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Measuring the Intensity of Competition Across Geographic Markets

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Abstract

This paper uses a modified cointegration method to determine how prices in different geographic areas "track" each other. Arbitrage across these geographic areas would be a natural explanation for prices tracking each other. Antitrust markets are defined as a group of products where arbitrage from outside would not defeat a hypothetical small but significant price increase within a year. We use an empirical market definition methodology recently proposed by Wu & Wu (1997) to measure the geographic extent of gasoline markets. This model essentially examines correlations between different prices, but does takes into account common cost and demand shocks across markets. A significant innovation of this approach is that it allows measurement of the degree and speed of arbitrage across markets. We find this method tends to correctly find larger markets and provides a quantitative method to determine the intensity of arbitrage rather than a simple determination of whether a competitor is "in or out" of a market. This method potentially allows for a full estimation of hypothetical price effects from a merger without placing the standard disproportionate emphasis on concentration indices.

Using publicly available gasoline price data by state, we test whether California prices "follow" prices in Nevada and Arizona. We cannot conclude that California is a distinct geographic market separate from these neighboring states. This suggests that California environmental standards do not remove that state from a larger gasoline geographic market in the Western United States.

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Market definition is a critical first step of economic analyses of price and welfare effects (and more important, liability and damages) before many adversarial, advocacy and regulatory proceedings involving diverse areas of law as antitrust, securities fraud, breach of contract and intellectual property. In intellectual property disputes, market definition is a first step in analyzing market power conveyed by, and therefore economic value of, an intellectual property asset. In antitrust analysis, market definition is required for subsequent analysis of competition within the market, entry conditions into the market, and, to a lesser extent, efficiencies.[1] Once again, determination of the relevant market is necessary for future determination of damages and appropriate relief. Much of the market determination literature discusses how to operationalize the generally imprecise notion of an economic market.[2] The conventional textbook model of competition assumes numerous sellers of a homogenous product. In reality, economic goods face varying degrees of substitutability with other goods because of differences in physical

[1] Many argue that out-of-market efficiencies should not count in the analysis of the net competitive effect of a merger.

[2] Commentators point to the language in Section 7 of the Clayton Act ("…prohibiting acquisitions likely to lessen competition substantially or tend to create a monopoly in any line of commerce or … section of the country…") as requiring a court to identify the product and geographic market within which competition would be harmed by an acquisition. [15 U.S.C. 18] Beginning with *Brown Shoe Co. v. U.S.*, establishing the relevant product market has been a necessary predicate for any antitrust claim. [370 U.S. 294, 335 (1962)].

attributes, geographic location of sale and timing of consumption. Clearly, a measure of the relative intensity of competition between goods is necessary to gauge which products should be grouped within a relevant market.

Market definition under the *Merger Guidelines*[3] asks whether a hypothetical monopolist could profitably raise prices by a small, but significant and non-transitory amount ("SSNIP").[4] If it is able to do so, then consumer substitution away from the monopolized set of goods will not defeat that profitable price increase. In the next step, the *Guidelines* ask which firms currently could (within a year without the expenditure of significant sunk costs) supply goods in the relevant market. The determination of market participants can be viewed as gauging the degree of arbitrage that will occur from outside the market in the event of a price increase that is limited to goods within a relevant market. If significant arbitrage occurs between demand-side markets, one would expect that prices in the different markets would move in parallel and the two demand-side markets would be considered in the same supply-side market.

When examining geographic market definition, the *Guidelines* offer a similar methodology. The operating question is, "If the firms in a particular region collude to raise prices by X%,[5] will arbitraging supply from outside the region defeat that price increase?" One can change the focus of the question from the amount of a price increase to the timing of its defeat. In other words, one can ask, "How long will it take for outside supply to restore prices after a permanent shock (caused by a hypothetical collusive price increase) in a hypothetical geographic market?" The *Guidelines'* suggestion that a firm that could supply product within a year without significant sunk cost be considered a market participant suggests that a one year standard should be appropriate to be deemed significantly swift arbitrage. Such a price shock may or may not result in a permanent increase in prices, depending on the "slope" of the long run equilibrium relationship between prices. A smaller permanent effect from a price shock and a faster speed of adjustment would suggest a greater degree of inter-regional competition.

The federal antitrust agencies are developing and using new tools for defining antitrust markets. In particular, there seems to be a move in the direction of estimating or otherwise characterizing quantitatively underlying systems of demand for multiple products. These multi-product demand curves may be used as inputs into theoretic models of oligopolistic pricing from which potential effects from mergers can be simulated.[6] This increased use of more theoretical pricing models has led to a greater interest in estimating demand and otherwise defining markets.

Several investigations highlight several methodologies in defining markets. There have been a number of recent consumer product mergers where consultants have estimated fairly complete systems of demand using retail scanner data.[7] In the FTC's successful challenge of the proposed Staples/Office Depot merger, the government and parties both presented elaborate price/concentration studies purporting to show the likely effect of the acquisition. Relying on thorough empirical work aided by a peculiar rhetorical twist the FTC successfully reversed the product market methodology by first establishing an econometric result and then concluding that the superstore product market was the only one likely to support such an econometric finding. Showing a price effect in Staples stores because of entry of nearby Office Depots, the FTC argued that office supply superstores constituted a relevant product market.[8] The Justice Department also recently advanced a novel product market challenging the merger of two prominent New York hospitals in an "anchor hospital" market in Long Island.[9] There is continued discussion of how to properly define markets in intellectual property.[10] Lastly, progress in applied econometric theory and greater data availability have not only reduced the cost but have also enhanced the expected information to be drawn from demand estimation and similar market definition exercises.[11] These factors will result in greater use of

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[3] U. S. Department of Justice, "Merger Guidelines, "*Antitrust Trade Regulation Report*, 1982, No. 1069; U. S. Department of Justice, "Merger Guidelines," *Antitrust Trade Regulation Report*, 1984, No. 1169; U. S. Department of Justice and Federal Trade Commission, "Horizontal Merger Guidelines," *Antitrust Trade Regulation Report*, 1992, No. 1559; and U. S. Department of Justice and Federal Trade Commission, "Horizontal Merger Guidelines," *Antitrust Trade Regulation Report*, 1997, No. 1806.

[4] Small but significant and non-transitory increase in price.

[5] The *Merger Guidelines* suggest a 5 to 10% standard. Others have suggested that this standard be adjusted by the degree of product heterogeneity to compensate for the view that a "significant" (one that might induce customers to switch suppliers within a market) price increase is likely larger for heterogeneous products.

[6] A complete demand system allows for varying degrees of cross elasticity between products. In this sense, it may be more precise than just determining whether a firm is in or out of a market. Unfortunately, merger simulations tend not to model the supply-side very well and the results of these models tend to say that anticompetitive effects are large if the relevant cross elasticities are big. This tends to make the demand estimation important in the review process, but tends to overshadow other components in a complete analysis of a proposed acquisition.

[7] For example, Guiness/Grand Metropolitan and General Mills/Ralston.

[8] FTC v. Staples, DC District Court, 97-701 (1997). The FTC argued that Staples price falling as a result of Office Depot entering would be consistent with prices rising if Office Depot were to exit. From this effect, the government argued, it would be necessary for superstores to be a relevant market because the effect could only occur is consumers did not defeat a price increase by choosing to purchase other products.

[9] The government's complaint challenges the proposed merger of Long Island Jewish Medical Center and North Shore University Hospital. The government contends that the relevant product market consists of "anchor hospitals." These are hospitals which are "reasonably convenient" with "a prestigious reputation offering an extensive array of high quality services." See, Bloch, Robert E., Scott P. Perlman and Robert L. Bronston, "Antitrust," *The National Law Journal* (Monday, July 21, 1997) at B5. Many have argued that defining a product market that is too narrow may lead to problems in geographic definition.

[10] Despite the general uncertainty and imprecision surrounding innovation markets, the agencies have negotiated consent agreements based on self-defined innovation markets. See, generally, Intellectual Property Guidelines; Novartis, FTC File No. 961-0055 (filed 12/5/96); Boston Scientific, 60 Fed. Reg. 32,323 (1995); Sensormatic Elec., Dkt. No. C-3572 (filed 4/18/95) Professor Spencer Waller has criticized this development. Spencer Weber Waller, "Prosecution by Regulation: The Changing Nature of Antitrust Enforcement," forthcoming *Oregon Law Review* ["In so doing, the agencies have created new doctrine without the need for, and largely insulated from, judicial approval."]

[11] Jonathan Baker, former Director of the FTC's Bureau of Economics, attributes the increased popularity of econometrics in regulatory proceedings to the following: (1) increased computational power; (2) advances in econometric methodology; (3) increased availability of disaggregated data; (4) differences in regulatory climate; (5) advances in theoretical Industrial Organization; and, (6) greater willingness by regulatory agencies to entertain analysis rigorously supported by econometric methods. Jonathan B. Baker, "Contemporary Empirical Merger Analysis," prepared remarks before the George Mason University Law Review Symposium (October 11, 1996).

econometric analysis in regulatory proceedings and litigation.

The *Guidelines* approach (as opposed to some econometric approaches) to merger analysis tends to compartmentalize market factors into various categories (Market Definition, Concentration, Entry, and Competitive Effect), which are then analyzed separately. This sequential approach tends to underestimate the interaction between these different categories of analysis.[12] Furthermore, the product and geographic market definitions posed by the *Guidelines* tend to elicit binomial responses. A firm is either in or out of a relevant market. Economists, however, would tend to view product spaces as continuous and would ask questions more akin to "Is Firm A closer to Firm B or Firm C?; questions designed to establish which firm conveys relatively more competitive pressure. The binomiality of a standard market definition analysis tends to not capture the relative intensity of competition between firms and may then lead to misleading results. Thus, we agree with recent work by Scheffman and Spiller and Scheffman that argue that a naive *Merger Guidelines'* approach typically results in unrealistically narrow markets.[13]

By putting more relevant factors of the merger analysis in an econometric exercise, one can conceptually jointly analyze the different categories of *Guidelines* information simultaneously with defining markets. The empirical approach of this paper examines prices and measures the relative intensity of competition from various sources. Prices contain information on likely supply response from outside the market and the likelihood of collusion given the current structure of the market. They also contain information on consumer demand. This analysis allows for an empirical reading of the likely outcome of an acquisition that is more accurate than simply looking at concentration ratios in an arbitrarily defined market. Parties that use this empirical approach may find that it gives an early reading of an acquisition's likely effects and an agency's likely response to a proposed acquisition. This method may be a least-cost method to determine strategy before an investigating agency.

This paper extends research by De-Min Wu and Lawrence Wu to geographic market definition under the *Merger Guidelines*.[14] Wu & Wu examine the degree of integration or intensity of competition between two products by determining whether the price paths of these products are cointegrated after taking into account exogenous cost and demand shocks. In our model of geographic differentiation, estimates of the cointegration equations provide information on the long-run equilibrium between prices at different locations. The properties of the estimation errors allow for estimates on the extent and speed of arbitrage between producers in these various areas.

Previous Work

There are a variety of statistical and economic methods available to determine relevant product and geographic markets. These include price correlation tests,[15] tests of price uniformity and arbitrage,[16] Granger causality tests,[17] residual demand analysis,[18] and shipments tests. The popularity of the various empirical approaches to market definition is a result of not only econometric advances, but also to the theoretical and conceptual evolution of the underlying theories.

In an attempt to overcome the binomiality inherent in market definition, cointegration tests have been used to determine whether the prices of different products or in different locations track each other.[19] If prices do track in a long run equilibrium relationship, the price series will be cointegrated. Short-run price movements to restore the equilibrium relationships are assumed to be the result of arbitrage. Thus, estimates of the cointegrating relationships yield information on long run equilibrium relationships and short-run disequilibrium responses between the different price series.[20] Examination of the residuals from the cointegrating relationships can yield information on the speed of this arbitrage.

The cointegration approach creates a metric measuring the distance that prices have deviated from an equilibrium. Although the speed at which prices adjust has received attention by other researchers,[21] cointegration allows one to construct direct measures of how quickly prices return to equilibrium. The speed of arbitrage is a natural metric for assessing market definition, for its is determined by the willingness of consumers to switch from one product to another and the responsiveness of firms in nearby markets to divert product into areas where prices have increased.

Cointegration models and correlation approaches in general, have been challenged on various grounds. In particular, Werden and Froeb (1992) list several potential difficulties with these approaches. First, there is the danger of spurious correlation. Prices in Markets A and B may have a common determinant Z. A shock to Z can cause prices in Markets A and B to be correlated, leading to the potentially

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[12] See, for example, Robert Brogan, "Simultaneity and the Merger Guidelines," *Journal of Reprints in Antitrust Law & Economics* Vol. 21, No. 1 (1992) 423-431; M.B. Coate & A.E. Rodriguez, "Pitfalls in Merger Analysis: The Dirty Dozen," *forthcoming* Competitive Enterprise Institute Working Papers (1998).

[13] Scheffman, David T., "Buyers, Market Power, and Market Definition," in M.B.Coate & Andrew N. Kleit, The Economics of the Antitrust Process (1996) 117-133; David T. Scheffman & Pablo T. Spiller, "Buyers' Strategies, Entry Barriers and Competition," *Economic Inquiry* 30(3) (1987) 418-436.

[14] Wu, Laurence and De-Min Wu, "Measuring the Degree of Interindustry Competition in U.S. v. Continental Can," *The Antitrust Bulletin* (Spring 1997) 51-74.

[15] See, e.g., Stigler, George & Robert A. Sherwin, "The Extent of the Market," Journal of Law and Economics Vol. 28 (1985) 555-585.

[16] Horowitz, Ira, "Market Definition in Antitrust Analysis: A Regression-Based Approach," 48 *Southern Economic Journal* (1981) 1; Spiller, Pablo and C. J. Huang, "On the Extent of the Market: Wholesale Gasoline in the Northwestern United States," 35 *Journal of Industrial Economics* (1986) 131-145.

[17] See, e.g. Slade, Margaret, "Exogeneity Tests of Market Boundaries Applied to Petroleum Products," *Journal of Industrial Economics* Vol. 44 (1986) 291-303; Uri, Noel, John Howell, & Edward J. Rifkin, "On Defining Geographic Markets," *Applied Economics* Vol. 17 (1985) 959.

[18] Baker, Jonathan B. and Timothy F. Bresnahan, "Estimating the Demand Curve Facing a Single Firm," *International Journal of Industrial Economics* Vol.6 (1988) 283-300.

[19] See, e.g. A.E. Rodriguez and Mark D. Williams, Is the World Oil Market "One Great Pool"? A Test," *Energy Studies Review* Vol. 5, No. 121 (1993).

[20] This is the Granger Representation Theorem, for a formal discussion see, James D. Hamilton, Time Series Analysis (1994) at 582.

[21] See, for example, A.E. Rodriguez and Mark D. Williams, "The World Oil Market *is* 'One Great Pool:" A Response, *Energy Studies Review,* Vol. 5, No. 3, 1993, pages 231--235,

false inference that arbitrage between markets is occurring when it is, in fact, not. For example, in markets for gasoline, a common shock in the price of crude oil would cause gasoline prices to be correlated across different locations even without arbitrage between these areas. Similarly, demand shocks, like nice driving weather across locations, can cause this "spurious correlation" across different gasoline retail markets in a naive cointegration model.

The standard method of avoiding spurious correlation is by controlling for common exogenous determinants in each of the price series examined. Spulber and Doane[22] for example, correct for spurious correlation by first running regressions of gas prices on the producer price index, oil prices, and seasonal dummy variables in each relevant region. Correlation statistics are then calculated from the residuals from each of these regressions and are interpreted as the degree to which different geographic markets are linked.

The Wu and Wu model corrects for potential spurious correlation in a cointegration context. In Wu & Wu, the cointegrating equation consists not just of the endogenously-determined price series for which one tests for cointegration, but also exogenous series measuring shocks to costs and demand. Wu & Wu simultaneously estimate a system of equations and test for cointegration between the endogenous variables.

A second objection raised by Werden & Froeb is that the correlation approach can be affected by different supply and demand elasticities across markets. Consider the following situation across two hypothetical markets A and B, connected by an arbitrage mechanism with a low elasticity of response to differences in pricing between markets. Suppose a demand shock increases prices in Market A relative to Market B. In response to potential profits, producers in Market B will ship products to A. However, these shipments may not completely return prices in A to the level they were before the shock. In a cointegration exercise, one might find that the cointegrating relationship is not "flat," but rather in the long run prices in the two markets are related but do not equalize. In this case, arbitrage between markets will not fully dissipate price increases. Whether or not firm in the different locations are considered in the same market depends on what standard is adopted that says arbitrage is "complete."[23]

Wu & Wu tested whether two separate products were in the same market when they presented their model.[24] We use their model to define geographic markets. In particular, test whether California, Nevada and Arizona are in the same geographic market for gasoline. We choose gasoline because it is a homogeneous product with what we believe to be an inelastic demand. Because gasoline is likely to be a well-defined product market, we can focus our attention entirely on whether the Wu & Wu method is useful in defining geographic markets.

We use data from Energy Information Administration of statewide[25] retail motor gasoline prices before taxes. Specifically, we interested in determining whether gasoline in California can be effectively arbitraged by gasoline in neighboring states. Some have argued that, because California has different environment-related specifications on gasoline, that state may have effectively taken itself out of a wider geographic market for gasoline. If that were true, we would likely find that arbitrage does not occur across boundaries and that California should be considered a separate relevant geographic market.

Wu & Wu devote much of their attention to the speed with which prices adjust. The failure to treat this time dimension explicitly is a discussed deficiency in many market definition exercises, both econometric and otherwise. Similarly, the appropriate time implicit in measured elasticities is an important consideration in assessing the competitive effects of acquisitions. These time periods have implications for the horizons over which pricing decisions are made. Obviously, the richness of the estimate depends on the frequency of data. For example, the availability of weekly data may permit estimation of the very short run demand functions that the seller faces from week to week.

The Deficiencies of Traditional Analysis

In a recent paper, Scheffman argues that the agencies may be defining markets far too narrowly and challenging acquisitions where the parties do not have any reasonable expectation of exercising market power.[26] In a traditional Guidelines market delineation exercise, much of the evidence used by the analyst in determining the relevant geographic market turns on the answer to the following questions. (a) What will be the response of a neighboring firm to a hypothetical 5-10% price increase in the price of the widget? (b) What do company and industry documents indicate about the location competitors viewed as being "the competition." The implicit limitation of that inquiry, according to Scheffman, is that it fails to recognize institutional features in the market that should correctly be inputs into the market definition problem. For example, firms may not look at short run elasticities of demand when choosing their pricing strategies, but rather may view price as an input into goodwill at a particular customers. Particularly in intermediate goods markets, producers tend to invest in customer-specific relationships (in goodwill or otherwise) and this limits the

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[22] Doane, Michael J. and Daniel F. Spulber, "Open Access and the Evolution of the U.S. Spot Market for Natural Gas," The *Journal of Law & Economics* Vol. 37 (October 1994) 477-517.

[23] Worden & Froeb (at 334-5) suggest a third potential problem with correlation models. There may be capacity constraints limiting the amount of arbitrage between markets. In the example above, a price increase in Market A could lead to a binding constraint on arbitrage from B to A. As a result, prices in A rise, prices in B rise and transport services prices rise. As arbitrage costs rise, however, the markets become less "connected." Yet a correlation analysis may indicate increased correlation between the markets during the post-demand shock period rather than before. This potential problem only arises is the cointegration model is misspecified. (This problem would also occur in other types of econometric market definition exercises, particularly demand estimation.) Presumably, if the constraint on arbitrage were important, a careful modeler would incorporate these considerations when setting up the systems of equations to estimate.

[24] Specifically, Wu & Wu determine whether metal cans and glass containers are in the same market. The question arose in U.S. v. Continental Can Co. 378 U.S. 441 (1964).

[25] There have been calls to investigate whether gasoline pricing in the San Francisco Bay area is too high relative to Los Angeles. A finding that this is true, would likely require that Los Angeles gasoline cannot arbitrage Bay area gasoline. Because we have only statewide data, we cannot address the question of whether these two locations are in separate geographic markets.

[26] Scheffman, *supra*, note 13.

desirability of exercising short run market power. A naive application of the *Guidelines* in a market definition exercise (particularly if the nontransitory nature of the hypothetical price increase is not stressed) tends to overestimate short run effects when determining whether a firm is in or out of a market.[27]

A complete merger analysis allows for these potential shortcomings in market definition to be addressed. For example, investments in goodwill can be treated in the competitive effects section of a *Guidelines* analysis.[28] However, as Sheffman has correctly noted, market definition and concentration measures have a disproportionate weight in prosecutorial and legal decisions.[29] Formally, a showing that a merger or transaction increases concentration in a relevant market raises a rebuttable presumption of illegality and this shifts the burden of proof to the merging parties.[30]

More importantly, a similar "market definition and concentration only" logic characterizes many internal debates within the agencies. As staff level investigations compete for management's attention and support to expand the scope of an investigation, the Herfindahl concentration index becomes an important summary statistic. Although everyone understands the limited amount of information contained within a Herfindahl calculation, few fail to begin their inquiry without first asking, "What are the Herfs?" While ultimately the numerous internal reviews and procedures (with chances for input from the parties) within the agencies will reject poor cases and challenge meritorious cases, this process tends to be costly both for taxpayers and especially the parties to the transaction under scrutiny. Procedures that allow earlier and more complete determination of the likely effects of an acquisition, rather than just definition of market and calculation of concentration, should reduce these costs. We believe that the cointegration method discussed next is one such cost-minimizing approach.

Model

In this paper, we attempt to estimate a long run equilibrium relationship between gasoline prices in California, Arizona and Nevada. We model prices in these states as endogenously determined by potential arbitrage between these states and by the influence of exogenous cost and demand shocks. Conceptually, one could specify a system of equations between these endogenous and exogenous variables and estimate its parameters by two or three stage methods. Unfortunately, the standard errors of these estimates will likely be inconsistent because the endogenous price series are unlikely to be stationary. However, if two nonstationary series are cointegrated, then one can measure existing equilibrium relationships between these series.

A time series is said to be stationary if all of its covariances over different time intervals remain finite or, more intuitively, if shocks to the series die out over time. If shocks persist over time in a series, as in a random walk model for example, then the series will be non-stationary. Price series, in particular, seem to often follow random walks, which have unit roots. If one takes the first difference of a random walk, one will find that the new series is stationary. A series is said to be integrated of order N if it takes N differences to induce stationarity.

Assume that the price series is integrated of order 1 (which we will show later). In this case, prices would wander over time. We could ask, however, whether the two series wander "close" to one another. Cointegration tests this concept. Two series (integrated of order 1) are said to be cointegrated if one can find a linear combination of the series that is stationary (*i.e.* integrated of order 0). The parameters of such a linear combination is said to be the cointegrating vector and represents the long run equilibrium between the two series.

The econometric model of the proposed long-run equilibrium relationship between gasoline prices in the three states is a simple reduced form.

$$(1) \qquad P_{it} = f(P_{jt}, \text{Demand Shifters}, \text{Cost Shifters}) + \text{stationary error}$$

The price of gasoline in state i is a function of the price of gasoline in other states and other exogenously-determined variables. The error of this regression equation will be stationary even if the original price series are not if there is a cointegrating relationship between the price of gasoline in different states.

Theory can help identify supply and demand shifters for gasoline. The demand for gasoline in each state depends *inter alia* on its price and gasoline prices in neighboring states.[31] Because gasoline demand is largely defined by driving habits, which display strong cyclical pattern, we include a dummy variable indicating summer. (Seasonal dummies are included as supply shocks as discussed below) We also assume unemployment rates as demand shifters.

Because much of the variability in downstream gasoline prices originates upstream, we use the price crude oil as a cost shifter.[32] While the supply and demand for crude oil is affected by several variables, including gasoline prices, we assume that crude oil prices are exogenously determined

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[27] Similar criticism noting the binomial nature of establishing whether alternative suppliers are "in the market" or "out of the market" has been advanced by Pitofsky and Baker & Bresnahan. Robert Pitovsky, "New Definitions of Relevant Market and the Assault on Antitrust," *Columbia Law Review* Vol. 90 (1990); Jonathan B. Baker & T. Bresnahan, "Empirical Methods of Identifying and Measuring Market Power," Antitrust *Law Journal* (1992).

[28] See the general description and criticism of the Guidelines' methodology in Judge Thomas opinion in U. S. v. Baker Hughes Inc., 731 F.Supp. 3 (D.D.C. 1990), *aff'd* 908 F.2d 981 (D.C.Cir. 1990).

[29] Scheffman, *supra*, note 13, at 122.

[30] However, a mere showing of increased concentration is unlikely to convince a Federal Judge to grant a Preliminary Injunction. In practice most preliminary injunction hearings end up being a de facto trial on the merits of the case. It is unlikely that an enforcement agency would seek a temporary restraining order armed only with evidence of increased concentration. Most agencies are well prepared to challenge the parties' attempts to rebutt the presumption of illegality. This preparation entails a full-fledged Guidelines economic and legal analysis.

[31] Arbitrage is expected to occur more on the supply side than the demand side.

[32] Balke, Nathan, S., Stephen P.A. Brown and Mine K. Yucel, "Crude Oil and Gasoline Prices: An Asymmetric Relationship?" *Economic Review of the Federal Reserve Bank of Dallas* (1998:Q1) 2-11; Severin Borenstein, A. Colin Cameron, and Richard Gilbert, "Do Gasoline Prices Respond Asymmetrically to Crude Oil Prices?" *Quarterly Journal of Economics* 112 (February) 305-39.

because this three state area constitutes only as small percentage of demand in the world crude oil market.[33] Depending on the degree of refining flexibility, distillate producers are able to vary the product composition derived from each barrel of oil, in response to fluctuations in relative demand. Thus, the supply of gasoline may depend on the relative demand for other related products such as heating oil, diesel and bunker fuels. For example, increased driving during the summer months increases the demand for gasoline, relative to heating oil. To the extent that their plant is capable, refiners will squeeze proportionately more gasoline from a barrel of oil and less heating oil and other lower-valued products. This seasonality will be captured with relevant dummy variables as supply shifters as well as demand shifters.

The time series methods we use allows us to determine the number of cointegrating relationships between the different price series. Because we have price data for three states, we may find up to two sets of cointegrating relationships. We will test whether there are zero, one, or two of these cointegrating vectors. If one were to find two cointegrating relationships, one could plot a line (assuming fixed values for the exogenous variables) representing the long run equilibrium between these three prices in three-space.

We then estimate the speed of adjustment by looking at the number of periods it takes for price shock in one state to dissipate and prices return to their long-run equilibrium relationship. We do this by forecasting a one-time permanent shock off of the long run relationship to each of the price variables in the system. We measure the speed of adjustment by the percentage of the adjustment completed in a given time period. This empirical tool is called the impulse response function. A persistence profile decomposes price variances into their sources, either shocks to exogenous variables or shocks affecting prices in other states.

Non-instantaneous price adjustments may be caused by long-term contracts, adjustment costs, natural barriers and other factors that may include institutional rigidities.[34] But ultimately, a close examination of the time it takes a price series to return to a stable equilibrium allows one to compare the speed of arbitrage to geographic market criteria in the *Guidelines.*

The impulse response function describes how the price differential between states might respond to a hypothetical one-time permanent shock in a proposed geographic market. In a *Merger Guidelines* context, this could be viewed as a hypothetical price increase from collusive behavior in a supposed geographic market. By measuring how long that price increase could be sustained reveals the extent to which the two regions are in the same geographic market. Note that a *Guidelines* market definition exercise looks solely at consumer and alternative supplier response within a year when defining markets. The characteristics of an impulse response function may reflect not only these factors but potentially also the ability of future entry and market dynamics to discipline an isolated price shock. In this sense, using a cointegration analysis in the context of a merger investigation allows one to simultaneously and quantitatively evaluate how market dynamics would discipline a hypothetical price increase arising from a merger.

We use a vector autoregression (VAR) procedure to estimate the long run equilibrium relationship between gasoline prices across states.[35] The VAR technique imposes no restrictions on the relationships between different variables and treats all as potentially endogenous. VAR procedures give summaries of empirical regularities between variables.

Using VAR's one individually regresses each variable in a system on lagged values (assuming a common lag across all endogenous variables) of itself and other variables in the system and on a common set of other terms including a constant, linear and quadratic time trends and seasonal dummies and exogenous variables. The results can allow for a number of useful tests. First, one can test whether past values of other endogenous variables have a significant effects (Granger causality). Second, autoregressive equations decompose effects from past movements of variables from present changes and, so, the residuals provide estimates of unanticipated movements, which can act as proxies for shocks. Correlations of these residuals may be interpreted as measures of short run relationships between unanticipated variable movements. Third, the VAR estimates may be transformed in a manner to yield estimates of how much of the variance of any variable in the system is attributable to itself and other variables in the system. These variance decompositions are useful in understanding the relative size of how exogenous shocks effect pricing relative to shocks in endogenous variables. Last, the stochastic process by which the market corrects or arbitrages between regions can be modeled by a vector error correction model (VECM).

Estimation

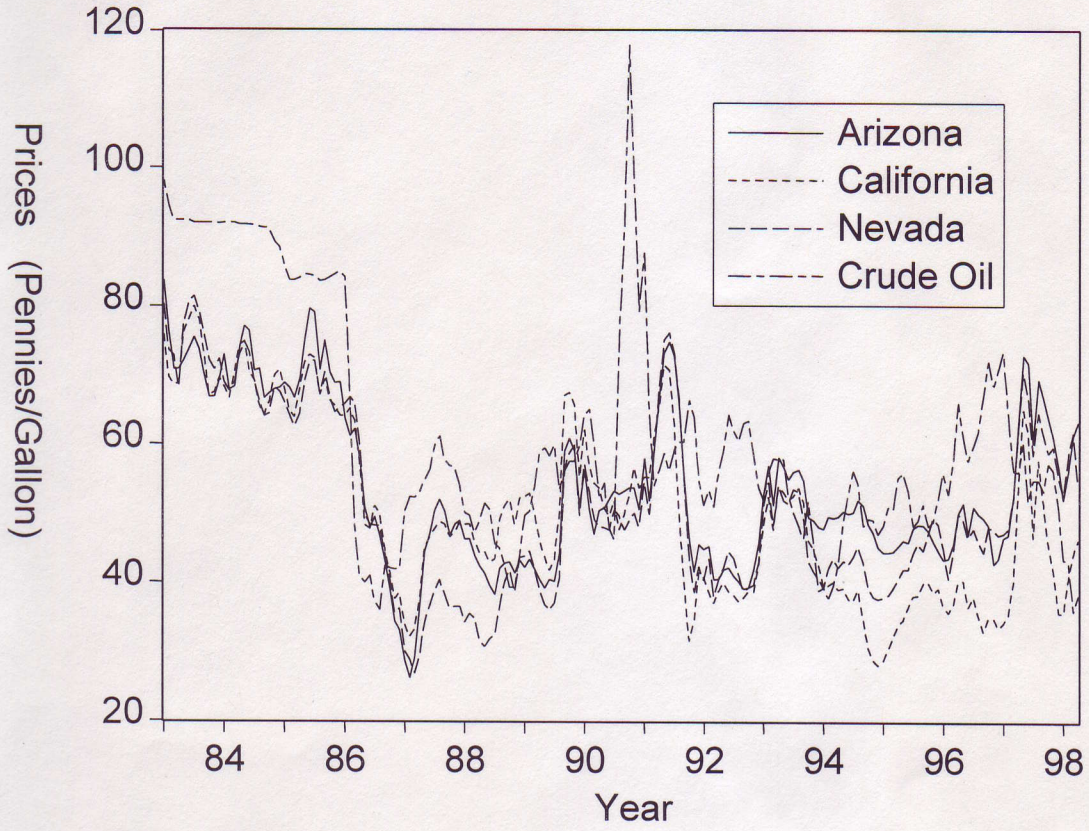
We gathered monthly, state-wide average regular gasoline prices from the Energy Information Agency over the time period from January 1983 to April 1998. The statewide average regular gasoline prices are plotted in Figure 1. Federal and state taxes were removed from these series using data from the Federal Highway Administration. The crude oil price series used was that for Domestic Crude published by the Bureau of Labor statistics. Demand shifters, including measures of unemployment rates, inflation and personal income were also downloaded from the BLS website (www.BLS.com). We further constructed seasonal dummies for summer as well as the Gulf War (September 1990 through March 1991).

[33] For a discussion of crude oil geographic market definitions, see the article cited in footnote 19 above.

[34] J.Y. Campbell and R.J. Shiller, "Interpreting Cointegrated Models," Journal of Economic Dynamics and Control Vol. 12 (1988) 505-522.

[35] We use the VAR estimation methodology developed by Johansen (1991); viz., Soren Johansen, "Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models," Vol. 59 *Econometrica* (1991), 1551–1580.

Figure 1. Statewide Gasoline Prices before Taxes



The first step in our procedure is to test whether the price series are stationary and what is their order of integration. To do this, we run the Augmented Dickey Fuller ("ADF") test with 4th order differences assuming an intercept term, but no trend. As shown in Table 2, all the series can be considered at least borderline non-stationary.[36]

Table 1
Unit Root Tests

Variable	Statistic		Critical Value
California gasoline prices	-2.82	1%	-3.47
Arizona gasoline prices	-2.90	5%	-2.88
Nevada gasoline prices	-2.88	10%	-2.58

The variance of time series with unit roots increases over time. If the time series are cointegrated, the cointegrating relationship represents the long run equilibrium between the variables. The equilibrium errors (the differences between its current price and what that price would be given the value of all other variables) will have a tendency to return to zero even though each of the price series do not have a tendency to return to any particular value. We use a VAR to estimate the cointegrating relationship between the price series.

The inclusion of exogenous variable as well as the lag order of the VAR is often selected somewhat arbitrarily. Below are the likelihood ratio, the Akaike information criterion, and the Schwarz information criterion for lag lengths of two through five using the three exogenous variables that we found to most improve the fit: the price of oil, the Gulf War dummy and the rate of inflation.

Table 2
VAR Lag-Length Determination

Lag-Length	2	3	4	5
Log Likelihood	-1230.948	-1221.168	-1207.961	-1190.867
Akaike Information Criteria	13.857	13.925	13.955	13.943
Schwarz Criteria	14.385	14.614	14.809	14.958

Because each of the gasoline price series is integrated of order one, we can test the number of cointegrating relationships between them. Using the VAR with 4 lags (that which maximizes the Akaike Information Criteria), we test the number of cointegrating relations using Johansen's method. Here we assume that the cointegrating relation contains constants but no trends, although the data can contain linear trends.

[36] If we were to find that all the price series were stationary, then all linear combinations of them would also be stationary, so a cointegration exercise would be inappropriate. If all the price series were stationary, classical regression techniques would be appropriate.

Table 3
Cointegrating Vectors

Eigenvalue	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value	Hypothesized No. of CE(s)
0.104479	47.50169	29.68	35.65	None **
0.086557	27.74918	15.41	20.04	At most 1 **
0.062453	11.54347	3.76	6.65	At most 2 **

** indicates rejection of hypothesis at 1% level.

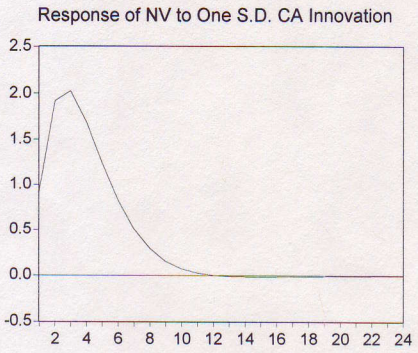
We find that there are 3 cointegrating vectors between the price series. This means that if one knows the values of the exogenous variables, then the equilibrium relationship between the three state's prices is a point in three-space. At each equilibrium point, the difference in price between, say, California and Nevada is the same. Why did we get this result? There are two alternative explanations. First, the Johansen's test statistics are constructed assuming no exogenous variables. The other explanation is that the non-stationarity in the price series is caused by "non-stationarity" in the non-stochastic exogenous variables. If one test whether there are any cointegrating relationships between each price series individually and the exogenous variables, one find that there may be one cointegration vector in each of the three VARs.

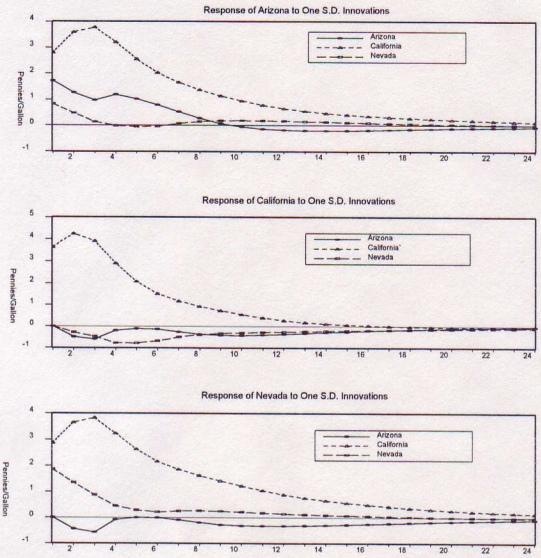
If there exist cointegrating relationships between the endogenous variables so that deviations from equilibrium never wander away from zero, then there must be an error correction mechanism that brings the prices back to equilibrium. A vector autoregressive system in error-correcting form ("VECM") can be written as:

$$(2) \quad \Delta x_t = \sum_{i=1}^{k-1} \Gamma_i \Delta x_{t-i} + \alpha \Pi_k x_{t-k} + \Phi D_t + \mu + \varepsilon_t$$

where $\alpha \Pi_k x_{t-k}$ represents the equilibrium error in the previous period, $\Gamma_i = -I + \Pi_1 + \ldots + \Pi_i$, I = 1, … , k -1, and Π_k is the long-run "level solution." The variables D_t are centered seasonal dummies orthogonal to the constant term μ and ε_t and normally with mean 0 and covariance Ω. Thus, this equation says that the change in the each of the exogenous and endogenous variables depends largely on past changes in the variables and the previous period's equilibrium errors in the three industries. The coefficient matrix, denoted by α, represents a matrix of adjustment coefficients. One can estimate the VECM equations using full information maximum likelihood.

The graphs represent the impulse response functions of the system of prices and shows how price differentials should react to an exogenous shock in one of the price series. Impulse response functions for each series are drawn for a 24-month time horizon and show the effect on all price series from a shock to each of the prices.[37]





The vertical scale on these graphs is arbitrary. In merger analysis, a one unit shock could be interpreted as a 5% increase in price. Shock to Nevada and Arizona prices are completely arbitraged out of the system in 9 months at the most (Arizona shock affecting Arizona prices) and more typically are gone after 4 months. Shocks to California take more time to dissipate. When these graphs are constructed with error bars, zero come within the margin of error after 8 months when looking at the impulse response function of California shocks to California prices. These results suggest that if firms in California were to collectively raise prices by 5%, it would be eroded almost completely within one year by arbitrage.

Conclusion

The methodology proposed by Wu & Wu to empirically define markets is a natural fit for market definition under the *Merger Guidelines*. For a properly defined market, it is necessary to show that prices can be increased in a sustainable manner over equilibrium competitive levels to demonstrate anticompetitive effects under the *Guidelines*. The Wu & Wu methodology complements more traditional market definition approaches by moving the debate about the measurement of the intensity of competition away from a competitive effects discussion and towards a market definition exercise. This front-loading of the analysis of an acquisition is likely to achieve more accurate predictions of market effect and

[37] These graphs depend on the ordering in which shocks are transmitted through the system. In this analysis, we assume shocks first affect California, then Nevada and lastly Arizona.

thereby minimize costly investigations arising from the *Guidelines'* inherent tendency to find overly narrow markets. Contrary to the Federal Trade Commission's consent in the Exxon-Mobil matter, we find no evidence that supports the hypothesis that California constitutes a separate market for gasoline from its neighboring states because of environmental or any other reason.

The Wu & Wu model can be used in fields other than antitrust where market definition is important. For example, in international trade matters, economists look at how changing trade patterns can affect profits, employment, prices and welfare in other countries. Much of this analysis boils down to whether these countries constitute separate geographic markets in different industries. In both general and partial equilibrium approaches to trade issues, analysis requires an estimate of cross-price elasticities of substitution between imported and domestic goods. If these elasticities are parameters in a system of inter-related products, the price of which are non-stationary, an approach such as this must be used.

In intellectual property disputes, estimating damages from infringement requires finding a plausible "but-for" alternative where the patent holder would retain its monopoly right to use a patent. Losses are in direct proportion to the rightful owner's being able to exploit that market power and raise prices over the current level. This, in essence, requires a market definition exercise to determine how easily products produced under infringed patent are arbitraged by alternative products. The Wu and Wu methodology can be used to measure the interaction between different product life cycles as well as looking in the price domain and can do so with more rigor than a visual inspection of the data.