Is the World Oil Market "One Great Pool"? A Test

A.E. RODRIGUEZ and
MARK D. WILLIAMS

In a recent paper Professor Robert Weiner has argued that crude oil markets are "regionalized," thus challenging Adelman's assertion that the world oil market is homogeneous. This argument bears on the effectiveness of various energy policies. We argue that these policies should be analyzed using constructs such as "antitrust markets," rather than in relation to an ad hoc definition of regionalization like that used by Weiner.

Using our definition of markets, we find that observed market behavior suggests different policy prescriptions. In particular, Weiner implicitly defines his markets too narrowly and this leads him to conclude that markets are regional. Patterns of trade in particular crude oils may not indicate regional market power. As a result, one can question the effectiveness of policies such as tariffs on imported oil.

Dans un récent article, le Professeur Robert Weiner argumentait que les marchés du pétrole brut étaient "régionalisés," défiant ainsi l'assertion de Adelman selon laquelle le marché mondial du pétrole serait homogène. Cet argument a une incidence en matière d'efficacité de diverses politiques énergétiques. Nous argumentons que ces politiques devraient être analysées à l'aide de constructions telles que celles des "marchés anti-trust," plutôt qu'en relation à une définition de la régionalisation adaptée aux circonstances comme celle utilisée par Weiner.

En utilisant notre définition des marchés, nous constatons que les observations sur le comportement du marché suggèrent le recours à des politiques différentes. En particulier, Weiner définit implicitement ses marchés de manière trop restreinte ce qui l'amène à conclure que les marchés sont régionaux. Les modèles d'échanges commerciaux, en particulier ceux du pétrole brut, n'impliquent pas forcément une influence du marché régional. En conséquence, on peut se poser la question de l'efficacité de politiques telles que celles des barrières douanières sur le pétrole importé.

Armando Rodriguez and Mark Williams are economists with the US Federal Trade Commission in Washington.

Opinions expressed in this paper are the authors' and are not necessarily those of the Federal Trade Commission. The authors thank Robert P. Rogers, Malcolm Coate and two anonymous referees for helpful comments on this paper.

1. Introduction

Adelman (1984a) argues that the world oil market behaves as "one great pool," where changes in market conditions in one area quickly affect other geographic areas. We believe that this view is held by most petroleum economists.[1] In a recent paper, Professor Robert Weiner (1991a) argues, to the contrary, that the world's oil markets are "regionalized," and changes in supply or demand amongst the participants in a limited geographic area do not fully "register" in other geographic markets.[2] Weiner claims that his views are consistent with the implicit views of policymakers who advocate national oil stockpiles, distinctions between "secure" and "insecure"

1/ For instance, Hogan (1983, pp. 49-50) notes that, "The essential international character of an oil stockpile derives from the inherent fungibility of oil in the world oil market. Net inventory transactions in any country are intended to translate into net changes in the demand for imports, which realigns the availability of oil for all consumers; hence, the use of an oil stockpile anywhere affects supply everywhere."

2/ See also Mossavar-Rahmani, 1988.

sources of supply and programs of supplier diversification.

In his reply, Adelman (1992) correctly points out that Weiner's argument regarding "regionalization" is tautological. Weiner *defines* regionalization as a lack of substantial transactions (involving specific crudes) between differing geographic locations. He finds that he rarely observes these transactions and concludes that he has shown regionalization. He does not show why his concept of regionalization is important in the analysis of policy.

Why should "regionalization" matter? We argue that regionalization in a policy context is only important if it gives rise to market power.[3] If so, regionalization may be best analyzed under the "antitrust product and geographic market" construct described in the newly revised *Horizontal Merger Guidelines* (1992). An antitrust product and geographic market is defined as the smallest group of products and the smallest geographic area over which sellers could cause a significant and nontransitory price increase.[4] Weiner appears to argue the consequences of regionalization but fails to submit his arguments to the scrutiny of a rigorous antitrust analysis. Put differently, Weiner fails to adequately differentiate between economic markets and antitrust markets, which are identical only occasionally.

By artificially defining product markets[5] too narrowly as individual types of crude oil, Weiner finds as an artifact in his data that geographic markets are small as well. Even after discounting some of the problems with his data analysis, his results can have different explanations than different regions being in different geographic markets.

This paper attempts to explore empirically this debate over the proper geographic characterization of crude oil markets. One approach (and the approach we shall use) asks whether prices at different locations are "co-integrated." Co-integration, along the lines suggested by Engle and Granger (1987), Johansen (1988; 1991) and Johansen and Juselius (1990), tests whether time series (prices) that are each non-stationary track each other sufficiently well that some linear combination of these series is stationary. If two non-stationary series are co-integrated, in essence, these series cannot get "too" far apart. The estimated weights in the linear combination of the co-integration may be used to evaluate long-run equilibrium responses between the non-stationary series.

We test whether individual crude oil markets are segmented by asking whether a linear combination of crude oil marker prices is stationary. Our data are monthly spot prices for several crude oils in 1982-1992. The results we obtain provide strong support for co-integrated markets. We find that crude oil markets are not regional and, by implication, support Adelman's assertion that the world oil market acts as "one great pool."

The following section discusses the distinction between economic and antitrust markets and demonstrates that Weiner's concept of "regionalization" must be based on antitrust markets to have policy importance. In section 3, we discuss Weiner's empirical results. Sec-

3/ By market power, we mean the ability of a buyer or seller to affect the price of the good rather than act as a price-taker. For example, this buyer or seller could be government rather than a company. By market power, we do not necessarily mean monopoly power.

4/ Stripped to its bare minimum, this paper discusses whether individual crude oils in any given region constitute an antitrust market. In determining the potential for market power, an economist first finds an appropriate antitrust market and then analyzes its structural characteristics, such as concentration and ease of entry. An anonymous referee noticed correctly that we do not address whether oil producers have global market power. Our market analysis, by itself, is unable to distinguish whether such global market power exists. Clearly, it is possible that, even if the world's oil supply acts as one great pool, a cartel might be able to raise prices. This paper, on the other hand, only examines whether individual crude oils constitute separate markets and, by implication, this gives rise to regional antitrust markets.

5/ "Product market" is antitrust jargon referring to the set of goods in an antitrust market. In this paper, we refer to downstream oil products as "distillates."

tion 4 discusses the relationship between market definition and its policy implications. In section 5, we test Adelman's proposition that the world oil market is "one great pool." We then provide conclusions and policy implications.

2. Regionalization and Geographic Antitrust Markets

Although not stated explicitly by Weiner, we assume that concern over increasing "regionalization" in crude markets arises due to concern over the effectiveness of various regional policy prescriptions because of the ease or difficulty of the exercise of market power by groups of buyers or sellers in an isolated geographic region. Only because of this can we conceive of the concept of "regionalization" having any policy importance. For example, the drawdown of a national strategic oil stockpile may be most effective in response to an adverse supply shock if the owner of that stockpile, in fact, has regional market power and can effectively change the price of crude in the country. Similarly, the potential for anticompetitive collusion between suppliers to a region exists only if the sellers enjoy sufficient market power so that they can increase prices without inviting demand or supply-side substitution.

Weiner's discussion of "regionalization" brings up questions posed by economists trying to define "antitrust markets" versus "economic markets." These two methods of defining markets generally lead to the inclusion of differing firms. Unless it includes the notion of market power, regionalization is unimportant in the analysis of many energy policies. Indeed, we believe that Weiner had antitrust markets in mind (not economic markets) when framing (but not defining) his concept of regionalization.

Economic markets are defined as groups of buyers and sellers that trade a product such that prices tend to equalize. If suppliers do attempt to raise prices in an *economic* market, suppliers that are currently only in other geographic areas may find it profitable to sell in that market at the new prevailing prices. As Stigler and Sherwin (1985) have shown, different regions can affect each other without there necessarily being any physical trade between them, and, as such, they would be in the same antitrust geographic market.

Price increases are an integral component of antitrust market analysis. In defining *antitrust* markets, an economist asks whether a hypothetical monopolist can profitably raise price by a small amount into the foreseeable future. If the price increase causes previously potential suppliers to enter the market, than these potential supplies are formally included in the market. If purchasers will instead buy substitute products, these products are also included in the market. Only by using antitrust market analysis can Weiner's concept of regionalization help judge the effectiveness of various regional energy policies.

An antitrust market must be defined with respect to both consumers and producers. If sufficient end use consumers can shift to alternative goods — e.g., directly imported distillates — to prevent crude suppliers from exercising market power, then crude does not represent an antitrust market. The supply response is equally important. If other suppliers from differing regions can quickly and profitably divert sufficient capacity to the region suffering the price increases, then these potential importers must be included in the market. In either of these cases, the valid antitrust market is probably larger than "crude from the current suppliers."

Note that the above discussion was in terms of *crude*, implicitly recognizing crude to be the product market. However, Professor Weiner implicitly advances even narrower, less plausible, markets by examining the prices of individual crudes. In other words, he implicitly assumes that Isthmus, Bonny Light, Saudi Light and other crudes are *distinct* antitrust product markets.[6] Since there is a great degree

6/ Much economic theory assumes markets of homogenous goods, something we rarely see. Often goods have varying degrees of substitutability. The degree of market power that individual crude oil suppliers in a region possess

of substitutability between crudes, it is erroneous to advance an empirical claim on the implicit assumption of such narrow individual crude markets.

3. Weiner's Empirics

To prove the notion of increased "regionalization," Weiner relies primarily on an approach employed by Spiller and Huang (1986). This latter approach is but one of a number of methods that rely on price information to empirically determine markets.[7] However, Weiner makes several mistakes in the implementation and the interpretation of the econometric results.

Since Weiner arbitrarily chooses regions as potential geographic markets, market-defeating arbitrage can occur from either outside or within the regions. Price-equalizing arbitrage can proceed from other regions besides those binary combinations analyzed by Weiner. For example, even if the price differential between Northern Europe and the East Coast of the US is sufficiently enticing for arbitragers to divert crude from Northern Europe, the gap may be even more enticing for arbitragers diverting South American, North African, Texas, or Canadian crude.

Weiner's analysis inexplicably studies the binary region combinations in terms of *specific* crudes. Crudes are substitutes for each other. Thus, one could conclude from Weiner's results that even though Mexican Isthmus might not be arbitraged by Mexican Isthmus, it is possible that Brent or Saudi Light or any number of comparable-quality crudes may be used to profitably close the gap. To correct this problem, Weiner should have included all substitutable crudes in his regressions.

Furthermore, Weiner's results indicate that transportation costs as percentages of the receiving regions' prices do not fall within the conventional grounds used in defining antitrust markets.[8] For example, the average transportation cost of moving Mexican Isthmus from Northern Europe to the US is 1.15 US$/bbl. According to Weiner's database,[9] the average landed cost of Isthmus in the US is 28.90 $/bbl. Clearly, a 5% price increase in the US price would make arbitrage likely. A similar calculation for Saudi Light suggests that transactions costs are approximately 6% of the landed costs of that particular crude. This suggests that while Saudi Light might not be used for arbitraging a 5% increase in US Saudi Light prices, other crudes, particularly Mexican Isthmus, certainly can. Thus, it is unlikely that any regional supplier could, unilaterally, profitably impose a price increase on a consuming region.

4. Policy Implications of Regional Markets

Weiner recognizes that if world oil markets are regional, then national strategic petroleum

---

is affected by the availability of good substitutes for Isthmus, Bonny Light, etc. An antitrust economist, trying to get a handle on which goods are "better" substitutes, starts by identifying the minimum set of crude oils and the smallest region over which a (hypothetical) monopolist could profitably and significantly raise prices. The (arbitrary) benchmark used by US antitrust agencies for a significant price increase is 5% or 10%.

7/ See Uri, Howell and Rifkin (1985), Baker (1987), and references therein.

8/ Prices in individual crude markets will seldom differ exactly by the transportation costs between them for various reasons. First, transportation costs are not uniquely defined over time. Second, in the absence of perfect foresight, stochastic shocks to demand and supply create divergent, temporary price movements even within the same market. Third, it is not uncommon for distillate prices movements to affect crude pricing. Fourth, differences in quality mix for a variable quality crude or compounded crudes, as well as factors such as credit risks, quantity discounts, inventory stocks, and seasonal variations can cause price differences and, hence, imperfect correlation of prices even in highly efficient markets. See Hay, Hilke and Nelson (1988).

9/ The data can be found in the working-paper version of the paper (Weiner, 1991b). Professor Weiner kindly provided us with a copy.

reserve (SPR) policies are more likely to be effective since the owner of the oil stockpile will have greater market power to change prices domestically.[10] If world crude markets are integrated, why would countries or regions rationally set up SPRs? One objective of SPRs is to allow consuming countries to cope with unforeseen interruptions in supply in times of national emergency. Clearly, inasmuch as reductions in supply force price rises, stockpiled crude will temper peaks in prices (Plummer, 1981; Mork, 1982).[11] Another reason is that the purchase of oil for the SPR provides countervailing buyer power against perceived global producer market power.

Weiner believes that crude-supply diversification policies are ineffective unless markets are regional. For example, the efforts of many oil importing countries to seek special arrangements for secure supply "makes no sense if the world crude market is integrated (Weiner, 1991a, p.95)." In addition, a policy of diversifying suppliers, practiced by many importers now, is "senseless in a globally unified market (Weiner, 1991a, p.95)." In our belief, a policy of supplier diversification may be rational even if the market is unified. Customers diversify to reduce the risk of costly supplier strategic behavior or just bad luck. Indeed, by purchasing inputs from a variety of suppliers, the firm or country can diversify away some of the price risk associated with satisfying demand exclusively from the single least-expected-cost supplier.[12]

It seems to us that the deliberate US policy to purchase oil from "secure," rather than "insecure," suppliers does not require as a precondition that the world's crude markets be regional. The policy, based on geopolitical considerations, was devised to reduce other countries' incentives to take unwanted unilateral strategic actions (IEA, 1983). In addition, regional energy integration may be the result of national oil companies' recent vertical integration attempts (Olorunfemi, 1991).

5. Our Empirics

We could, of course, redo Professor Weiner's empirics using spot prices and broader crude oil markets. We will however directly test Adelman's implicit claim of a worldwide crude oil market. Formally, we will show that a relevant antitrust product market is no narrower than crude oil and the appropriate geographic market is the world. In assessing whether buyers or sellers have market power in specific geographic regions, we do not show whether our relevant market behaves monopolistically. Rather, we only test a necessary precursor to regional market power, that a relevant market definition is regional. Our burden — market definition — is less onerous than that of Weiner, who must not only establish regional product markets, but also must

---

10/ For example: "An important concern regarding SPR drawdowns is that most of the benefits will spill over to the other oil-importing nations. The more regionalized is the world market, however, the smaller will be the spillover effects of SPR releases on the other regions and, in consequence, the greater will be the price reduction at home (Weiner, 1991a, p.96)."

11/ The effectiveness of strategic oil stockpiles has not been tested even though the world has experienced two major oil supply disruptions since the establishment of the International Energy Agency in 1974.

12/ Wolak and Kolstad (1991) find empirical support for arguments suggesting that firms trade off expected input cost against its variability (risk) in selecting the optimal input supply mix. Their model is applied to the Japanese steam-coal import market, but they contend that such producer behavior is characteristic of any industry in which a large portion of variable costs is taken up by a single homogeneous factor of production. Crude oil refining is such an industry.

Paradoxically, concern over global market power may lie behind a *deliberate* policy of regionalizing purchases. In 1990, Presidents Salinas of Mexico, Gaviria of Colombia and Perez of Venezuela called for the formation of a Western Hemisphere Energy Community. A US Department of Energy study was favorable because the formation of a group was believed to enhance energy security through the reliance upon more secure sources of crude oil (Bailey and Zoakos, 1992; 1993).

show that the players in that market enjoy market power.

We attempt to show that arbitrage precludes any possible price divergence between different types of crude oil and different geographic regions because of the significance of spot market transactions and the common linking of prices to those of "marker" crude oils. The oil industry has historically used spot transactions in the crude oil market, but it wasn't until 1983 that spot and spot-related trade began to grow appreciably. In 1985, the spot market accounted for 80-89% of internationally traded oil (Razavi, 1989). Various mechanisms have been used to tie the price of all crude oil to prevailing spot prices. These mechanisms include countertrading, netback pricing, discounts and premiums, and, increasingly more popular, formula pricing (Razavi, 1989; *PIW*, 1990). New commercial "marker" crude oils, West Texas Intermediate (WTI), Brent blend (Brent), Alaskan North Slope (ANS), and Dubai's Fateh (Dubai) crude, have emerged that reflect market conditions more realistically than Saudi Light, once the premier high-volume crude oil.

We will establish that the prices of these "marker" crude oils tend to track each other. Because these crude oils are produced in various locations throughout the world, this will suggest that the geographic markets for crude oil are not regional. Consider the following example, which illustrates this intuition. Suppose the WTI-Brent price differential in the United States increases from its equilibrium level. In Weiner's analysis, arbitrage would return the differential to its equilibrium only if Brent flowed to its now higher valued use in the US. However, because the prices of several other crude oils are linked to the WTI, Brent and other "marker" prices, we do not believe it is necessary that the equilibrating arbitrage be in Brent oil. The price of Mexican Isthmus, linked by formula both to Brent and to WTI, will reflect the change in the price differential and may provide the arbitraging flow. The possibility of arbitrage through other crude oils suggests that the system of "marker" prices reflects a long-term equilibrium relationship between crude oils. Since most crude oils are linked by formula to "markers," we will show that the world crude oil market is "one great pool" by showing a long-term relationship between "marker" crude oil prices.

We do not wish to suggest that the product market is limited to crude oils. Indeed, the increasing international trade in crude-oil products, from avgas to asphalt, keeps differing crude oil prices from getting out of whack.[13] Trade in finished product will pressure crude oil prices as refiners or distributors, perhaps encountering a limited supply of gasoline required to meet contractual obligations, may purchase finished product rather than process additional crude oil. Conceptually, this trade in finished products serves to highlight the linkage between crude oil prices, including "marker" crudes, but finished products are linked to crude oils in a physical sense rather than via a pricing formula. Because finished products are substitutes with crude oils for some consumers, it may be appropriate to include them in our product market definition.

Furthermore, crude oils and its finished products are storable goods. Inventories can limit short-run price changes not reflecting long-run supply and demand conditions. Intertemporal arbitrage may suggest that the product market includes not only the production of crude oil, but that inventoried as well.

The data we use are monthly spot prices spanning from January 1982 to December 1992 of four high-volume "marker" crude oils available: WTI, Brent, ANS, and Dubai. We obtained Brent and Dubai prices for the time period January 1982-December 1990 from the Department of Energy. These two series were later updated to December 1992 from the *Oil*

13/ For example, between 1982 and 1990 avgas imports increased by a factor of 4: from 29,000 bbls/day in 1982 to 108,000 bbls/day in 1990; similarly gasoline imports increased from 197,000 bbls/day in 1982 to 342,000 bbls/day in 1990 and increase of almost 75%. By comparison, crude oil imports increased from 3.5 MM bbls/day to 5.9 MM bbls/day, an increase of 69% over the same period (EIA, 1992).

Daily. The ANS and WTI series were provided by the State of Alaska Department of Revenue. Although most of series are available back to 1971 we started our sample in January 1982, when the spot market expanded significantly (Razavi, 1989).[14] To compare prices over time, we first deflated all prices by a US GDP deflator[15] and then logged.

Using a test proposed by Stigler and Sherwin (1985) that quantifies the sensitivity of prices between crude oils as a correlation coefficient, one can test whether crude oil markets are regional. Weiner also used this test, but in terms of implausibly narrow product markets. Several authors have criticized this correlation approach because it implicitly assumes that supply and demand shocks are specific to individual regions.[16] However, this test allows us to reject Weiner's implicit conjecture that prices in regional markets are uncorrelated.

Table 1 shows our sample correlation matrix for the monthly changes in the logarithms of the real spot prices for "marker" crude oils (i.e., the monthly growth rates of prices).

For each pair of crude oils, one can reject the null hypothesis of no correlation[17] at the 5% level.[18] Similarly, one can reject the hypothesis that these "marker" crude oil prices are jointly uncorrelated.[19]

While it may not be unreasonable to rely exclusively on price correlations to define markets, one can further buttress one's empirics by testing whether sets of prices are co-integrated. If one finds that two price series are co-integrated, then a long-run equilibrium relationship between these prices can be found. Rather than test for co-integration between binary sets of price series, we use the approach suggested by Johansen (1988) to test whether our four "marker" crude oil price series have a joint long-run relationship.

In a world with no transportation or transactions costs or quality differences, perfect, but not instantaneous, arbitrage would lead the prices of differing crude oils to equalize throughout the world. In such a world, for example, the price (in logs) of WTI would be equal to the price of Brent:

$$P_{WTI} - P_{Brent} + \mu_t = 0$$

where μ_t is a zero mean stationary process.

Table 1: *Correlation of Changes in the Log of Monthly Marker Crude Prices (January 1982 — December 1992)*

	Brent	*Dubai*	*ANS*	*WTI*
Brent	*1.000*			
Dubai	*0.904*	*1.000*		
ANS	*0.903*	*0.916*	*1.000*	
WTI	*0.900*	*0.896*	*0.949*	*1.000*

14/ Until 1985, most of the world's traded oil was supplied under long-term contracts between state-owned exporting companies and major oil companies or other large refiners. These contracts, which were adjusted infrequently, were typically for fixed quantities at the OPEC official price. Then, the spot market was very thin, serving mainly to adjust for unseen imbalances (Hubbard and Weiner, 1989; Razavi, 1989).

15/ We filled out the monthly GDP deflator series by interpolating between published quarterly GDP deflator figures using monthly changes in the CPI series.

16/ See Baker (1987) and references therein.

17/ Obviously, it is difficult to determine what level of correlation between prices indicates that the products are strong enough substitutes to be in the same market. Some authors have argued that a positive correlation of 0.5 or higher is consistent with qualitative statements that indicate that products are in the same market (Cartwright *et al.*, 1989).

18/ One would reject the null hypothesis using an asymptotic likelihood ratio test if the sample correlation is greater than 0.112.

19/ See Pyndick and Rotemberg (1990) for the asymptotic likelihood ratio test to determine whether the sample correlation matrix is significantly different from an identity matrix. The ratio of the restricted to the unrestricted likelihood function is $\lambda = |R|^{N/2}$, where $|R|$ is the determinant of the sample correlation matrix. The test statistic, $-2\log\lambda = 806.2$, is distributed chi-square $(1/2)p(p-1) = 6$ (where p is the rank of the correlation matrix) under the null hypothesis.

However, given general transportation costs, quality differentials and market imperfections as well as possible measurement error, it is unlikely that an estimated relationship between the two price series will have a common coefficient of one. We, in fact, estimate a more general relationship between prices (in logs):

$$\beta_1 P_{WTI} + \beta_2 P_{Brent} + \beta_o = \mu_t$$

One would expect that if the two crude oils were in the same market then such a stable relationship between prices would exist and μ_t would be stationary. If we find this is so, the variables are co-integrated. Given that μ_t is a random, but stationary, variable, if two or more variables are co-integrated, they must be in a long-run equilibrium relationship from which they may substantially diverge in the short run. Our prior expectation is that all four series will be co-integrated (with three co-integrating vectors).

First, one should test whether each series is stationary and does not have unit roots. If a series had unit roots, then a shock to P_t would have permanent effects. If one found this, it would indicate that if this same shock did not have a similar effect for a different crude oil, then these crude oils would be in different markets. If one finds that the individual price series are non-stationary, then a test for co-integration indicates whether the crude oils are in the same market. In fact, we cannot reject that each series has unit roots and is first order integrated.[20]

We then test how many co-integrating vectors we have between the four "marker" crude oil price (in logs) series. We find that there are three of these vectors, which suggests that all four series are interrelated with each other.[21]

Both our correlation and co-integration results suggest that there is an equilibrium long-run relationship between the prices of "marker" crude oils, most likely due to arbitrage. This supports Adelman's conjecture that the world crude oil market behaves as "one great pool."

6. Conclusion

We challenge Professor Weiner's notion that crude markets are regional and act not as "one great pool." By drawing clear parallels between the concept of regionalization and antitrust markets we show that (a) because of Weiner's flawed methodological and empiri-

20/ We used an Augmented Dickey-Fuller ("ADF") test (Dickey and Fuller, 1979, 1981).
ADF statistics:

Crude	Levels	First Differences
Brent	-2.5	-9.8*
Dubai	-2.3	-7.9*
ANS	-2.4	-8.0*
WTI	-2.3	-8.0*

* 5% statistical significance
Asymptotic Critical Value at 5% level: $\tau^* = -3.41$
Source: Davidson and Mackinnon (1993), Table 20.1.

21/ Since we have four price series, we use the general methodology of Johansen and Juselius (1990) to identify and estimate a vector autoregression (VAR) system rather than use the Engle and Granger (1987) approach, which tests for unit roots in the estimated residuals from pair-wise regressions. First we need to determine how many lags to include in our estimation. Both the Akaike Information Criterion (AIC) and the Schwartz Criterion (SC) suggest that the appropriate order for our VAR system is 4 months. Using the Johansen and Juselius (1990) testing sequence, we find, and show below, that, at the 5% significance level and as we expected *a priori*, there are three co-integrating relationships between the price series.

Likelihood Ratio Tests On The Number of Co-integrating Relationships

Null Hypothesis	-2ln(Q)	Fractiles		
		0.90	0.95	0.99
$r \leq 3$	0.08	6.69	8.80	11.58
$r \leq 2$	41.50	15.58	17.84	21.96
$r \leq 1$	65.86	28.44	31.26	37.21
$r \leq 0$	210.30	45.25	48.42	55.55

Source: Johansen & Juselius (1990), Table A.2.

cal approach, it is not clear that crude oil markets are, in fact, regional, and, (b) policies that seem, at first glance, to require regional markets to be effective, may be explained even if the world oil market is unified. Indeed, using Johansen's (1988) methodology to estimate co-integrating relationships, we have provided strong evidence in support of Adelman's conjecture of homogenous world oil markets.

The homogeneity of crude-oil markets may have implications for recently proposed policies like a US oil import tariff (*Business Week*, 1993). Assuming the free-trade agreements with Canada and Mexico preclude taxes on either Mexican or Canadian crude but not on other imports, then an American oil import fee is unlikely to raise substantial amounts of revenue nor decrease US reliance on foreign oil. If the world crude oil market acts as "one great pool," then a tax on only a portion of imports will only lead to the replacement of current foreign crude oil suppliers by others. Unless the tax is accompanied by some means of deterring this arbitrage in both crude oil and finished product, Mexico, Canada or any number of domestic traders will face substantial incentives to divert nontaxable oil to the United States.

Obviously, the substantial interest generated by Professor Weiner's work is topical and crucial. Researchers should continue to look at the growing tendency towards regional energy integration, the reasons for it, and what this may imply. In our view, economic constructs found in antitrust analysis can substantially contribute to enacting this research agenda.

References

Adelman, M.A. (1992) 'Is the World Oil Market 'One Great Pool'?—Comment,' *The Energy Journal*, 13:1:157-58.

—(1984a) 'International Oil Agreements,' *The Energy Journal*, 5:1:1-9.

—(1984b) 'Sense and Nonsense about World Oil,' *The Energy Journal*, 5:1:169-71.

Bailey, Norman and Criton M. Zoakos (1992) 'Oils Well That Ends Well,' *The International Economy*, March/April, pp.55-58.

—(1993) 'An American OPEC,' *The International Economy*, March/April, pp.50-51.

Baker, Jonathan B. (1987) 'Why Price Correlations Do Not Define Antitrust Markets: On Econometric Algorithms for Market Definition,' Working paper No.149 (Washington: Federal Trade Commission).

Business Week (1993) 'Which Energy Tax?' February 8, 28-29.

Cartwright, Phillip A., David R. Kamerschen, and Mei-Ying Huang (1989) 'Price Correlations and Granger Causality Tests for Market Definition,' *Review of Industrial Organization*, 4:2:79-98.

Davidson, Russell and James G. Mackinnon (1993) *Estimation and Inference in Econometrics* (New York: Oxford University Press).

Dickey, D.A. and W.A. Fuller (1979) 'Distribution of the Estimators for Autoregressive Time Series with a Unit Root,' *Journal of American Statistical Association*, 74:366:427-31.

—(1981) 'Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root,' *Econometrica*, 49:4:1057-72.

Energy Information Administration (1992) *Petroleum Supply Annual 1991* (Washington: Energy Information Administration) June.

Engle, Robert F. and C.W.J. Granger (1987) 'Co-integration and Error Correction: Representation, Estimation and Testing,' *Econometrica*, Vol.55, pp. 251-76.

Hay, George, John C. Hilke and Philip B. Nelson (1988) 'Geographic Market Definition in an International Context,' *Chicago-Kent Law Review* 64:3:711-39.

Hogan, William W. (1983) 'Oil Stockpiling: Help Thy Neighbor,' *The Energy Journal*, 4:3:49-71.

Horizontal Merger Guidelines (1992) Issued by the U.S. Department of Justice and the Federal Trade Commission, April 2.

Hubbard, R.G. and R.J. Weiner (1989) 'Contracting and Price Adjustment in Commodity Markets: An Application from Copper and Oil,' *Review of Economics and Statistics*,

Vol.71, pp.80-89.
International Energy Agency (1983) *International Energy Agency* (Paris: IEA).
Johansen, Soren (1988) 'Statistical Analysis of Co-integration Vectors,' *Journal of Economic Dynamics and Control*, Vol. 12, pp.231-54.
—(1991) 'Estimation and Hypothesis Testing of Co-integration Vectors in Gaussian Autoregression Models,' *Econometrica*, Vol.39, pp.1551-80.
Johansen, Soren and Katarina Juselius (1990) 'Maximum Likelihood Estimation and Inference on Co-integration—With Applications to the Demand for Money,' *Oxford Bulletin of Economics and Statistics*, Vol.52, pp.169-210.
Mork, K.A. (1982) 'The Economic Cost of Oil-Supply Disruptions,' in J.L. Plummer (ed.) *Energy Vulnerability* (Cambridge, MA: Ballinger).
Mossaver-Rahmani, Bijan (1988) 'Oil Prices and the Oil Supply Chain,' in B. Mossaver-Rahmani (ed.) *Lower Oil Prices: Mapping the Impact*, Harvard International Energy Studies No. 4 (Cambridge MA: Energy and Environmental Policy Center).
Olorunfemi, Michael A (1991) 'The Dynamics of Oil Companies,' *OPEC Review*, Winter, 321-33.
Petroleum Intelligence Weekly (1990) Special Supplement Issue, January 29.
Pindyck, Robert S. and Julio Rotemberg (1990) 'The Excess Co-Movement of Commodity Prices,' *The Economic Journal*, Vol.100, December, pp.1173-89.
Phillips, P.C.B and Pierre Perron (1988) 'Testing for a Unit Root in Time Series Regression,' *Biometrika* 75:2:335-46.
Plummer, J. (1981) 'Policy Implications of Energy Vulnerability,' *The Energy Journal* 2:2:25-36.
Razavi, Hossein (1989) *The New Era of Petroleum Trading: Spot Oil, Spot-Related Contracts, and Futures Markets*, World Bank Technical Paper No. 96 (Washington: World Bank).
Spiller, P.T. and C.F. Huang (1986) 'On the Extent of the Market: Wholesale Gasoline in the Northeastern United States,' *The Journal of Industrial Economics*, 35:2:131-45.
Stigler, G. and R. Sherwin (1985) 'The Extent of the Market,' *Journal of Law and Economics*, Vol.28, pp.555-85.
Uri, Noel D., John Howell and Edward J. Rifkin (1985) 'On Defining Geographic Markets,' *Applied Economics* Vol.17, December, pp.959-77.
Weiner, Robert J. (1991a) 'Is the World Oil Market 'One Great Pool?'' *The Energy Journal* 12:3:95-107.
—(1991b) 'Is The World Oil Market 'One Great Pool?': An Economic Approach to Regionalization,' Working Paper—Energy 91-1, (Cambridge, MA: Kennedy School of Government, Harvard) April.
Wolak, Frank A. and Charles D. Kolstad (1991) 'A Model of Homogeneous Input Demand Under Price Uncertainty,' *American Economic Review*, 81:3:514-38.