

Stigler, George J.; Sherwin, Robert A.

Working Paper

## The Extent of the Market

Working Paper, No. 31

**Provided in Cooperation with:**

George J. Stigler Center for the Study of the Economy and the State, The University of Chicago Booth School of Business

*Suggested Citation:* Stigler, George J.; Sherwin, Robert A. (1983) : The Extent of the Market, Working Paper, No. 31, The University of Chicago, Center for the Study of the Economy and the State, Chicago, IL

This Version is available at:

<https://hdl.handle.net/10419/262433>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**Terms of use:**

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*



## The Extent of the Market

George J. Stigler; Robert A. Sherwin

*Journal of Law and Economics*, Vol. 28, No. 3 (Oct., 1985), 555-585.

Stable URL:

<http://links.jstor.org/sici?sici=0022-2186%28198510%2928%3A3%3C555%3ATEOTM%3E2.0.CO%3B2-B>

*Journal of Law and Economics* is currently published by The University of Chicago Press.

---

Your use of the JSTOR archive indicates your acceptance of JSTOR's Terms and Conditions of Use, available at <http://www.jstor.org/about/terms.html>. JSTOR's Terms and Conditions of Use provides, in part, that unless you have obtained prior permission, you may not download an entire issue of a journal or multiple copies of articles, and you may use content in the JSTOR archive only for your personal, non-commercial use.

Please contact the publisher regarding any further use of this work. Publisher contact information may be obtained at <http://www.jstor.org/journals/ucpress.html>.

Each copy of any part of a JSTOR transmission must contain the same copyright notice that appears on the screen or printed page of such transmission.

---

JSTOR is an independent not-for-profit organization dedicated to creating and preserving a digital archive of scholarly journals. For more information regarding JSTOR, please contact [support@jstor.org](mailto:support@jstor.org).

# THE EXTENT OF THE MARKET\*

GEORGE J. STIGLER *and* ROBERT A. SHERWIN  
*University of Chicago* *Lexecon Inc.*

**T**HE role of the market is to facilitate the making of exchanges between buyers and sellers. It is inherent in any exchange, whether of one good for another good or for money, that there be a rate of exchange between the *quid* and the *quo*: a quantity of something is exchanged for a quantity of something else. Therefore to say that a market facilitates the making of exchanges is equivalent to saying that markets are where prices are established. One may *quote* a price for a commodity on the moon if one is visiting that celestial body, but one can only *establish* a price by making a trade.

The market is the area within which price is determined: the market is that set of suppliers and demanders whose trading establishes the price of a good. If one draws demand and supply curves that do not represent the traders in a market, the intersection of the curves is economically meaningless. The infrequency with which one encounters actual market size determinations outside the antitrust area is surprising and perhaps disquieting.

The central role of price in defining a market is the reciprocal side of this relationship between price determination and market determination. Consider the basic definition of the area of a market: "A market for a good is the area within which the price of a good tends to uniformity, allowance being made for transportation costs."<sup>1</sup> If there is a single price (allowing for transportation costs) over a given area, that must mean that either buyers or sellers (or both) can and do consider transactions at any

\* We are greatly indebted to Claire Friedland for statistical assistance and to members of the Economic and Legal Organization Workshop. We are also indebted to George C. Tiao and Stephen M. Stigler for statistical advice. We also thank Rebecca A. Bissi, Anita Garten, William J. Lynk, Lynn Shishido-Topel, and Robert S. Stillman.

<sup>1</sup> This is the fundamental definition of Cournot and, following him, of Marshall, who states the rule: "Thus the more nearly perfect a market is, the stronger is the tendency for the same price to be paid for the same thing at the same time in all parts of the market: but of course if the market is large, allowance must be made for the expense of delivering the goods to different purchasers. . . ." Alfred Marshall, *Principles of Economics* 325 (variorum ed. 1961).

[*Journal of Law & Economics*, vol. XXVIII (October 1985)]

© 1985 by The University of Chicago. All rights reserved. 0022-2186/85/2803-0005\$01.50

point within the area to be an excellent (in the limit, a perfect) substitute for transactions at other points within the area. Hence the market area embraces the buyers who are willing to deal with any seller, or the sellers who are willing to deal with any buyer, or both.<sup>2</sup>

The literal translation of the definition into observable data would be illustrated by the situation in which a good is produced in place A and supplied to place B with transportation costs  $T_{ab}$ , so that  $P_b = P_a + T_{ab}$ . This equation would hold continuously if knowledge were perfect or the product could be stored free. In general, however, these conditions are not met in real markets.

Consider the workings of the gold standard before World War I. The pound sterling was worth \$4.8665 at the mint ratio of the gold content of the two currencies. The "gold points," the prices of one English pound at which it paid to export gold from New York or import gold from London, were approximately \$4.89 and \$4.845, respectively. Yet the exchange rate was almost never at these precise points: about three-quarters of the time the exchange rate was within these limits and the remainder of the time often outside these limits.<sup>3</sup> Yet there can be no doubt that there was an international gold market that normally confined the foreign exchange rate within one-half of 1 percent of \$4.8665. Exchange rates outside this range were usually quickly corrected; the longer exceptions were apparently due to interventions by the Bank of England and the U.S. Treasury.<sup>4</sup> The rate was seldom at the gold points because the main instrument of control of the exchange rate was the transfer of funds by speculators and traders.

The same phenomenon is true in commodity markets: prices in two places will seldom differ by exactly "the" transportation costs for several reasons:

1. There is no unique transportation cost. (The gold points varied with shipping time, interest rates, and shipping costs.) The costs of movement may be less for some buyers than it is for others, as when a trucking firm fills the tanks of trucks wherever fuel prices are low. The costs of transportation—really, of transportation including transaction costs—will be influenced by, among other things, the size of shipments and the movements of other goods (providing backhauls).

2. Stochastic shocks to supply and demand will create divergent price

<sup>2</sup> It is not necessary that *all* buyers or sellers consider the various points substitutes for one another as long as *enough* of either do.

<sup>3</sup> See O. Morgenstern, *International Financial Transactions and Business Cycles* 177, 195 (1959).

<sup>4</sup> Truman A. Clark, *Violations of the Gold Points, 1890–1908*, 92 *J. Pol. Econ.* 791 (1984).

movements in parts of a market in the absence of perfect foresight. These divergent price movements will usually be limited in size and duration because of the possibility of corrective movements of goods or buyers or of intertemporal substitution by sellers or buyers. In the markets for durable stocks such as residential housing, however, the period required for similar houses in different areas to attain similar prices (land values aside) can be extremely long.

3. There are conditions, such as those described in the factor equalization theorem, under which price equality in one good can be achieved by free movement of another good.

The test of a market that we shall employ is the similarity of price movements within the market. This criterion captures the essential role of competition in dominating the price movements within each part of the market. The criterion could fail to identify a single market if the costs of "transportation plus transactions" were highly volatile between parts of that market, but that is an improbable circumstance.

The analytical claims of this criterion of similarity of price movements are reinforced by the often modest data requirements. In general, as we shall see below, it is sufficient simply to compare prices at the various places, without recourse to transportation costs, because transportation costs are usually either a minor or a stable source of price differences between communities. If we find closely parallel price movements, the loci of the prices are in the same market. If we find significant nonparallel price movements, the loci of the prices are *not* in the same market unless the discordance in movements can be traced to changes in transportation costs.

### I. MARKETS, COMPETITION, AND MONOPOLY

The parallel price movement test of market areas is equally applicable to competitive and monopolistic markets. If a monopolist dumps his product in (say) a foreign area, and he is protected in this price discrimination by the barriers to reimportation of low-price foreign goods, price tests will reveal that they are separate markets.<sup>5</sup> If the price discrimination is not geographical but (say) functional, as when professional journals have higher subscription rates for institutional than for personal subscribers, the test will also reveal the separateness of the two markets.<sup>6</sup>

<sup>5</sup> This would be strictly true only if we make the further and reasonable assumption that the foreign price would be subjected to a different set of demand shocks from those facing the domestic price.

<sup>6</sup> In this case, indeed, the "transportation cost" between the two classes of subscribers is zero from the viewpoint of the seller.

The purpose of the market definition is to identify the sellers and buyers who establish the price for the product in the area. It is not a purpose of the market definition to determine whether the market is competitive or monopolistic, although the determination of the market is usually an essential step in that investigation.

The presence or absence of monopoly may affect the size of a market, just as monopoly will affect the price in a market. Consider an (improbable) example. Two competitively organized markets, A and B, are separated by substantial transaction costs, so neither ships appreciable amounts to the other market. Our test of course reveals their separateness. Now let A become monopolized and choose to set a higher price in its region equal to the price in B plus transportation costs to A. Our test will now show that A and B are one market and, of course, will identify the date of the extension of the market size. Without additional information we cannot determine whether the enlargement of the market was due to the formation of a regional monopoly, a reduction in transportation costs, or a change in the comparative costs of production in the two regions.<sup>7</sup> The market definition tells us what it is supposed to tell: the identity of the sets of buyers and sellers who are establishing the common price in A and B, and it also tells us when the market area has changed. Conversely, if the original market included A and B, a merger of the firms in one area would not affect prices unless that merger created a firm with market power in A and B combined. In general, the detection of monopoly in a market requires an additional investigation.

#### A. *The General Nature of the Price Test*

The relation between two prices within a single market will not be strictly constant over time: their differences will not be a constant or a constant proportion of one price. Nevertheless, the parts of a market will be more closely integrated, the closer the movement of their prices. In addition to the disturbing factors discussed above, there are almost always further sources of differences in price movements at different places in one market. For example:

- i) If the quality of the good is variable, differences in quality mix will create price differences.
- ii) If the lot size of transactions varies, differences in prices will usually be created.

<sup>7</sup> If there was no (appreciable) importation of the product from B into A, or exports from A to B, the possibility of a monopoly in A would be indicated. Of course the formation of the monopoly in A would affect the price in B unless B has constant supply price.

iii) Similarly, if prices do not pertain to the same time, they can differ.

These and related sources of price dispersion (including errors in reporting prices) will cause the correlation of price movements to be less than perfect even in highly efficient markets.

### B. An Application

We can form an idea of how close the price movements can be in well-organized markets by examining the price of December 1982 silver futures on the New York Commodity Exchange and the Chicago Board of Trade.<sup>8</sup> The closing prices per ounce on thirty consecutive trading days (June 23–August 4, 1982) are plotted in Figure 1. It is apparent that our example does not pose an interesting question about whether the two centers are in the same market: they clearly are. The price movements may be summarized:

	New York	Chicago	Difference
Mean price	\$6.689	\$6.702	\$.013
Mean absolute difference in price			.037

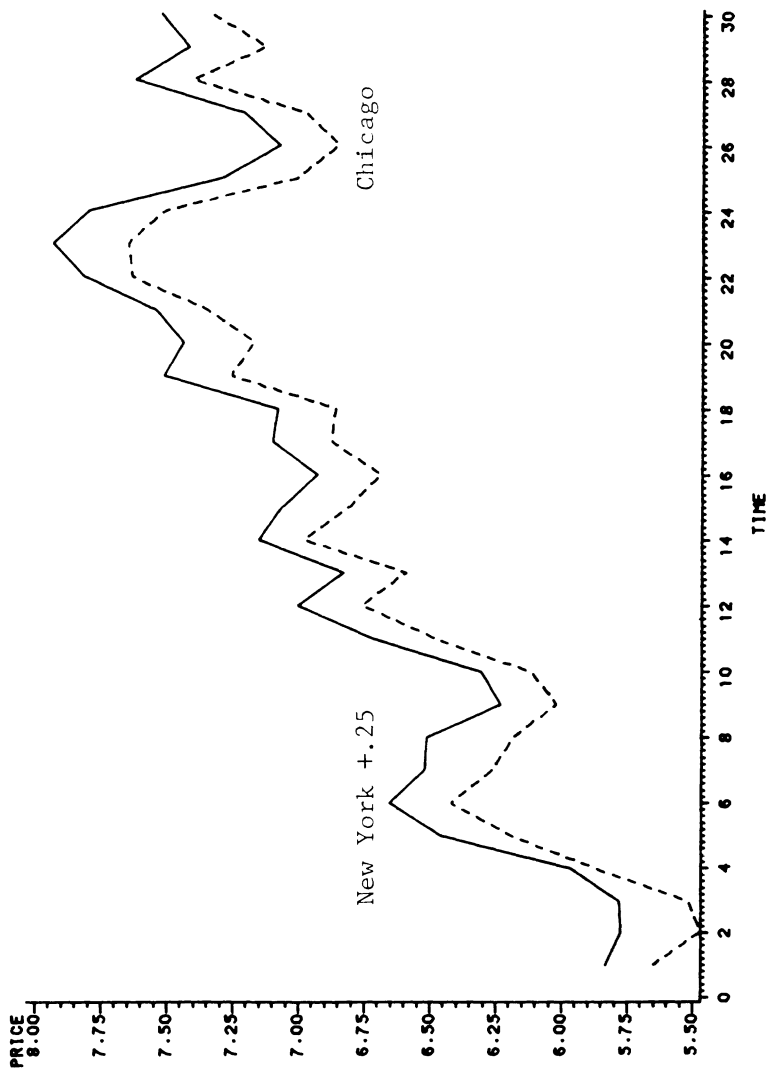
The correlation coefficient between the two price series is .997. We should note that in this example there are no literal transportation costs worthy of mention: the transfers are effected by book transactions or warehouse receipts.

The price series with which we shall deal first, including those for silver, have high serial correlations (.924 for New York and .921 for Chicago) but virtually no serial correlation of the first differences of prices.<sup>9</sup> These price series are essentially random walks in the first differences of prices and are fully characterized by this property (see the Appendix for the statistical role of the correlation of first differences). We shall accordingly rely heavily on the correlations of first differences in the price series to test their significance: this is .956 for the two silver series. But it remains true that competition will serve to bring the prices in different parts of a market to equality, and only indirectly does it tend to bring about equality in the changes in these prices.

Even the simple example of the silver prices poses a useful question: How often should prices be collected, and should they be averages or

<sup>8</sup> The contracts are different in two respects: the Chicago contract is for 1,000 ounces, the New York contract for 5,000 ounces; and the trading hours are not identical.

<sup>9</sup> They are .085 for New York and .011 for Chicago.



(June 23 = 1)

FIGURE 1.—Closing prices of December 1982 silver futures in dollars per troy ounce, June 23–August 4, 1982 (Wall Street Journal).



individual transaction prices? If we had access to the individual transactions in the two exchanges, we could have had many pairs of transactions in each day if we did not require strict simultaneity but only (say) trading within half-hour time units. Even from published records we could record low and high daily prices and not simply closing prices. Alternatively, with fuller reporting we could calculate the average price each day, weighted by volume of transactions.

For a study of speculative markets very fine time units may be useful or necessary but in a study of commodity markets we will normally have longer periods in mind. We are interested in the ability of buyers and sellers to shift between the two or more places: if the price rises in A relative to B, can buyers shift to B or sellers to A? If the prices in the two places have a measure of independence in the short run, but that independence is not large (we face this question below), the two are in one market.<sup>10</sup> Moreover, even if pricing independence is substantial in the short run, neither significant monopolistic nor significant monopsonistic pricing is likely to occur in one area if large price differences do not survive beyond the short run. A firm with a large share of the sales in one area is unlikely to charge significantly more than the competitive price for a short time if the result is that a host of new competitors from outside its area soon begin to sell there. (Moreover, buyers may well anticipate the lower future price and either postpone current consumption or consume from inventories.)

In the absence of large changes in transportation costs it is unlikely that the relative price behavior in two areas of one market varies much with the time period covered, once we use time periods within which a substantial volume of transactions is effected. In a market in which workers are commonly employed for one to three years (college instructors) it may require a comparable period for their compensation to reach "equality" (in other words, equality of net advantages for given quality instructors). On the other hand, if we enlarged our silver futures prices to weekly or monthly averages we would hardly affect the measure of concordance of movement in the two price series.

In most market analyses we cannot attain the essential identity of prod-

<sup>10</sup> The theory of competition predicts that

$$\frac{\text{volume of trades in A}}{\text{volume of trades in B}}$$

is strongly negatively correlated with  $P_a/P_b$  if buyers are the main source of arbitrage and if the changes in relative prices are caused by changes in the relative conditions of supply (in other words, holding relative demands constant).

ucts possessed by our example of silver futures contracts, so there is a compelling case for using averages of prices of numerous transactions.

### *C. The Criterion of a Single Market*

What is the level of correspondence between two price series, either directly or in first differences, that determines that they are in the same market? Few will quarrel with the statement that the two silver trading pits are in the same market; indeed, few would quarrel even without knowing that the two prices have a correlation coefficient of .997 and a correlation coefficient of first differences of .956. We believe that no unique criterion exists, quite aside from the fact that the degree of correspondence of two price series will vary with the unit and duration of time, the kind of price reported, and other factors.

In Section II, we shall propose one method of establishing a sufficient value of the correlation of first differences to characterize a single market. However, the more general answer is that there is no unique criterion: markets can show every level of interdependence from absolute homogeneity to complete independence—the continuity of the conventional criteria of cross-elasticities of demand and supply are enough to suggest that. If a coefficient of .9 makes the two silver markets one market, a coefficient of .8 or .7 implies lesser degrees of interdependence. We would then examine more closely the nature and duration of the disparate movements.

## II. THE EXTENSION TO COMMODITY MARKETS

### *A. The Case of Flour*

Consider the monthly wholesale prices of flour in Minneapolis and Kansas City, Missouri, two centers of the flour-milling industry, for the eleven year period, 1971–81 (Figure 2).<sup>11</sup> The two series are obviously highly correlated, ( $r = .97$ ), and even their first differences are closely related ( $r = .92$ ).<sup>12</sup>

If we wish to reassure ourselves that these two areas are in the same market, we can turn to supporting data:

<sup>11</sup> This is the first of several examples we use in which one or both of the authors were involved in antitrust cases that involved market determinations.

<sup>12</sup> The serial correlations in the first differences of the price series are again small: Minneapolis, .150; Kansas City, Missouri, .162; Portland, Oregon, .038; Buffalo, .101. We omit the first nineteen months, when prices were apparently controlled. We use logarithms of prices here and in most of the subsequent statistical analyses, but we continue to present the figures (other than Figures 4 and 5) in original units.

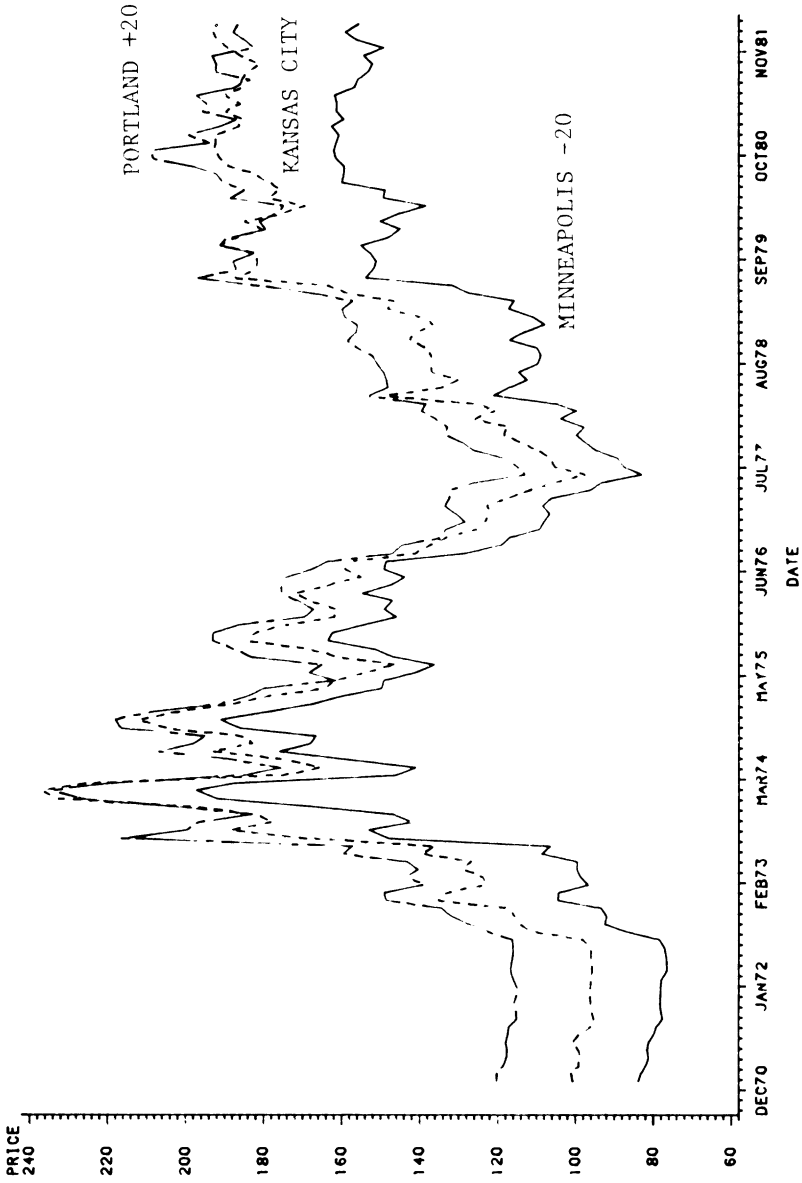


FIGURE 2.—Wholesale flour prices, index (1967 = 100), January 1971–March 1982 (U.S. Bureau of Labor Statistics)

1. We can search for buyers who are patronizing both production centers. They will be easy to find: large national bakers such as ITT Continental Baking, Campbell Taggart, American Bakeries, and General Mills buy extensively in these and other flour-milling production centers.

2. We can examine the shipment data, to determine whether important consuming areas are within the common shipping distances of both centers. The census reports that 28 percent of flour is shipped 500 miles or more,<sup>13</sup> and two major flour-milling companies (Peavey and ConAgra, which recently merged) shipped 36 percent of their flour 500 or more miles. The airline distance between Kansas City and Minneapolis is only a little more than 300 miles.

3. The area within which Kansas City and Minneapolis lie contains many other flour mills.

It is easy to accept the conclusion that Minneapolis and Kansas City are in the same flour market. We propose to use the correspondence of the price movements in these two cities to test whether other cities are in the same market (see Figures 2 and 3). By this test Buffalo is in the same market as Minneapolis, and Portland, Oregon, is probably in the same market as Kansas City (see Table 1). How shall we interpret the fact that the correlation of price movements is lower, although still fairly high ( $r = .807$  in panel B) between Buffalo and Portland? The direct and reasonable answer is that flour prices in these widely separated cities have a significant measure of independence but that they share all major movements of prices.

The example raises the question of the transitivity of the relationship of correspondence of price movements: let  $r_{ab}$  be the correlation of the first differences of price movements in A and B, and  $r_{ac}$  and  $r_{bc}$  the corresponding correlations for A and C and B and C. If  $r_{ab}$  and  $r_{ac}$  are high, what can be deduced about  $r_{bc}$ ?<sup>14</sup> It is tempting to give a formal answer: for example, if consumers are uniformly distributed along a road, and sellers are equally spaced in order A, B, and C,  $r_{ac} = r_{ab}^2$ . But even in such simplified models this sort of answer has at best only a very short-run, small-shock validity. If buyers and/or sellers can move, the relationship for longer periods and larger price movements is more likely to be such that  $r_{ab}$  and  $r_{ac}$  are approximately equal. In our example, we interpret the lower correlation of price movements in Portland and Buffalo as showing a larger (but not absolutely large) degree of short-run indepen-

<sup>13</sup> 1977 Commodity Transportation Survey, Table 3 (TCC Code 20411).

<sup>14</sup> There are a variety of formal inequalities, such as

$$r_{bc} \geq 2[(r_{ab} + r_{ac}) - \frac{3}{2}],$$

which are generally weak if the right-side coefficients of correlation are not near one.

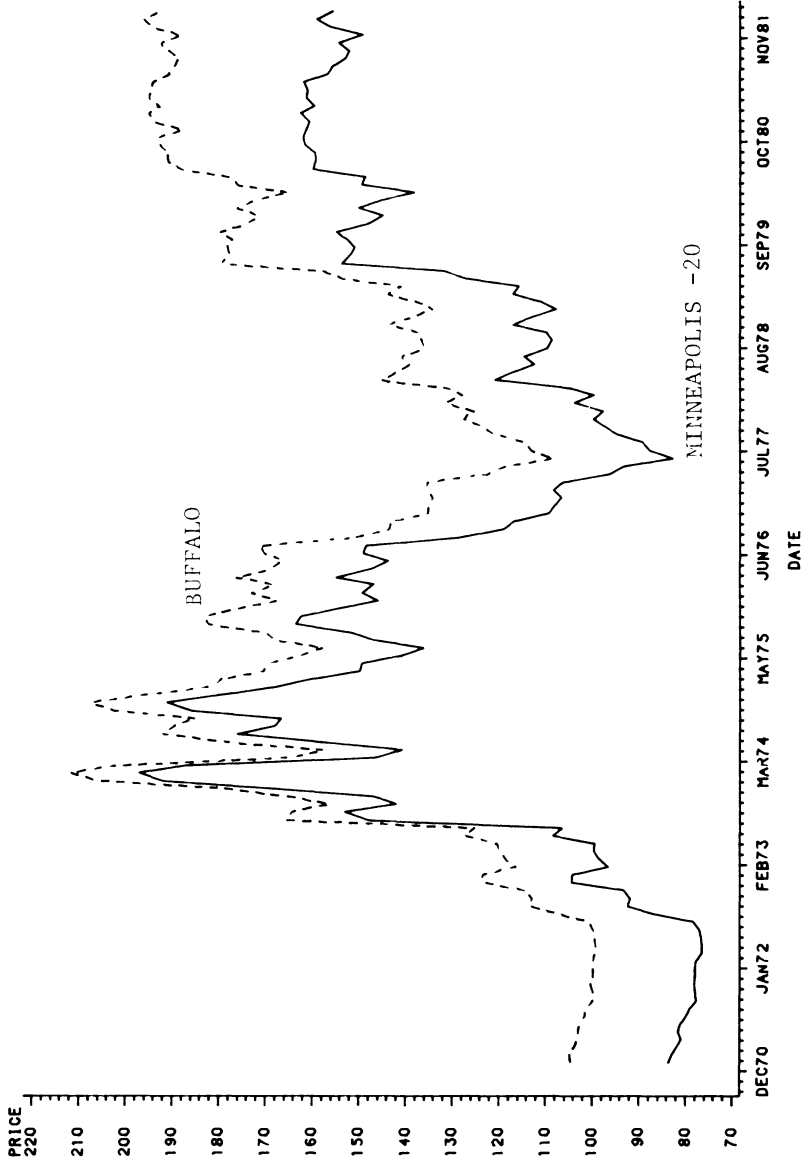


FIGURE 3.—Wholesale flour prices, index (1967 = 100), January 1971–March 1982 (U.S. Bureau of Labor Statistics)

TABLE 1  
CORRELATIONS OF PRICES OF FLOUR IN FOUR CITIES

	Minneapolis	Kansas City, Missouri	Portland, Oregon	Buffalo
A. Correlations of Logarithms of Monthly Prices, August 1972–March 1982				
Minneapolis	1.000	.972	.951	.982
Kansas City		1.000	.975	.959
Portland			1.000	.928
Buffalo				1.000
B. Correlations of First Differences of Logarithms of Monthly Prices, August 1972–March 1982				
Minneapolis	1.000	.922	.809	.978
Kansas City		1.000	.773	.884
Portland			1.000	.807
Buffalo				1.000
C. Correlations of First Differences of Logarithms of Average Annual Prices, 1973–81				
Minneapolis	1.000	.981	.962	.998
Kansas City		1.000	.993	.973
Portland			1.000	.951
Buffalo				1.000

SOURCE.—U.S. Bureau of Labor Statistics, Producer Prices and Price Indexes.

dence of prices. When we correlate changes in annual prices (see Table 1, panel C) the association between price changes in distant cities rises more than that between near cities; hence the interdependence of prices in distant cities is essentially complete in the long run.

### B. The Product Range

We propose the same criterion for joining two products into one market that we employ with respect to the geographical dimension. *Two products are in the same market (are close substitutes in production or consumption or both) when their relative prices maintain a stable ratio.* This definition is essentially equivalent to the more common one that the two products should be combined when the cross-elasticities of demand or supply are high, because high cross-elasticities imply that given changes in their relative prices would lead to large changes in the relative quantities that will be produced or purchased.<sup>15</sup>

<sup>15</sup> On the demand side, from the equation  $X_1 = f(P_1, P_2, R)$ , where  $R$  is income and  $f$  is a homogeneous function of degree zero,

$$0 = \frac{\partial X_1}{\partial P_1} P_1 + \frac{\partial X_1}{\partial P_2} P_2 + \frac{\partial X_1}{\partial R} R,$$

We may illustrate the procedure with a continuation of our flour-milling example. We present the delivered prices received by a flour miller at his various mills for a sixty-five-month period, January 1977–May 1982, for three kinds of flour (Figure 4). We observe a fairly high correlation between the prices of flour made from hard winter wheat and soft wheat: there is good substitution between them.<sup>16</sup> The correlations of first differences of logarithms of prices follow:

	Hard Winter Wheat	Soft Wheat	Durum
Hard winter wheat	1.000	.644	.521
Soft wheat		1.000	.385
Durum			1.000

The price movements of durum flour are rather more independent of prices of other flours, especially soft wheat flour. This partial independence can be seen by comparing the prices during a subset of the full period during which durum flour prices diverged from and then returned to the price level of other flours. We predict the price of durum from the price of hard winter wheat after May 1979, based on their relationship before that date: the predicted price of durum flour is shown in Figure 5. The divergence of predicted durum flour prices from actual prices is so large and the period so long that durum flour prices clearly can undergo substantial independent price movements. It would require a much longer period to determine whether the price of durum flour persistently returns to near equality with the price of hard winter wheat flour, as Figure 4 suggests.

A second example of the analysis of the product range of a market is taken from petroleum products (Table 2). These correlations indicate that not only are regular and unleaded gasoline in the same market, as we should expect from supply conditions alone, but that diesel oil is also a very close substitute in supply. The price of residual oil, on the other hand, is only weakly associated with the prices of the refined products.

### III. STATISTICAL COMPLICATIONS

Not all price series display the random walk pattern of first differences found for silver and flour. The price of gasoline (regular, unleaded, at full

or  $0 = \eta_{11} + \eta_{12} + \eta_{1R}$ , so large cross-elasticities imply large own-price elasticities. If we calculate  $\partial(P_1/P_2)/\partial X_1$  with  $X_2$  constant, we find that the elasticity of  $(P_1/P_2)$  with respect to  $X_1$  equals  $[(1/\eta_{11}) - (1/\eta_{12})]$ , which is small if  $\eta_{11}$  and  $\eta_{12}$  are large.

<sup>16</sup> The substitution extends to the supply side: mills designed to grind soft wheat can grind winter wheat efficiently (but not vice versa) and new mills are being designed to handle both.

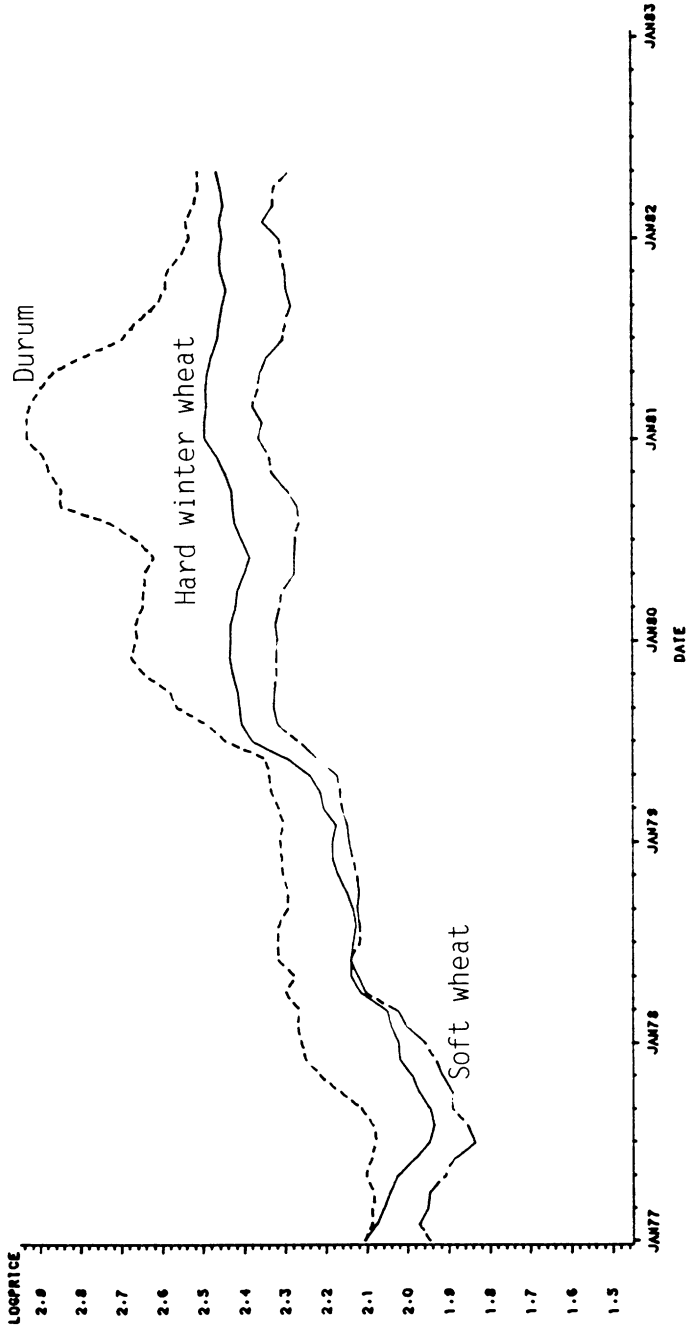


FIGURE 4.—Log<sub>e</sub> of delivered flour prices per 100 pounds, January 1977–May 1982 (company data)



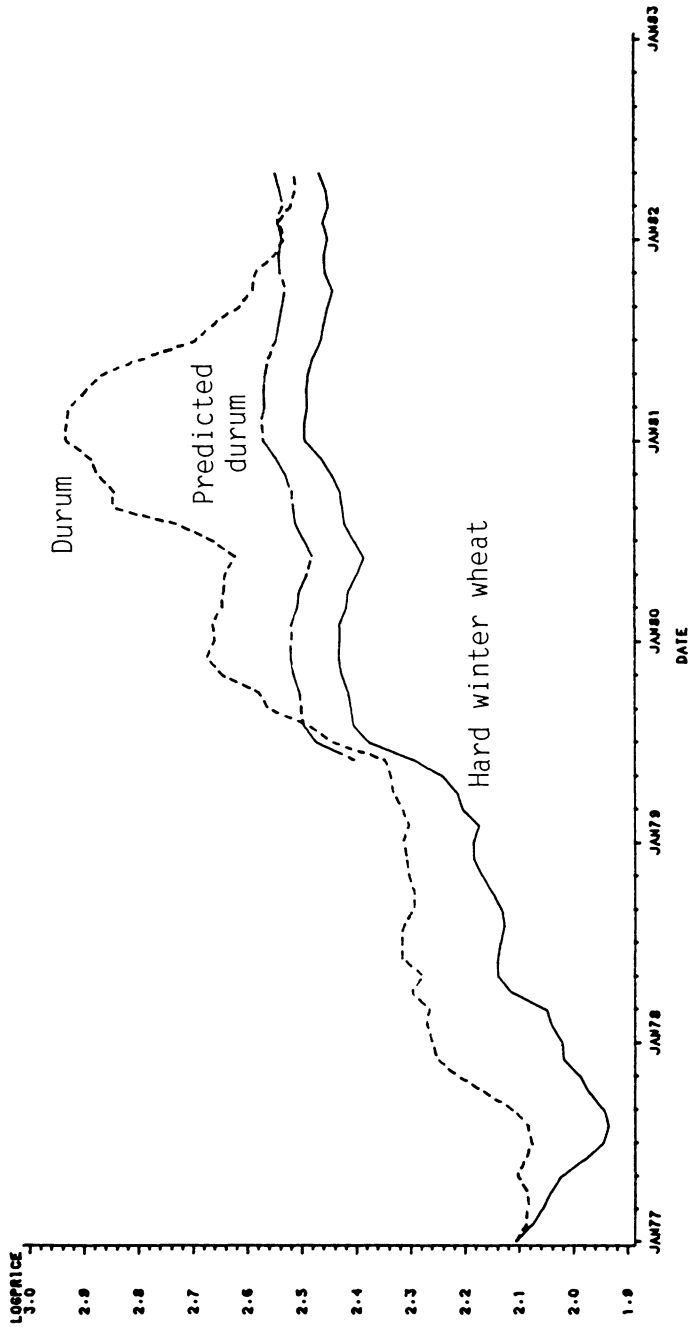


FIGURE 5.—Log<sub>e</sub> of delivered flour prices per 100 pounds, January 1977–May 1982, actual and predicted (company data)

TABLE 2  
CORRELATIONS OF PRICE MOVEMENTS OF PETROLEUM PRODUCTS,  
DECEMBER 1979–NOVEMBER 1982  
(First Differences in Logarithms of Prices)

	GASOLINE		DIESEL FUEL	RESIDUAL FUELS
	Regular	Unleaded		
Gasoline:				
Regular	1.000	.989	.902	.255
Unleaded		1.000	.890	.231
Diesel fuel			1.000	.347
Residual fuels				1.000

SOURCE.—U.S. Bureau of Labor Statistics, *Producer Prices and Price Indexes*.

service stations) is displayed for three cities for a four-year period in Figure 6. The congruence of movement of the series is, of course, striking (the correlation coefficients of the first differences of logarithms of prices (Table 3) are all .85 or over for city pairs) but these price differences display serial correlation even in the first differences of the logarithms of prices. That serial correlation vitiates simple comparisons of price series.

The serial correlation of first and even second differences of the logarithms of prices is frequently encountered in the wholesale price statistics. One, and possibly the major, source of that inertia in the prices is the persistence of quoted prices, which may or may not be actual transaction prices. Thus, in the Bureau of Labor Statistics wholesale prices, the frequency of changes in monthly prices is strongly influenced by the number of company reporters.<sup>17</sup> One may deal with the problem with autoregressive moving average models, but we can also display and isolate the effect of serial correlation by comparing every other or every third price, as is done in Table 3. The serial correlation is eliminated by taking every third price, without any appreciable influence on the correlations between the movements of prices in the various cities.

We may observe that the main direction of flow of gasoline (and crude petroleum) is from the South Central area to the North and East, and the

<sup>17</sup> See *Government Price Statistics, Hearings Before the Subcommittee on Economic Statistics, Joint Economic Committee, 87th Cong., 1st Sess., January 24, 1961, at 390*. For prices of various nonfood materials as reported by the BLS, during 1953–56 there were

- .103 price changes per month, one company reporting;
- .143 price changes per month, two companies reporting;
- .206 price changes per month, three companies reporting;
- .207 price changes per month, four companies reporting;
- .392 price changes per month, five companies reporting.

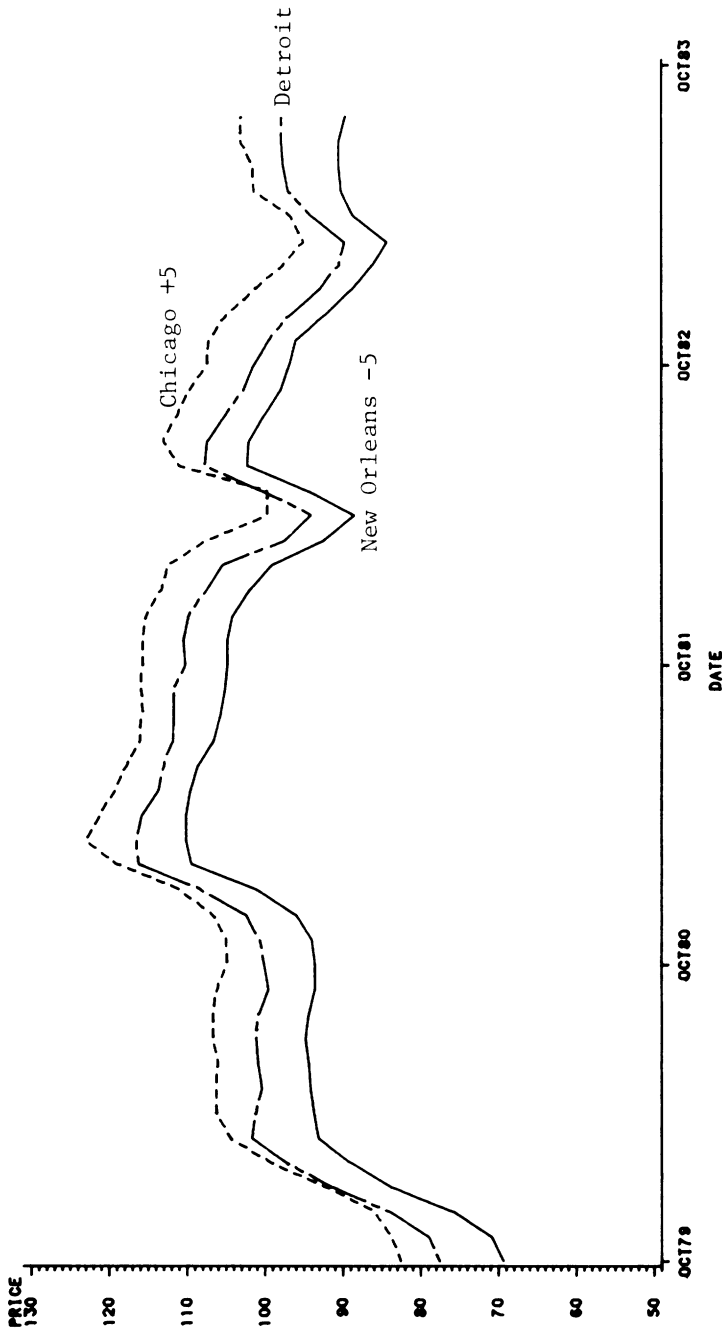


FIGURE 6.—Wholesale gasoline prices in cents per gallon, October 1979–October 1983 (Platt and Lundberg surveys)

TABLE 3  
UNLEADED GASOLINE: WHOLESALE PRICES, OCTOBER 1979–OCTOBER 1983 (Forty-nine  
Months) SERIAL AND CROSS-CITY CORRELATIONS

	LOG <i>P</i>	Log <i>P</i>	FIRST DIFFERENCES IN:	
			Every Second Log <i>P</i>	Every Third Log <i>P</i>
A. Serial Correlations				
New Orleans	.942	.612	.282	.027
Chicago	.932	.541	.143	– .054
Detroit	.932	.609	.221	– .057
B. Cross-City Correlations				
New Orleans–Chicago	.985	.864	.910	.943
New Orleans–Detroit	.992	.978	.988	.990
Chicago–Detroit	.978	.850	.900	.934

SOURCE.—Platt and Lundberg surveys.

New Orleans price is commonly lower than elsewhere. It would be quite overwhelming to measure transportation costs directly, since a complex network of pipelines (plus barges and other transportation) allows either the crude or the refined product to reach northern cities by many routes. Our best estimates of the costs of transportation of gasoline to Chicago and Detroit are the mean differences between their prices and that in New Orleans: from New Orleans to Chicago, 1.1392 per gallon; from New Orleans to Detroit, 1.1582 per gallon.

#### A. A Common Influence

Often two price series are subjected to a common influence: in our example, the price of petroleum has a large influence on that of wholesale gasoline. A high rate of inflation or deflation will impart a common time profile to prices of unrelated goods. These two influences are different in their economic significance but can be handled by the same procedures.

We can regress the price of gasoline in each city on a single (national) price of petroleum and then correlate the residuals. There is, however, an economic objection to this procedure: the tendency for value added of different areas or firms to approach equality under competition is weaker than the tendency of their prices to approach equality. The value added at the wholesale level would be the desired price to study if we were concerned with the provision of wholesaling services in a local market: there should be an equality in the price of wholesaling (in other words, the value added) throughout the relevant geographic market. But if the “price” of

wholesaling is an important part of the wholesale price, then our test will reveal any significant geographic differences. And, if the price of wholesaling is not important, then it should be ignored. Almost any price will have some geographic elements (reflecting, for example, different local taxes or legal rules regarding warranties, and so on) and the removal of *all* common elements of price is to predestine the outcome of the inquiry.

We shall illustrate a method of dealing with common inputs by comparing the city prices of gasoline after allowing for crude oil price fluctuations.<sup>18</sup> We regress the price of gasoline in each city upon the national BLS price of crude oil (using first differences of logarithms), and correlate the residuals across cities; the results are New Orleans–Chicago .792, New Orleans–Detroit .967, and Chicago–Detroit .770.<sup>19</sup> Two of the correlations are reduced appreciably in comparison with the original correlations of price changes, and the reduction may well reflect errors introduced by the regressions on the input prices.

### B. Coincidences

We have already encountered the problem of the possible role of extraneous factors such as inflation in producing very high correlations between commodities that are surely not competitive with each other. Many years ago, Daniel Suits produced several such coincidences in wholesale prices from 1913 to 1939.<sup>20</sup> He found tolerably similar movements in the prices of (1) saws and granulated bulk salt, (2) plows and cotton yarn, and (3) hides (Texas) and medium salt.

The correlations of the annual indices of the second and third pairs were not high (.524 and  $-.414$ , respectively) but the first pair were well correlated ( $r = .844$ ); for saws and medium salt, for which a longer series is available,  $r = .937$ .<sup>21</sup> The nonsense correlations are usually easy to detect. Thus, one may remove the general movement of prices (by correlation of residuals from a regression of price on the appropriate wholesale price index) or one may shorten or lengthen the period.<sup>22</sup>

<sup>18</sup> The flour prices of various cities could equally well be analyzed after allowing for the effect of wheat prices.

<sup>19</sup> The autocorrelations for the three comparisons are .213,  $-.056$ , and .029, respectively.

<sup>20</sup> Daniel Suits, *Business Concentration and Price Policy* 48–55 (Nat'l Bur. Econ. Research 1955); George Stigler had provoked the comparisons.

<sup>21</sup> The correlations are similar if we employ first differences of logarithms as in our previous examples.

<sup>22</sup> For example, the correlation between saws and bulk salt is .979 for 1913–19 and  $-.650$  for 1920–28. The most stubborn of these nonsense correlations is plows and yarn, and it vanishes if we correlate the residuals of logarithms of prices regressed on the logarithm of the wholesale price index for the two commodities.

The elimination of nonsense comparisons is of no real interest but it poses again an important question: Why "deflate" any series? If in a violent inflation prices of a product or service in two cities march in close step, that concordance is the product of economic forces, not some arithmetic of escalation. What large general market forces do is bring about a rough concordance of movement of prices that are not closely related by competitive supply and demand forces, so the standard by which to judge the approach to price equality should be more severe. The elimination of broad external forces may be an efficient way to deal with the problem, given the frequent unavailability of finer price data, but it is not inherently necessary.

#### IV. FURTHER ILLUSTRATIONS AND EXTENSIONS

Three different kinds of markets are examined in this section: a capital market, commodities with heavy transportation costs, and labor markets.

##### A. *Capital Markets*

The interest rates charged on new mortgages are collected monthly for many Standard Consolidated Statistical Areas (and, in some cases, Standard Metropolitan Statistical Areas) by the Federal Home Loan Bank Board. The interest rates are on twenty-five year mortgages, with a 75 percent loan-to-value ratio, and include amortized initial fees and charges. The period we present in Figure 7 runs from June 1979 through January 1983 (forty-four months), a period of great fluctuations in the rates. In the figure we remove minor irregularities by using three-month moving averages, and we displace several series vertically to preserve legibility. The means for the original monthly series in the cities for the forty-four months are New York, 15.13 percent; Chicago, 15.38 percent; Los Angeles, 15.13 percent. The concordance of the movements of the rates in these cities is high. There is only modest autocorrelation of the residuals from these cross-city regressions with first differences, and from the other regressions presented in this section.

	CORRELATION COEFFICIENTS	
	Logs	First Differences of Logs
New York-Chicago	.979	.809
New York-Los Angeles	.954	.835
Chicago-Los Angeles	.954	.833

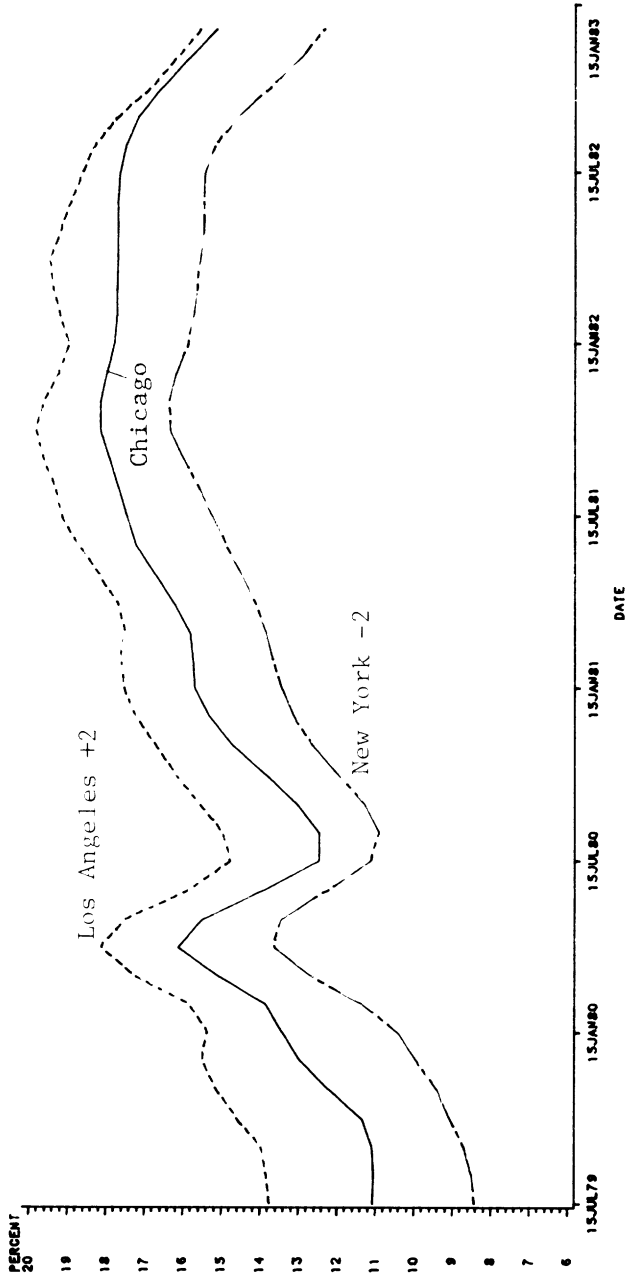


FIGURE 7.—Centered three-month moving averages of mortgage interest rates in percentages, June 1979–January 1983 (Federal Home Loan Bank).

The market for mortgage funds is clearly national in scope. The concordance of interest rate movements is higher than one might expect, given the lack of rigorous standardization of loans inherent in the valuation of houses for the 75 percent loan-to-value ratio.

### *B. Commodities with Heavy Transportation Costs*

If the markets for a commodity are strongly localized, so that there are many markets in a large economy, then it is probable that the price series of the various markets will not be collected. Thus we have not found adequate price data for asphalt, sand and gravel, bricks, and other commodities with (arguably) local markets. The degree of independence of these local markets from one another would be a fascinating area for study.

Residual oil, which is used as a fuel for merchant ships, is one of the least valuable of the oil products; and because it is a by-product of normal refinery operations, its supply is not easily adapted to local demand. Of course a ship has some choice in its sources of supply, but it is far from complete, especially in the short run. Accordingly, we see substantial variations in the movements of the price of residual oil from July 1975 to December 1979 in the major markets (see Figure 8).<sup>23</sup> The various regions may be in a common market over long periods but that is not the case in periods of one to three years.

### *C. Labor Markets*

The definition of a market does not depend on the characteristics of the commodity or service that is being examined, so our standard definition should be fully applicable to the determination of the size and scope of labor markets. Two apparent problems are encountered in actual applications: the products are not rigorously homogeneous, and the nature of the relevant transportation costs is not evident.

<sup>23</sup> The correlation coefficients of first differences of logarithms (with number of months for which data are available) are

---

New England–Mid-Atlantic	.200 (44)
New England–West South Central	.151 (43)
New England–Pacific	.160 (45)
Mid-Atlantic–West South Central	–.141 (46)
Mid-Atlantic–Pacific	.157 (47)
West South Central–Pacific	–.039 (50)

---



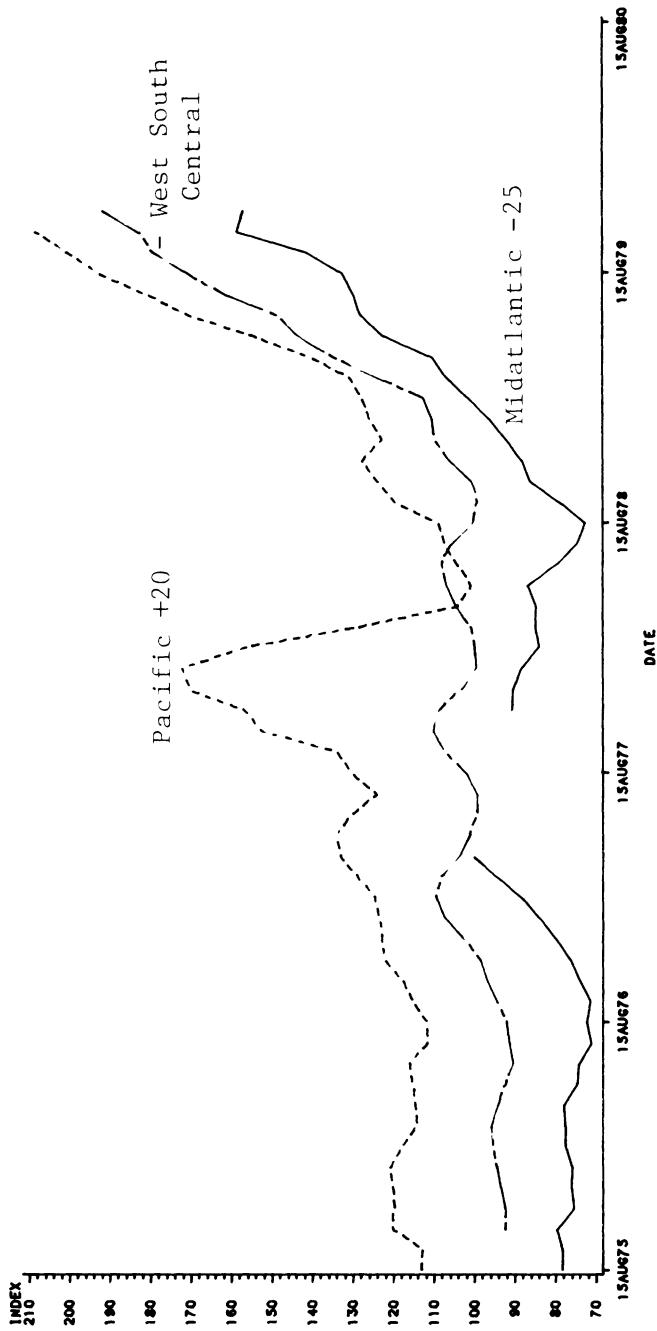


FIGURE 8.—Centered three-month moving averages of wholesale residual fuel oil prices, index (July 1975 = 100), July 1975–December 1979 (U.S. Bureau of Labor Statistics). Mid-Atlantic data for June 1977–September 1977 not available.

The first problem is of course not unusual: extraordinarily few commodities or services are rigorously homogeneous. It may not be worthwhile to distinguish among gallons of "standard" unleaded gasoline, but the concept of an average home is at least as great an abstraction as an average physician. The market will treat closely similar units of any good as identical if it does not pay to carry the measurement of characteristics further. The wage rates of workers can be standardized with the usual human capital model.

The "transportation costs" for which allowance must be made in examining the tendency of wage rates to equality are more troublesome. Employments have a variable but substantial time dimension, so the costs of movement of laborers that are appropriately compared to differences in wage rates are some daily or weekly or annual amortization of the total costs of movement. Unless the movement is very costly (for example, including the learning of a new language) or the expected duration of the new job very brief, the costs of movement will usually be small in such amortized units. The differences in nominal wages, which do not allow for differences among places in the cost of living, will usually be larger. Fortunately the differences in costs of living among places within a country will usually be dominated by the size-of-community effect and should be relatively stable.

Most specific wage series are reported (often irregularly) at intervals of about a year, so their behavior will be dominated by the rising price level of the past decades. One set of such series (which have been deflated by the CPI) is given in Figure 9.

These data, for industrial nurses working in manufacturing establishments, are given (usually) for the years 1954-78.<sup>24</sup> On the whole, the four

	Boston	New York	Chicago	Los Angeles
Boston	1.000	.308	.785	.703
New York		1.000	.630	.584
Chicago			1.000	.861
Los Angeles				1.000

wage series display a good degree of similarity of movement: each shows a strong advance to 1972 and then a decline for three years. The correla-

<sup>24</sup> Average straight-time weekly earnings for a selected month for each city. Includes incentive bonuses but not overtime pay. The series have been extended from 1973 to 1978 using the percentage change in average hourly earnings. U.S. Bureau of Labor Statistics, Area Wage Surveys.

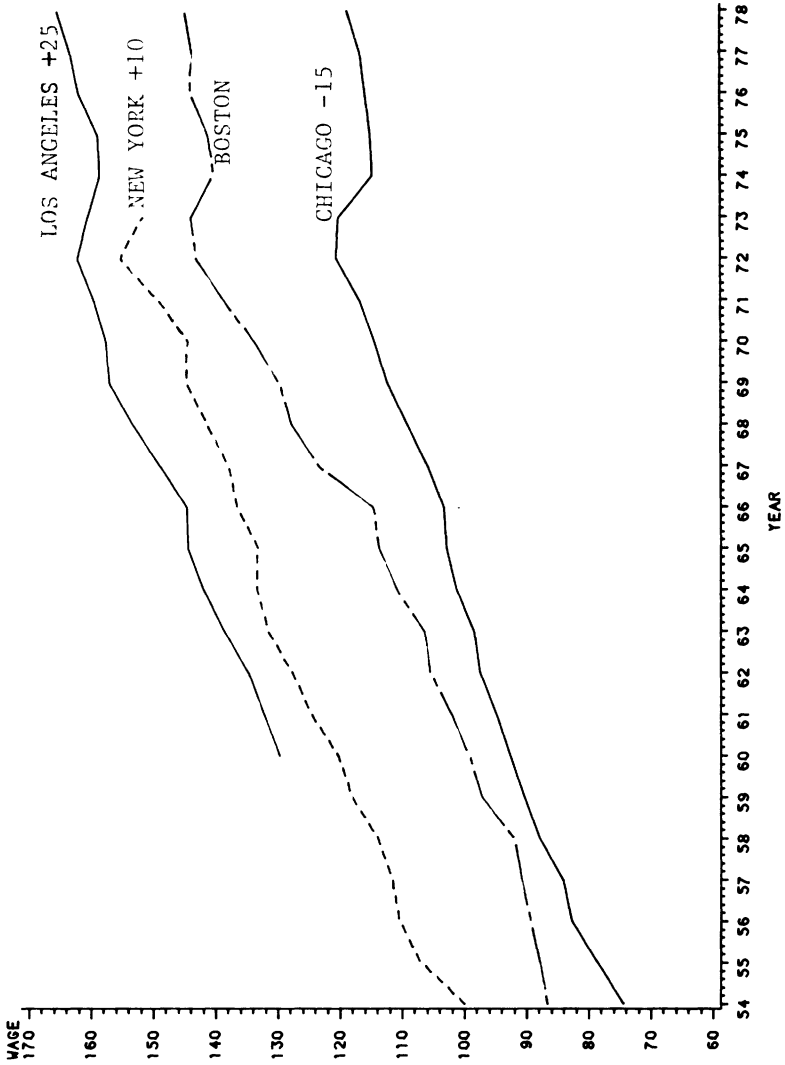


FIGURE 9.—Real weekly wages of nurses in 1967 dollars, 1954–78 (U.S. Bureau of Labor Statistics)

tion coefficients for first differences of logarithms of undeflated wages for the common period, 1961–73, are shown in the table. Because of the small sample sizes, none of these correlations differs significantly from the others (except, barely, Boston–New York, compared with Chicago–Los Angeles).

These often low correlations are representative of those we find among large cities: in thirteen of 120 pairs of large cities, the correlation coefficients for nurses are below .5, and similar results are obtained for female accounting clerks.<sup>25</sup>

### V. THE PHYSICAL MOVEMENT OF GOODS

The physical movement of goods (or buyers) from one place to a second is a potential source of information on the geographic extent of a market.<sup>26</sup> One expects to find such movements (directly, or through intermediate links) playing a fundamental role in explaining the price uniformity which we have reaffirmed as the basic criterion of a market.

No volume of physical movement, however, will insure that two areas are in the same market. Let a substantial amount of the product produced in area A come from B: they are separate markets if price discrimination (the producer in area B is dumping) is causing the price in A to be lower than in B despite the transportation costs. A related concern sometimes expressed is that producers in area B may be shipping to A because the producer (or cartel of producers) in A is charging a supracompetitive price. We believe, however, that such a situation is unlikely to occur because profit-maximizing behavior would establish the price in A at a point just short of encouraging imports.<sup>27</sup>

Moreover, there is no natural level of import or export of goods from an area that will reliably bring about price equality, even in the absence of price discrimination.<sup>28</sup> The extent of imports or exports depends, given

<sup>25</sup> For eight metropolitan areas (1960–81), we find thirteen of the twenty-eight pairs of cities have correlations below .4, and again the Boston–New York figure is bizarrely low (–.003).

<sup>26</sup> Thomas Hogarty & Kenneth Elzinga, *The Problem of Geographic Market Delineation in Antimerger Suits*, 28 *Antitrust Bull.* 45–81 (1973), propose such movements, compared to consumption and production in each area, as the primary criterion of a market.

<sup>27</sup> See William M. Landes & Richard A. Posner, *Market Power in Antitrust Cases*, 94 *Harv. L. Rev.* 937 (1981).

<sup>28</sup> Hogarty & Elzinga, *supra* note 26, propose two criteria that, unless they both reach a critical value of .75 or alternatively .9, denote a single market: LIFO (little in from outside) and LOFI (little out from inside), where

$$\text{LIFO} = \frac{\text{local consumption from local supplies}}{\text{local consumption}}$$

$$\text{LOFI} = \frac{\text{local consumption from local supplies}}{\text{local production}}$$

transportation costs, on the correlation of the geographical patterns of production and consumption *and* the elasticity of demand for the product. An import balance of 10 percent in an area is sufficient to lower price in that area by 33 percent if the elasticity of demand is  $-\frac{1}{3}$ .<sup>29</sup>

Moreover, equality of price of a good can be achieved without *any* movement of that good. Let wheat be more expensive to transport than flour (as is true with nondiscriminatory freight rates because a fourth or more of wheat ends up as products other than flour). Let the flour market be national. Then the competition of flour millers can bring about equality in the price of wheat, allowing for *flour* transportation costs, in the various areas where wheat is grown. This is a rather extreme case, but it emphasizes the fact that competition of mobile buyers can bring about price equality without a movement of the good in question in its primary form, and is well known in trade theory as the factor equalization theorem.

It is fair to conclude that neither the physical shipment of goods nor its absence always gives a reliable proof that the two areas are or are not in the same market. That is not to say that a detailed knowledge of the movements of goods and buyers would be of no value. If two competitively organized centers (that is, excluding price discrimination) are shipping to a third center, all three centers are in the same market, and price uniformity after adjustment for transportation costs will be observed. If one area is regularly importing appreciable quantities of a good from a second area, and again no price discrimination is practiced, the two areas are in the same market. But observe that even in these cases, the physical movements are ambiguous in the absence of either price information or of information concerning competitive structures in the two areas.

Two related problems are encountered in the use of physical shipment

<sup>29</sup> Let  $P_1 = G(\bar{x})$  and  $P_2 = g(\bar{x})$  be the demand functions in two areas. We start with  $P_1 > P_2$ , and  $G(\bar{x}) > g(\bar{x})$ . To equilibrate prices, we must find a  $\Delta$  such that  $G(x + \Delta) = g(x - \Delta)$ , or, using a Taylor series approximation,  $G(\bar{x}) + \Delta G'(\bar{x}) = g(\bar{x}) - \Delta g'(\bar{x})$ , or,

$$\Delta = \frac{g(\bar{x}) - G(\bar{x})}{G'(\bar{x}) + g'(\bar{x})} \tag{i}$$

Let the elasticity of demand be constant and equal in the two areas, with  $P_2 X^n = K$  and  $P_1 X^n = \lambda K$ ,  $\lambda > 1$ , and

$$\eta = \frac{G}{xG'} = \frac{g}{xg'} \tag{ii}$$

Substituting into (i), we get

$$\begin{aligned} \frac{\Delta}{x} &= \eta \frac{(g' - G')}{g' + G'}, \text{ and with } g'/G' = (1/\lambda) \\ &= \eta \frac{(1 - \lambda)}{1 + \lambda} \end{aligned} \tag{iii}$$

data to define markets. The first problem is that there is no guidance in this method to the definition of the products whose shipments are to be examined. Should the shipments be of flour or hard winter wheat flour; of coal, or coal and petroleum equivalents, or steam coal? Clearly, the analysis of shipments is unusable until this problem is solved. It is usually "solved" by casual recourse to physical similarity of products or data reporting practices.

The second problem is that one must shift to a different method to define the proper range of products. The common recommendation is reliance on cross-elasticities of demand and supply. But these cross-elasticities are essentially equivalent to comparisons of price movements, and less accessible in practice. If either the demand or the supply cross-elasticity is high, the prices of the two products being compared will (must) move together. But if this is true, why use a method only to define products which also serves to define geographic limits of a market? It is inescapable that when price data exist, they should be consulted in the course of a market determination.

## VI. OTHER TESTS

### A. *Department of Justice*

The Department of Justice Merger Guidelines define a market as "a group of products and an associated geographic area such that (in the absence of new entry) a hypothetical, unregulated firm that made all the sales of those products in that area could increase its profits through a small but significant and non-transitory increase in price (above prevailing or likely future levels)."<sup>30</sup> The purpose of this definition is to identify markets that are sufficiently insulated from competition to allow some exercise of market power. This market definition has one, wholly decisive defect: it is completely nonoperational. No method of investigation of data is presented, and no data, even those produced by coercive process, are specified that will allow the market to be determined empirically. Its serious analytical defects may be passed here.<sup>31</sup>

As mentioned above, markets can be defined at any level of interdependence with the excluded portion of the economy. The Guidelines make an effort to quantify this level of interdependence by setting a 5 percent test

<sup>30</sup> U.S. Department of Justice, Merger Guidelines, at 4 n.6 (1982).

<sup>31</sup> These defects include the following: (1) the ambiguity of the concept allows both over and under inclusion of firms that are obviously in the same market; (2) prior nonprofit maximizing behavior would excuse monopolistic mergers; and (3) production and sales are not properly integrated in the discussion.

of profitability.<sup>32</sup> Roughly stated, a possible market is a market if all the firms in that market could collusively raise prices by at least 5 percent and increase profits. Why the factual inquiry necessary under this 5 percent approach—coupled with quantification of market shares and judgment concerning the level and changes in concentration—is any easier than asking directly whether the merger will result in an increased price (the question that is, after all, the one to be answered) is beyond us.

Moreover, the Guidelines are inconsistent in defining markets. For instance, producers who could use existing facilities to enter within six months are included in the market even though their competitive influence may be less than that exerted by similar goods that would not have been included in the market because the 5 percent test was already satisfied. Similarly, current geographic sales patterns will be used to make the initial selection of the geographic market even though areas will be included that would not have been under the 5 percent test. Further, and paradoxically, the Guidelines' 5 percent test will ensure that markets with prices currently above the competitive level are defined more broadly than otherwise identical markets experiencing competitive pricing. Finally, whether 5 percent is appropriate for the policy of the antitrust laws, or whether one should define markets on the assumption that either all firms in a market will collude or none will (the basis of this 5 percent test), are not the subjects of this paper. Rather, we simply note those possible problems here.<sup>33</sup>

### B. Horowitz

We are not alone in proposing the use of price data for market definition. Ira Horowitz's central concern with a test of price uniformity in defining a market is that in the short run irrelevant coincidences or disparities may arise.<sup>34</sup> He believes, however, that over time prices in the same market cannot get "out of line," presumably meaning they cannot differ by other than transportation costs. He proposes to eliminate the

<sup>32</sup> The 1984 Revisions state that more or less than five percent may be used. Justice Department Merger Guidelines, 1169 Antitrust & Trade Reg. Rep. (BNA) S-1, S-2 (1984).

<sup>33</sup> For instance one could hope that the Herfindahl Index levels utilized by the Guidelines are based on the voluminous empirical work on the concentration-collusion hypothesis. Yet we doubt that the Guidelines' notion of a market is even close to the same as the market definitions implicitly used in these studies. The possibility that critical Herfindahl Indexes determined in the study of, say, markets that would on average pass a 25 percent test will be used to condemn mergers in 5 percent markets makes us wonder whether the Guidelines are on balance an improvement.

<sup>34</sup> Ira Horowitz, Market Definition in Antitrust Analysis: A Regression-based Approach, 48 S. Econ. J. 1 (1981).

disequilibrium price differences between possibly two parts of a market by an adaptive lag-price model. Let  $D_L = P_i - P_j$  be the long-run equilibrium difference between prices in two areas and  $D_t$  the corresponding differences in any one time period, so the model asserts that

$$D_L - D_t = \lambda(D_L - D_{t-1}) \quad (|\lambda| < 1).$$

But this particular model has no general validity as an approach to (and departure from!) equilibrium, and can yield peculiar results.<sup>35</sup> Horowitz's own example is inappropriate.<sup>36</sup> The problem here unsuccessfully addressed is how to choose the time interval to which price quotations pertain. That period, to repeat, may be ten minutes for a commodity market speculator, but should generally be much longer for purposes of determining market power of individual firms.

## VII. CONCLUSION

We have argued that the classical theory of the market has direct applicability to empirical market determinations and indeed that the applications are manageable in both their data requirements and their methodology.

The empirical study of markets has been concentrated on questions of monopoly. Yet markets are central to all of price theory, and for many problems the size of the market is important. Studies of labor mobility, for example, must be incomplete in the absence of knowledge of how quickly wage differentials in different areas are brought to equilibrium values. The distinction between internationally and domestically traded goods is essentially a market question. The competition of states for industry or for tax revenues from excises is strongly influenced by market sizes of the relevant commodities or services.

The time dimension of the movement of relative prices deserves a much closer examination than we have given it. We have chiefly studied markets in which the equalization of prices at different points proceeds with great rapidity. The mechanisms by which this convergence is achieved

<sup>35</sup> In our silver example, his estimating equation (3) becomes  $D_t = \alpha + \lambda D_{t-1} + e$ , where  $D_t$  = the difference between the Chicago and New York prices in period  $t$ ;  $D_{t-1}$  = the difference in period  $t - 1$ ; and  $e$  = a random disturbance term. The results were:  $\alpha = \$0.012$ , significant at the 20 percent level;  $\lambda = -0.17$ , insignificantly different from zero; and  $R^2 = .029$ . His critical variable,  $\lambda$ , gives us no information on the rate of approach of the price differences to equilibrium and does not tell us if there are one or two markets involved.

<sup>36</sup> Horowitz, *supra* note 34. He compares retail prices of six meat products in twelve metropolitan areas. Wholesale prices would be appropriate in determining whether the twelve areas are in one market. Retail prices within a metropolitan area would be appropriate in determining whether the metropolitan area was one market.



and the factors that delay the convergence for substantial periods are topics we commend to subsequent students of the area.

APPENDIX

To determine whether two places are in the same market, we compare the differences in their prices, or price movements, with the average (or sum) of the prices or price movements. Indeed the speculative trade called a "spread" is designed precisely to profit from nonequilibrium price differences between two places. The spread is in effect achieved also for commodities that are not traded on organized exchanges by shifting purchases or sales. We employ this approach, using first differences in the logarithms of prices.

Let the price series be random walks, so that if  $Z = \log \text{price}$ ,

$$Z_{it} = Z_{i,t-1} + a_{it}$$

is the characterization for city  $i$ . Also let  $\rho = \text{correl}(a_{1t}, a_{2t})$  and  $\sigma^2 = \text{var}(a_{it})$ . It is natural to test whether two cities are in the same market by comparing the differences in their prices with the average or sum of their prices, where

$$Z_{1t} - Z_{2t} = Z_{1,t-1} - Z_{2,t-1} + a_{1t} - a_{2t}$$

$$Z_{1t} + Z_{2t} = Z_{1,t-1} + Z_{2,t-1} + a_{1t} + a_{2t}$$

Let  $a_{1t} - a_{2t} = b_{1t}$  and  $a_{1t} + a_{2t} = b_{2t}$ . Then

$$\text{var}(b_{1t}) = 2\sigma^2 - 2\sigma^2\rho = 2\sigma^2(1 - \rho)$$

$$\text{var}(b_{2t}) = 2\sigma^2(1 + \rho) \approx 4\sigma^2.$$

$$\frac{\text{var}(b_{1t})}{\text{var}(b_{2t})} = \frac{1 - \rho}{1 + \rho},$$

so  $\rho$  is the critical statistic. One may also ask the question: If we forecast  $(Z_{1t} - Z_{2t})$  and  $(Z_{1t} + Z_{2t})$  on the basis of their relationship up to a certain date, what is the ratio of their variances? The variances of the forecast errors are

$$n2\sigma^2(1 - \rho) \text{ for error lag } n, \text{ for } Z_{1t} - Z_{2t};$$

$$n2\sigma^2(1 + \rho) \text{ for error lag } n, \text{ for } Z_{1t} + Z_{2t};$$

and their ratio is  $(1 - \rho)/(1 + \rho)$  for all  $n$ .