model of the Northeastern U.S. gasoline market in which they estimate the probability of being in a given regime, both ex ante and ex post (conditional on the size of the observed locational price spread). To make the model tractable, they impose quite strong assumptions on the dynamic processes generating the excess demand shocks and transport rates. In particular they assume that $a_{2t}-a_{1t}$, r_{12t} and r_{21t} are mutually independent and serially independent. Recently Currie has estimated a similar model that relaxes some of these assumptions.

In the Spiller and Wood approach a test for market integration shifts from a test on regression coefficients within a regime to a test of the size of the regime probabilities. The hypothesis of a well integrated market with a stable trade pattern (say with trade from location 1 to 2) is equivalent to the hypothesis that the associated regime probability equals one and that the others regime probabilities are each zero.

Sexton, Kling and Carman examine the issue of market efficiency rather than integration. They study a market (U.S. celery) that can safely be assumed to be linked by unidirectional trade (say from location 1 to 2) and develop a switching regime model in which arbitrage conditions may be violated. Their model is similar to that of Spiller and Wood in that they use a switching regime regression approach but the three regimes are defined in the following way:

1) $p_{2t}-p_{1t} < r_{12t}$
2) $p_{2t}-p_{1t} > r_{12t}$
3) $p_{2t}-p_{1t} = r_{12t}$.

Only in regime 3 are the markets efficient and hence efficiency is equivalent to the hypothesis that the probability of regime 3 is equal to 1 and the other regime probabilities equal zero. Baulch developed a similar model but interpreted the three regimes as no trade, inefficient trade and efficient trade.

Both of these approaches model the probability of the price spread using a mixture of three distributions:

$$f(s_t \mid \theta) = \lambda_1 f_1(s_t \mid \theta_1) + \lambda_2 f_2(s_t \mid \theta_2) + (1-\lambda_1-\lambda_2) f_3(s_t \mid \theta_2),$$

where $s_t = p_{2t}-p_{1t}$, and θ_j are parameters.[17] λ_1 and λ_2 are the ex ante probabilities that the market will be in regime 1 and 2, respectively. In Spiller and Wood, $\lambda_1+\lambda_2$ can be thought of as a measure of the degree of integration of the market, whereas in SKC it is a measure of the inefficiency of the market.

A different interpretation emerges if it is recognized that use of a mixture distribution is one way to flexibly model a probability distribution. Thus either of these models can be viewed as nothing more than flexible models of the price spread distribution. The believability of the regime interpretation rests very strongly on the believability of the distribution assumptions. For example, the papers cited assume that f_3 is normally distributed and that the other two regimes are one sided (support on only one side of the mean of f_3). The empirical results could therefore be interpreted as measuring the degree to which the price spread distribution deviates from normality above and below its mean. In that economic theory generally has little to say about the normality of such a distribution, this seems to be a rather fragile approach with which to analyze spatial price patterns.[18]

Unspecified Alternative Model

In practice, few analysts have used a switching regime regression model to study spatial prices. Instead there is an implicit assumption that deviations from an efficient market can be represented by an arbitrary lag structure in the response of prices to excess demand and transport rate shocks. This suggests that prices don't equilibrate instantly and hence there is some short run inefficiency in the market.[19]

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17. A distinction between the approaches is that Spiller and Wood treat the λ_i as endogenous (functions of the θ_j), whereas SKC treat them parametrically.

18. It is also not clear whether this model can be generalized to include more locations. Regions can be integrated by sharing common trading partners even when they do not engage in direct trade. Including all possible regimes in a multi-location model, however, is infeasible.

19. Labelling short-run deviations from equilibrium as inefficiencies is hazardous. Such deviations may represent rational responses to inevitable shipping or informational lags.

One problem with interpreting rejections of so-called market integration tests is that the null hypothesis is that the markets are both efficient and perfectly integrated. Rejections of the tests could be caused by either inefficiencies or lack of perfect integration (including, in the extreme case, market isolation). Rejection of the tests are inherently incapable of determining which. Furthermore, if test rejections are caused by lack of perfect integration due to changes in the pattern of trade, the regression model is misspecified. It is not clear how lack of integration would affect parameter estimates in a dynamic regression model and therefore whether any conclusions can be drawn about why the market fails to be integrated.[20]

Apparent Market Failures and Alternative Models of Spatial Price Determination

The simple point-location model can be criticized on a number of grounds and it clearly is a poor description of some spatial market structures. It is limiting for the study of market integration because locations are either fully integrated or they are isolated from each other. Thus, locations that are linked by trade in every period must by fully integrated. One way to address this concern is with a model in which transport rates tend to rise as transport services are more heavily used. Suppose that location 1 ships to location 2 and that the transport rate is a linear function of the amount shipped: $r_t=\rho_t+\phi q_{2t}$, where q_{2t} is the quantity shipped. The equilibrium arbitrage relationship for this market is

$$p_{2t}-p_{1t} = \rho_t+\phi q_{2t}$$

and the market clearing condition requires that

$$q_{1t} = b_2(a_2-p_2) = -b_1(a_1-p_1).$$

These conditions can be solved to express the two prices as functions of the underlying parameters:

$$p_t = \frac{1}{b_1+b_2+\phi b_1 b_2}\begin{bmatrix} b_1+\phi b_1 b_2 & b_2 & -b_2 \\ b_1 & b_2+\phi b_1 b_2 & b_1 \end{bmatrix}\begin{pmatrix} a_{1t} \\ a_{2t} \\ \rho_t \end{pmatrix}$$

$$= \begin{bmatrix} \omega_1 & (1-\omega_1) & (\omega_1-1) \\ (1-\omega_2) & \omega_2 & (1-\omega_2) \end{bmatrix}\begin{pmatrix} a_{1t} \\ a_{2t} \\ \rho_t \end{pmatrix},$$

where $(1-\omega_j)<\omega_i<1$.

There are three important implications of this model for price behavior. First, shifts in the excess demand functions (i.e., changes in the a_i) have a greater impact on the price in the location where they occur than in the other location:

$$(1-\omega_i) = \frac{\partial p_{it}}{\partial a_{jt}} < \frac{\partial p_{jt}}{\partial a_{jt}} = \omega_j.$$

Thus a shock originating in one location is not fully transmitted to the other location.

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20. Goodwin, Grennes and Wohlgenant (1990A and 1990B) are among the few studies that have attempted to carefully model the effect of frictions on tests of spatial efficiency; in their case, the effect of delivery lags and expectations (their approach uses a static regression framework).

Instead, some of the shock is absorbed by in changes in the transport rate. Second, a shift in the supply of transport services is not fully absorbed by the commodity price changes.

$$\frac{\partial(p_{2t}-p_{1t})}{\partial \rho_t} = \frac{b_1+b_2}{b_1+b_2+\phi b_1 b_2} < 1.$$

Some of the supply shift is absorbed by the carrier in the form of reduced shipments. The price differences can be written as a weighted average of the transport rate shock and the difference in the excess demand shocks:

$$p_{2t}-p_{1t} = \lambda\rho_t+(1-\lambda)(a_{2t}-a_{1t}),$$

where $\lambda=(b_1+b_2)/(b_1+b_2+\phi b_1 b_2)$, implying that $0\leq\lambda\leq 1$.

The third implication is that there are more sources of noise than there are variables in the model. This makes it impossible to associate the effects of the price prediction errors (innovations) with specific sources of economically meaningful noise. It is not clear that anything meaningful can be said about pricing efficiency using only price data in this situation.

There are also situations in which an point-location model may not be appropriate (Faminow and Benson). For example, if producers are located in rural areas and have choices about where to market their goods, an agents-on-links model may better represent the price determination process.

Even simple agents-on-links models have complicated equilibrium conditions. Consider a market with two demand centers and with producers evenly distributed along the transport link between the centers. The production in each time period is an exogenously determined amount s_t. Each of the demand centers has downward sloping demand $q_{it}=b_i(a_{it}-p_{it})$. The distance between the centers is normalized to equal 1 and the transport cost per commodity and distance unit is r_t.

If this market is integrated and in equilibrium it satisfies the following set of conditions. A market clearing condition:

$$b_1(a_{1t}-p_{1t})+b_2(a_{2t}-p_{2t}) = s_t,$$

and a spatial arbitrage condition:

$$p_{1t}-r_tB_t = p_{2t}-r_t(1-B_t)$$

where B_t is the distance from location 1 of the producer who is indifferent between selling in locations 1 and 2. In this simple model B_t is also the share of the production sold in location 1:

$$B_t = q_{1t}/s_t.$$

Solving these conditions for prices yields:

$$\begin{bmatrix} p_{1t} \\ p_{2t} \end{bmatrix} = \frac{1}{(b_1+b_2)s_t+2b_1b_2r_t}\begin{bmatrix}(b_1a_{1t}+b_2a_{2t}-s_t)s_t-b_2(2b_1a_{1t}-s_t)r_t \\ (b_1a_{1t}+b_2a_{2t}-s_t)s_t-b_1(2b_2a_{2t}-s_t)r_t\end{bmatrix}$$

$$= \begin{bmatrix} \omega_{1t} & 1-\omega_{1t} & -\dfrac{1+b_2z_t}{b_1+b_2+2b_1b_2z_t} \\ 1-\omega_{2t} & \omega_{2t} & -\dfrac{1+b_1z_t}{b_1+b_2+2b_1b_2z_t}\end{bmatrix}\begin{bmatrix}a_{1t}\\ a_{2t}\\ s_t\end{bmatrix},$$

where $z_t=r_t/s_t$ and $\omega_{it}=(b_i+2b_1b_2z_t)/(b_1+b_2+2b_1b_2z_t)$. The equilibrium prices are weighted averages of the reservation prices less a term that increases in the amount produced. The size of the weights varies over time with z_t as does the coefficient on the s_t term. To the extent that z_t is stable over time this yields an equilibrium that is linear in three driving forces, the two demand reservation prices a_i and the total production s_t.[21]

The agents-on-links model has features similar to that of the point-location model with upward sloping transport supply. In particular, a shock originating in one location (a_i) has a larger price effect there than at the other location ($(1-\omega_j) < \omega_i$). Furthermore, price differences are functions of all of the shocks:

$$p_{2t}-p_{1t} = \frac{2b_1b_2z_t}{b_1+b_2+2b_1b_2z_t}(a_{2t}-a_{1t}) + \frac{b_2-b_1}{b_1+b_2+2b_1b_2z_t}r_t.$$

In the simple point-location model the nature of price adjustment to shocks originating in one of the locations is quite simple. If the locations are linked by trade, both prices adjust equally, otherwise there is no adjustment. In both of the models of this section marginal adjustments can occur, so the adjustments can lie somewhere between all and nothing. Price differences are not associated just with transport rate changes. How important such effects are has not been examined empirically.

The ability to derive economically meaningful information from dynamic regressions of prices is quite limited if these effects are important. With three (or more) interpretable sources of randomness and only two observable variables, it will not be possible to identify the effects of the demand and supply shocks. Furthermore, there is no expectation that a shock originating in one location will have the same effect on both prices. As in the case of an upward sloping transport supply function, shocks originating in one location have a larger price effect there then in the other location. Thus we expect that the transmission of shocks is less than complete and the basis for the market efficiency/integration tests is lost.[22]

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21. The stability of z_t is an empirical matter. It will be stable if transport rates increase proportionally with production and hence with the amount transported. It should also be noted that this model takes no account of the possibility of regime shifts that would arise if transport rates become high relative to the price. It would then be possible that some producers would elect to not ship at all because the price they receive, net of transport costs, would be negative.

22. Faminow and Benson combine the agents-on-links framework with the existence of imperfect competition at the market centers. They argue that Ravallion-type tests should be reinterpreted. They argue that the short-run tests are symptomatic of a base point pricing system (collusion) in which one firm (location) sets a base price and other locations match that price net of transport costs. This conclusion rests on the assertion that competitive price adjustments must take time. Such adjustments could occur within a week or month, the intervals generally used in studies of spatial prices. It is an open issue whether collusive and competitive markets can be distinguished by examining prices alone.

Long Run Analysis and Cointegration Based Tests

Importance of the stationarity properties of spatial prices has been emphasized in many recent studies. Most studies of commodity prices that have examined the issue have found that spatial prices tend to exhibit unit-root nonstationarity. A number of analysts have suggested, however, that efficient and well integrated spatial prices should be cointegrated (Ardeni). In essence, this means that some linear combination of the nonstationary prices is stationary and hence the prices tend to move towards this relationship in the long run. It has also been argued that cointegration is not enough, but that the linear relationship should have a slope of one (Baffes). This is equivalent to the price spreads being stationary.

Cointegration based tests are tests of long-run tendencies rather than of period-by-period equilibrium. These tests are generally justified by the assertion that arbitrage opportunities prevent spatial prices from drifting too far apart. Within the context of a linear dynamic regression model, the only way that nonstationary prices can be assured of not drifting too far apart is to have stationary price spreads.

At first glance the notion that spatial prices cannot drift apart has some intuitive appeal. It should be noted, however, that at a minimum this assertion makes the implicit assumption that transport rates are stationary. Clearly if transport rates are non-stationary then prices that are observed to drift apart may not represent arbitrage opportunities at all. In the simple point-location model with stable trading patterns the price spread is equal to the transport rate and thus should reflect its stationarity properties. Thus cointegration is not a necessary condition for market efficiency and integration.

Some evidence for this is found in Goodwin (1992) who showed that wheat prices in three locations (U.S. Gulf, Rotterdam and Japan) exhibited only 1 cointegration relationship. However, after adjusting the latter two prices by subtracting the ocean freight rates from the U.S. Gulf, the prices exhibited two cointegrating relationships. Examination of the freight rates suggested that the Gulf-Japan rate was nonstationary.

If the transport rate is stationary, the simple point location model can be used to derive testable restrictions on the price VAR. For example, one can show that, if n-1 cointegrating relationships exist in an n location model, that an efficient and well integrated market will exhibit stationary price spreads. Stationarity of price spreads can, therefore, be used to suggest that markets are efficient and integrated in the long run.

The relationship between cointegration and efficiency, however, is complex, even if the transport rate is stationarity. In the alternative models considered (the switching regime, the point-location with upward-sloping transport supply and the agents-on-links models) price spreads depend on all of the model shocks. For example, with upward sloping transport supply, the price spreads are given by:

$$p_{2t}-p_{1t} = \lambda\rho_t+(1-\lambda)(a_{2t}-a_{1t}),$$

where $0 \leq \lambda \leq 1$. Transport rate stationarity, therefore, is not sufficient to ensure price spread stationarity in an efficient market; one must also have stationarity of excess demand shock spreads as well. Although this is possible, spatial arbitrage cannot be the mechanism that ensures it. In the switching regime model, it is possible to have an efficient market with changing trading patterns and fail to observe cointegration or stationary price spreads (McNew and Fackler).

A tentative conclusion that emerges from these remarks is that price spread stationarity is consistent with a market in which locations are, in the long run, both efficient and fully integrated. This means that, in some sense, the market equilibrates in the long run (arbitrage opportunities are exploited) and that shocks originating in one location are eventually transmitted fully to the other location. On the other hand, a conclusion that the price spreads are not stationary is more difficult to interpret. It may imply that the markets are in a long run disequilibrium situation. More likely, however, it implies that integration is less than complete, either because the markets become isolated or because marginal adjustments occur. In this case, however, conclusions about the extent of integration are difficult to justify using linear dynamic regression, either because a switching regime regression is more appropriate or because the structural model is not identified using only price data.

Before leaving the subject of long-run equilibria, it is useful to remark on alternative views of the meaning of this concept. There are two ways of evaluating long-run impacts in dynamic systems. The first uses what have been termed the long-run multipliers. These measure the eventual impact on an endogenous variable of a permanent incremental change in the value of an observable exogenous variable:

$$\lim_{h\to\infty}\sum_{i=0}^{h}\frac{\partial E_t[p_{t+i}]}{\partial x_t}$$

The other long-run concept measures the eventual impact on an endogenous variable of a one time incremental change in the value of one of the unobserved system shocks:

$$\lim_{h\to\infty}\frac{\partial E_t[p_{t+h}]}{\partial e_t};$$

i.e., the time limits of the impulse response functions.

A number of analysts, including Ravallion, use the former concept, implicitly treating the reference location price as exogenous. Notice that the hinterland price can be written

$$p_{1t} = \left[\frac{c_0-\sum_{k=1}^{m} c_{2k}L^k}{1-\sum_{k=1}^{m} c_{1k}L^k}\right] p_{2t} + v_t = S(L)p_{2t}+v_t.$$

If p_1 were exogenous the long-run impact multiplier is equal to S(1). Setting this equal to 1 yields Ravallion's long-run integration criterion. The reference price cannot be assumed to be exogenous, however, as this would be tantamount to assuming that shocks originating in the hinterland never affect the reference location price.

Conclusions

Prices in efficient and integrated spatial markets are endogenously and simultaneously determined. Although this should lead to testable restrictions on the behavior of prices, attempting to derive such restrictions from fully specified models of price determination demonstrates that this is not as simple as it might seem. Only one simple, highly stylized model is capable of generating any of the tests of efficiency and integration that have been proposed in the literature.

The simple point-location model leads to tests similar to those proposed by Ravallion and provides some justification for cointegration based tests. It also can be used to demonstrate weaknesses in Timmer's criteria, impulse analysis based on recursive identifications and Granger-causality tests.

Although the point-location model is useful in generating a base-case model, it is difficult to see how it can justify the commonly used dynamic regression framework when the market fails to be well integrated and efficient. Some markets do not transmit local shocks on a one-to-one basis, such as markets in which transport links break down in some periods or marginal adjustments occur in the transport linkages. In such cases, it is not clear that a dynamic regression is a good model because the dynamic regression model nests the null hypothesis but not reasonable alternatives. This makes it difficult to interpret test rejections, even when the tests are well founded under the null hypothesis of well integrated and efficient markets.

Fortunately, these conclusions provide a basis for further investigations. The approach taken with the simple point-location model could also be applied to the other models of price determination. This would help to identify what kinds of price behavior should be expected given a richer set of assumptions about the price determination process.

How far such a research agenda can be taken remains to be seen. Due to the interpretive difficulties in studies based on price data alone, a natural proposal is to use more complete market data to address spatial market issues. Barrett has argued that transport rate and trade flow data may be needed before some controversies are resolved. The discussion contained herein would seem to support that view.

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Table 1. A Summary of Empirical Dynamic Spatial Price Analyses

Authors	Date	Location	Product	Method of Analysis
Adamowicz, Baah & Hawkins	1984	Canada	Hogs	Granger causality
Alderman	1993	Ghana	Grains	Ravallion/Cointegration
Alexander & Wyeth	1994	Indonesia	Rice	Cointegration
Ardeni	1989	International	*	Cointegration
Baffes	1991	International	*	Cointegration
Baulch	1994	Philippines	Rice	Switching regime
Benson & Faminow	1990	Canada	Hogs	Granger causality
Benson, Faminow & Fik	1992	Canada	Hogs	Ravallion
Benson, Faminow, Maquis & Sauer	1994	Canada	Hogs	Cointegration
Bessler & Fuller	1994	U.S.	Wheat	Cointegration
Blank & Schmiesing	1988	U.S.	Corn	Granger causality
Borsen, Chavas, Grant & Ngenge	1985	U.S.	Grains	Impulse analysis/Granger causality
Currie	1995	U.S.	Petroleum	Switching regime
Dahlgran & Blank	1992	U.S.	Hay	Ravallion
Dercon	1995	Ethiopia	Teff	Cointegration
Dries & Unnevehr	1990	International	Beef	Granger causality
Faminow & Benson	1990	Canada	Hogs	Ravallion
Goletti	1994	Bangladesh	Rice	Cointegration/Multipliers
Goletti & Babu	1994	Malawi	Maize	Cointegration/Impulse analysis
Goletti & Christina-Tsigas	1995	**	Rice/Maize	Multipliers
Goodwin	1992	International	Wheat	Cointegration
Goodwin, Grennes and McCurdy	1996	Russia	***	Impulse Analysis
Goodwin & Schroeder	1991	International	Wheat	Impulse analysis
Goodwin & Schroeder	1991	U.S.	Cattle	Cointegration
Gordon, Hobbs & Kerr	1993	Britain/France	Lamb	Granger causality
Gupta & Mueller	1982	Germany	Hogs	Granger causality
Heytens	1986	Nigeria	Gari & yams	Timmer
Higginson, Hawkins & Adamowicz	1988	Canada/U.S.	Hogs	Granger causality/Impulse Analysis
Jordan & Van Sickle	1995	U.S./Mexico	Tomatoes	Ravallion/Granger causality
Klein, Rifkin & Uri	1985	U.S.	Flour	Granger causality
Koontz & Garcia & Hudson	1990	U.S.	Cattle	Granger causality
Loveridge	1991	Rwanda	Dry Beans	Correlation
Lutz, Van Tilburg & Van Der Camp	1995	Benin	Maize	Cointegration/Ravallion
Mendoza & Rosegrant	1992	Philippines	Corn	Granger causality
Mendoza & Rosegrant	1995	Philippines	Corn	Granger causality/Multipliers
Mendoza & Rosegrant	1995	Philippines	Copra	Granger causality/Ravallion
Michael & Nobay	1994	International	Wheat	Cointegration
Mjelde & Paggi	1989	U.S.	Corn	Impulse analysis
Palaskas & Harriss-White	1993	India	****	Cointegration
Ravallion	1986	Bangladesh	Rice	Ravallion
Sexton, Kling & Carman	1991	U.S.	Celery	Switching regime
Silvapulle & Jayasuriya	1994	Philippines	Rice	Cointegration
Slade	1986	U.S.	Petroleum	Granger causality
Spiller & Huang	1986	U.S.	Gasoline	Switching regime
Spiller & Wood	1988	U.S.	Gasoline	Switching regime
Teklu, von Braun & Zaki	1991	Sudan	Sorghum/cattle	Timmer
Thompson, Eales & Hauser	1990	U.S.	Grains	****
Timmer	1987	Indonesia	Corn	Timmer
Tschirley	1995	Ecuador	Maize	Timmer
Uri, Chomo, Hoskin & Hyberg	1993	International	Soy	Granger causality
Uri, Howell & Rifkin	1985	U.S.	Flour	Granger causality
Webb, von Braun & Yohannos	1992	Ethiopia	Grains	Timmer
Williams & Bewley	1993	Australia	Cattle	Impulse analysis

* Wheat, wool, beef, sugarcane, tea, tin, zinc
** Bangladsh rice and Malawi maize
*** Eggs, milk, vegetable oil, potatoes
**** Rice, potatoes, mustard
**** Uses a spatial basis regression model