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METHODOLOGICAL APPROACHES FOR STUDYING THE COMPETITIVENESS OF GAS PIPELINE TRANSPORTATION

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SUMMARY

Following years of increased competition in the natural gas industry, the issue of pipeline deregulation has moved to center stage. Pipelines argue that the transportation segment has become competitive, largely because of open access in conjunction with the development of secondary markets. Pipelines make the point that while during off peak periods they are forced to discount prices for released capacity and short-term firm and interruptible service below the tariff level, during peak periods they are barred from charging prices that will recover the full market value of their services. Thus, on both efficiency and equity grounds, they support deregulation or, at the minimum, less stringent regulation of prices. The Federal Energy Regulatory Commission (FERC), on the other hand, believes gas transportation still has features, including significant barriers to entry, that render it uncompetitive and susceptible to market power abuse.

In this paper, we revisit regulatory issues concerning gas pipeline transportation. We first discuss why the issue of deregulation of gas transportation has become an issue. Second, we explain why setting prices differently for off peak and peak periods within the confines of annual rate-of-return (ROR) based tariff setting may only marginally improve economic efficiency. Third, we argue that the specter of market power abuse would be most evident during periods of peak demand. To have a last word on gas pipelines deregulation, therefore, it becomes necessary to investigate the possibility of market power abuse.

The final focus of this paper is on reviewing generic approaches for the study of the competitiveness of the transportation sector. We conclude that a transaction cost approach would be most suitable for that purpose.

INTRODUCTION

The demand for pipeline transportation is ultimately derived from the demand for natural gas in retail markets. The demand for pipeline service is more price inelastic if the service is essential and there are no good substitutes, and if the total expense for pipeline service constitutes a small portion of total delivered cost. If these conditions prevail, price discrimination and other symptoms of market power can appear. Price discrimination can also more readily occur if the market can be easily segmented and if the price elasticities of demand vary across separate markets. For example, pipeline revenues could be increased by charging a higher rate in those segments where markets are less price elastic. Actual and potential competition of other pipelines located in a given pipeline's region of operations can have a significant effect on the level of demand for its transportation services.[1] Such competition among pipelines takes two general forms: competition in rates and competition in service. Pipelines competing with holders of capacity rights represent a form of intramodal competition.

In economics, transportation costs are viewed as an intermediate cost whose price depends on the competitiveness of both the end-use market and the transportation sector itself.[2] Transportation costs have similar effects as an excise tax or a transaction cost. The degree of competition depends, among other things, on the diversity of origin and designation points for gas movements, the range of pipeline services, and flexibility in gas movements and routing. If pipelines rates are well above costs, market participants may over time find ways to do with less transportation –

[1] Intermodal competition is virtually non-existent, as pipelines are really the only economical form of gas transportation. Under the old pre-reformed gas industry, (1) a single pipeline linked fields and city gates, (2) transportation and gas were bundled, (3) gas buyers and sellers did not have access to one another, and (4) gas purchases and supplies were made under long-term contracts. Overall, gas pipeline transportation was highly monopolistic with little resemblance to a competitive market.

[2] Transport prices represent differences in prices between spot markets – without constraints and losses, the price at each spot market should equal the system marginal cost (or the marginal cost of gas in a defined market). The reason for this is that without constraints the spot price would be the same across each sub-market (i.e., the "law of one price" would apply with different locations integrated into one market); arbitrage would equate spot prices across locations; the market price equals the price where total supply equals total demand (i.e., the market price would equal the short-run marginal cost or economic value of gas at times when demand can be met with available supply).

product and location substitution, new technologies, and anything that reduces dependency on natural gas transportation would be seriously explored.[3]

This paper outlines issues revolving around the competitiveness of gas pipeline transportation. This study purposes to provide a background for an investigation into the policy question, to what extent should the Federal Energy Regulatory Commission (FERC) liberalize the pricing of interstate gas pipeline transportation? To start with, the paper briefly discusses why the issue of liberalization of pipeline pricing has gained currency lately, especially since a few years ago when FERC entertained the idea of deregulating short-term transportation services. We also discuss why the FERC 's policy, pursuant to Order 637, of allowing differentiated prices for peak and off peak demand periods within cost-of-service based tariff setting may not lead to significant improvements in economic efficiency.[4] This leads to an analysis of the conditions under which deregulation of pipeline transportation prices may be rationalized. Next, in a more formal section, we examine the existing literature to assess approaches that have been used to examine the competitiveness of gas pipeline transportation. We conclude with a proposal to study market power and its impact on gas pipeline prices during peak demand periods.

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[3] Accordingly, a constraint on the exercise of market power by pipelines includes the risk that users will reroute their shipments or create their own capacity by tying into the open grid at strategic points. For natural gas, where the share of transportation costs in the value of delivered gas is high (implying a high elasticity of demand), a principal constraint on higher pipeline rates is not diversion to other modes of transportation, but a reduction in the quantity of gas shipped.

[4] While peak and off-peak revenues combine to equal the pipeline's annual revenue requirement, FERC can improve the economic efficiency of pipeline prices in short-term and long-term markets by adopting ratemaking methods that allocate annual costs so as to set higher prices in peak periods and lower prices in off-peak periods.

REGULATORY QUESTIONS

Why Deregulation of Gas Transportation Has Become an Issue

A major issue facing FERC involves the pricing of gas pipeline service. FERC addressed this issue a few years ago in its Order 637. It concluded that interstate gas pipelines generally do not operate in a sufficiently competitive environment to warrant market-based pricing of most pipeline services. As of today, FERC still applies largely traditional cost-of-service ratemaking principles to prices of most pipeline services.[5] FERC's policy is premised on the absence of sufficient competition in most pipeline markets. FERC has allowed market-based pricing only when the pipeline applicant is able to demonstrate the lack of market power.[6] The criteria established by FERC have made it difficult for a pipeline to show this; FERC looks at two principal factors in evaluating requests for market-based rates: (1) the ability of the applicant to withhold services, thereby increasing price, and (2) the ability of the applicant to unduly discriminate in prices or terms and conditions (especially a problem when the applicant has an affiliate). In determining market power, FERC uses the conventional antitrust 3-step approach: (1) define relevant markets, (2) measure the firm's market share and market concentration, and (3) evaluate other relevant factors. FERC uses a HHI value of 1,800 as the level at which scrutiny will be given to an applicant: if the HHI is at 1,800 or above, the Commission will give the applicant closer scrutiny because the index

[5] In recent years, on a limited basis FERC has allowed pipelines more freedom in setting prices. For example FERC has permitted pipelines to depart from the straight-fixed variable (SFV) rate design as long-term contracts expire and capacity turnback increases. FERC regulations allow for price discrimination, but not what is called "undue discrimination." The Commission has allowed differences in rates by permitting pipelines to discount rates for certain services and customers; the Commission has maintained that these differences in rates are justified if a discount is necessary to meet competitive circumstances and customers are not in similar competitive positions. Thus, pipelines are expected to negotiate rates in a manner that is not unduly discriminatory and that treats similarly situated shippers equally.

[6] Where a pipeline can show lack of market power, then competition in the market would ensure that the company's rates will be just and reasonable – in this circumstance according to FERC, the goals and purposes of the Natural Gas Act are met in that any rates that would be charged would be just and reasonable, either under cost-based or market-based analysis.

indicates that the market is highly concentrated and the applicant may have market power. Up to this point in time, pipelines have rarely petitioned FERC for market-based rates.

The efforts of pipelines to liberalize pricing have met strong opposition from those who fear that lifting or even liberalizing pricing controls on most pipeline services would result in the exercise of market power, and, thus, higher prices.[7] Up to now, FERC has been reluctant to grant pipelines more discretion in their pricing, other than in selective situations dictated by competitive pressures. This policy can be questioned as inconsistent with the evolving realities of the gas marketplace where market forces may be able to provide adequate constraints on the ability of pipelines to exercise market power. At least this is the position of pipelines and some analysts.

Pipelines allege that while they are forced to discount their prices for released capacity and short-term firm and interruptible service to market levels during off peak periods, during peak periods they are barred by FERC from charging prices that would recover the full value of their services; this deprives them the opportunity to compensate for the low prices sustained during off-peak periods.[8] Also, as buyers and sellers receive wrong price signals, shippers lack the proper incentive to use alternatives like storage and fuel-switching. Consequently, a tight demand/supply situation on top of an annual price cap based regime exaggerates the problem of capacity shortage.

To elaborate, Pipelines have argued that they are in a predicament where the FERC price cap really does not apply to many of their services. Shippers have different alternatives in transporting their gas to specific delivery points. For example, many shippers can choose between short-term or long-term firm service, interruptible service, released capacity, bundled ("gray market") service, and combination of transportation

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[7] Those who argue that pipelines possess market power point to three major sources: (1) capacity not available at peak times, (2) only a small portion of new pipeline capacity is dedicated to existing markets, and (3) few competitive alternatives exist for pipeline gas.

[8] This also triggers cost shifting from interruptible to firm consumers. For a discussion see FERC Order 637.

and storage service. Several features of the market prevail to control pipeline rates; these include multi-pipeline routes to a market area, alternative fuels substituting for gas, alternative pipeline services, as listed above, promotional rates for new pipeline service, and market centers/hubs. Of course, these options vary across shippers, with some limited in their ability to substitute one of these services for another. Consequently, since price-cap revenues correspond to their cost of service, they are unable to collect sufficient revenues on an annual basis. In effect, they maintain that FERC should lift the cap so that they could receive market-based prices during peak periods, which the caps prevent them from currently doing.[9]

Pipelines refer to the example where regulated rates prevent them from raising prices to market levels under constrained capacity and where competition prevents them from charging the regulated rate during other times (i.e., they are forced to discount during off-peak periods).[10] They argue that the "basis differential" between two spot markets imposes a cap on what shippers and others are willing to pay for pipeline capacity. With FERC Order 637, holders of firm pipeline capacity can rebundle services and compete with pipelines in the short-term market but without the handicap of regulated price caps. This so-called "gray market" for gas can be described as follows. First, it should be said that the objective of the seller of bundled service is to circumvent regulation of pipeline prices. Under such a tie-in transaction, price regulation of pipelines can be evaded. An example is when commodity gas is unregulated and transportation is price regulated; the middle person (e.g. the marketer) ties commodity gas to transportation – namely, in procuring commodity gas, the buyer must also purchase regulated, under-priced transportation. In its effort to extract the full value of transportation, the marketer sells gas only under the condition that transportation is provided as well. By selling at a single bundled unregulated price, the marketer can

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[9] Eliminating price caps during peak periods remedies what economists call "allocative inefficiency." Elimination of price caps would improve economic efficiency in that it permits consumers who are willing to pay more than the regulated price during peak periods to obtain the capacity they desire.

[10] Marketers, aggregators, and off-system LDCs can take advantage by trading in pipeline capacity to capture value in short-term market swings; pipelines have argued that their ability to control their own capacity has greatly eroded over the last several years; pipelines also contend that control over their capacity has migrated to marketers, aggregators, and off-system LDCs, who are in a better position than they are to compete; finally, pipelines argue that price caps only serve to constrain them.

extract the full market value of transportation from buyers. The objective of the marketer is to evade price controls and, thereby, increase profits. Although evading regulation may not want to be encouraged, this tying does not appear to raise any serious competitive concerns.

It is argued that with the unbundling of transportation from the commodity, natural gas now trades in competitive commodity markets that are increasingly consolidating into a single unified market.[11] Also, it is argued that the commodity markets are in effect determining the value of transportation. In mathematical terms if the price of gas at the city gate is P_c, and if the price of gas at the hub is P_h, then the value of transportation of gas from the hub to the city gate is $P_c - P_h$. During peak periods, the value tends to be higher than the price cap set by FERC and during off peak periods the value tends to be lower than the price cap. In peak periods therefore, this situation tends to encourage holding of capacity by shippers, and during off peak periods sellers do not find buyers at FERC's price cap. As a consequence, pipelines find it very difficult to cover their cost of service and, understandably, are critical about the current state of restructuring. Additionally, the situation threatens to adversely impact the viability of new investment in pipelines. In view of these arguments, the matter of deregulation of pipeline prices has gained interest lately.

Setting Prices Differently for Off Peak and Peak Periods

It would seem that one of the ways to get around the problem of pipeline receiving deficient revenues is to allow pipelines to set different prices for peak and off peak periods, while still requiring pipelines to follow annual rate of return (ROR) cost-based tariff setting. This is precisely what FERC has recently allowed pipelines to do.

[11] While it is almost certain that many city gates are not competitive, it would be of great interest to ascertain whether most hubs are also competitive or not. If suppliers have market power, they may be inclined to physically withhold capacity from the market or economically withhold capacity. While in the first case units with relatively higher marginal cost get dispatched, in the second case the supplier may bid a very high for a plant or a unit to force a price much higher than the marginal cost or the unit or plant not being dispatched at all (resulting in a physical withholding of capacity). By constricting the capacity, the supplier is able to raise the wholesale price enough that for dispatched units it gets revenue that is more than what it would get if capacity were not constricted.

But, because tariffs are embedded in historical cost, pipelines' freedom to set prices to reflect the economic value of pipeline service is significantly eroded. Pursuit of economic rents as opposed to monopoly rents leads to lower distortions in prices and reflects the market's ability to move players to reveal the true value of resources and economic activities. Pipelines are allowed to set tariffs of all services such that they may not necessarily reflect the embedded cost incurred in their provision individually. The requirement that overall revenue from tariffs should just cover only the annual total costs (albeit, along with a rate of return on rate base), however, restricts severely the room for extraction of economic rents, which necessarily are results of a wedge between the cost of service for infra-marginal pipelines and the value that consumers put on that service. By not allowing pipelines to garner more than normal profits, cost-based tariffs essentially clip the desirable incentive of a pipeline to pursue economic rents. Consequently, it may well be true that allowing pipelines to charge rates differently for peak and off peak capacity, provisioning within the framework of annual ROR based tariff setting, would have little effect on improving economic efficiency.

Viability of Deregulation

We have of course skirted an important issue in the above discussion. While there are good reasons to believe that wellhead gas supply is highly competitive, we ought to examine whether prices at the city gates reflect the workings of a competitive market. If the market at a city gate were actually highly competitive, any attempt by a shipper to withhold pipeline capacity to increase the city gate price would induce other competitors (other capacity holders in the same pipeline or other pipelines) to crowd out such a shipper. Thus, if indeed the market at a city gate were highly competitive, shippers would have little incentive to withhold capacities.[12]

It goes without saying that if a city gate is indeed competitive and wellheads are operating in a competitive market, the entire wedge between the supply price at the

[12] It would still be true that given the regime of price caps, price signals would be wrong and resources would be inefficiently used. While it may be socially more desirable to have more pipelines, the price cap regime would tend to discourage their construction.

wellheads and the price at the city gate would be the value attached to transportation service. Thus, any attempt by a pipeline to restrict its capacity to raise the price at the city gate would be futile as buyers would switch suppliers and would never pay more than the value of transportation.[13] Thus, a highly competitive situation, at both the wellhead and city gate, would be conducive to complete deregulation of pipeline services.

The real issue is, how do we know whether a particular pipeline is a good candidate for deregulation or not? There are essentially two ways to approach this problem. First, we should ascertain whether indeed a pipeline connects two highly competitive markets.[14] If so, it should be a prime and an obvious candidate for deregulation.[15] Second, if indeed we find that a city gate is not reasonably competitive, we ought to inquire whether deregulating the pipeline could stop shippers from exploiting market power. Inherently, if pipelines were left to themselves in less than reasonably competitive situations, they too would have incentives to abuse market power; but if we believe that FERC can constrain pipeline practices better than shippers, it could be argued that proper monitoring of pipelines, even if they are no longer subjected to price caps, may ensure that pipelines are not unreasonably exploiting market power. Removal of price caps along with the abandonment of cost-of-service tariff setting would then be expected to improve allocative efficiency. This

[13] This, of course, assumes that there are many alternatives available for gas transportation from wellheads to a city gate. If this assumption is violated, the situation may not be conducive to deregulation. This issue is discussed later.

[14] The degree of city gate competition places constraints on how much shippers would be willing to pay for transportation, namely, the consumer's value of gas minus non-transportation costs. Competition would tend to drive the transportation price down to the marginal cost of the transporter. The marginal cost of the shipper for transportation depends upon the pipeline rate, which in turn depends upon the degree of competition in the pipeline sector. For example, even when the shipper is constrained in pricing by competition in the market it sells to, pipelines may be able to exploit market power if the service provided is not directly subject to strong competitive pressures; take the case where the value of city gate gas is $5, the price of wellhead gas is $2, and the marginal cost of pipeline service is $1; the pipeline could then charge up to $3 without exceeding the consumer value of gas at the city gate; competitive pressures at the city gate would lower the prices that transporters could charge, thereby forcing down pipeline rates, but still exploitable opportunities exist for pipelines. In fact, a pipeline knowing the value of gas at the city gate could squeeze city-gate providers by setting high prices with the provider collecting less profits.

[15] Again, as noted in footnote 13, exceptions may result.

process should also be monitored to ensure that the city gate market is, over time, becoming more competitive.

Of course, checks to detect whether pipelines are resorting excessively to market power once their prices have been deregulated should be put into practice. If one could demonstrate that pipelines are constraining capacity to increase prices, or have increased prices with minimal sales losses, regulators ought to be wary and should either suspend the rights of certain pipelines to set their own prices or earmark institutional arrangements that would penalize pipelines for resorting excessively to market power abuse. Much can also be said about the important role that state commissions can perform in ensuring that city gates remain competitive. While incumbent distribution companies are subject to considerable controls by a state commission, other shippers often are not in the purview of commission monitoring. To better gauge how shippers are operating, state commissions may need better access to market information.

MEASURING MARKET POWER ABUSE

An important question that we have only briefly touched until now is, how do we detect whether a city gate is reasonably competitive? It helps to again look at how a competitive situation would look like. If indeed shippers were operating in a highly competitive market, they would charge a price that is equal to the marginal cost of supplying gas at the relevant city gate. This cost would be the purchase cost of gas at the wellhead plus the transportation cost at the margin. With a price-cap regime in place for pipeline service, when demand outstrips pipeline capacity, shippers would first exhaust pipeline capacity before opting for other costlier modes. If indeed the shippers were behaving competitively, the gap between the prices at the city gate and the hub would be larger than the price cap only if the entire pipeline capacity was exhausted.[16] Any signs, therefore, that pipeline capacities were being withheld while prices at the city gates were significantly higher than the wellhead prices by more than the price cap, would suggest that shippers were extracting something more than just economic rent during periods of peak demand. This would be a signal that the city gate is not a sufficiently competitive market.

Thus, even though we may want to know whether a pipeline is competitive enough or not, given the present regime of price caps, it should be of concern to regulators whether shippers are abusing market power in any form at a specific city gate. One way to check for this would be to ascertain whether pipeline capacities were being withheld during times of peak demand by shippers around the city gate. If in the present regime, we find that shippers at a city gate have abused market power, one could argue that unregulated pipelines around that city gate would also tend to abuse market power, at the least, if they are not subject to any monitoring.

As should be amply evident from the discussion so far, the urgency of implementing deregulation is intrinsically linked to whether or market power abuse in the current regime is a potentially significant problem. The experience of the electricity

[16] The wedge between the supply price and the city gate price may well be more than the price cap because of congestion and the fact that the marginal supplier may indeed be very costly.

sector provides some guidance in deciding how to go about investigating the above issue in the gas sector. In the electricity sector, with restructuring being equated to greater competitiveness and more choices for end-use consumers, any attempt to quantify erosion of market abuse has been rather difficult. Since actual prices paid by retail consumers choosing a competitive supplier are not made public, indirect measures like offers being made to residential consumers, potential savings opportunities, number of suppliers in the area, the type of offers being made, and the percentage of customers that have selected an alternative supplier, have to be relied on to measure the state of competitiveness in the market. Such a conventional analysis would also be useful for the gas industry, with an attempt made to collate relevant data for such a study. Here though, it may be useful to suggest alternative approaches to studying whether market power is being abused or not in the gas industry.

The following section reviews the literature on gas-pipeline competitiveness; but before doing that, it would be instructive to point out how one could measure market concentration (McAvoy [2000] calculates market concentration and analyzes its impact on prices; we will discuss his approach later). We may want to measure market concentration keeping in view the markets at the city gates and hubs. For illustrative purpose, suppose the industry looks like figure 1. The market at hub D for instance would be expected to be more competitive than the one at hub F.[17] If a single owner dominates the pipeline capacity at hub F, it could withhold capacity to exploit market power and artificially raise the market-clearing price considerably at hub F. The same owner, though, would not be able to exploit any market power at D, as D is served by other pipelines like AD and BD, and other pipeline owners would likely undercut any attempt by it to raise the price.

[17] Pipeline hubs are points where several pipeline systems intersect in a radial pattern of spokes around the hub. Hubs are important in promoting competition because they allow pipelines to be connected readily by adding short links.

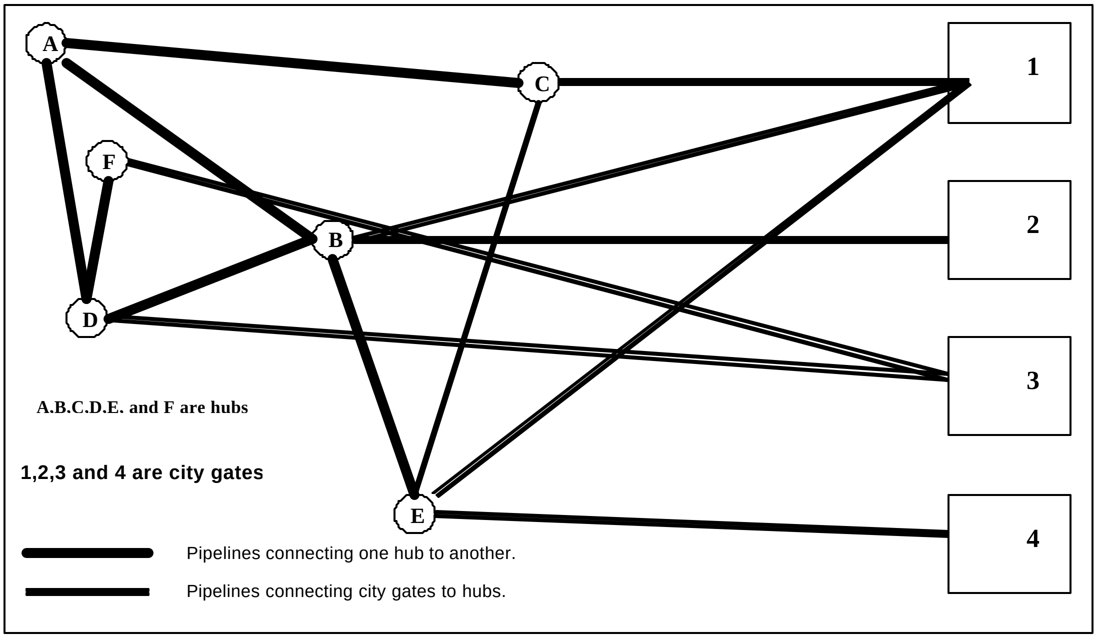

Figure 1. How market conentration matters?

Similarly, an owner having a large share of the pipeline connecting B to 2 would have greater market power than a similar sized owner of the capacity connecting B to 1, as the shippers at city gate 1 would have far more alternative choices to transport gas, i.e., other capacity between B and 1, capacities between C and E to 1, and other non-pipeline sources, while the shippers at city gate 2 would have just the residual of pipeline capacity from B to 1 and other non-pipeline sources as alternative sources. Thus, it would be highly useful to find out the market concentration of hubs and city gates with regard to pipeline transportation service, so that we can proceed to investigate whether shippers could have wielded market power at specific city gates.[18]

In sum, whether a pipeline can exercise market power depends on several factors; they include the ability to constrain capacity to increases prices, the ability to increase prices with minimal sales losses, market concentration, barriers to entry, conditions for collusion, and the price elasticities of demand of shippers and other purchasers of pipeline service. Taken together, these factors determine the market power of a pipeline. Unless one assesses these factors for specific pipeline markets, it becomes difficult to judge whether a particular pipeline has market power.[19]

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[18] For some city gates, it may be relatively easy to answer whether the markets there are competitive or not. With few pipelines connecting a city gate to suppliers, it could be safely assumed that market power abuse would be an issue at such a city gate. For such pipelines, deregulation of prices, even under the watchful eyes of the FERC, may lead to serious market power abuses (simply because it may be too costly for FERC to monitor such market abuses). Some measure of market concentration at a city gate for transportation service may be useful in ascertaining what should be the cut-off below which we can conclude that city gates are sufficiently competitive to warrant deregulation of prices. Even if it may appear that there are many shippers at a particular city gate and pipeline capacities are being exhausted in the present regime, a deregulated could wield lot of market power on both end-use consumers and shippers, as it may be a dominant pipeline pipeline service provider to the city gate. It could simply deny the shippers a large chunk of the pipeline capacity and create a monopolistic situation at the city gate. Thus, while a quick look at whether shippers are withholding market power or not may indicate that shippers have not unduly resorted to market power abuse, the sheer high market concentration of pipeline services may render deregulation at such a city gate rather risky. Something like the HHI may be useful to measure the market concentration of pipeline services at a city gate (Werden 1996). A high level of market concentration may warrant significant divestiture before deregulation can be implemented. What the cut off level should be, would require more thought, but it may be instructive to point out that Joskow (1995) in the case of retail electricity supply had suggested that HHI of less than 2,500 should allow us to presume that the market is competitive.

[19] If pipelines are in fact oligopolies, (which may be the situation in some if not most regions), it is unclear whether price regulation is required. Theories of oligopoly differ on the extent to which firms are able to exercise market power. In most oligopoly industries, the market is allowed to set prices in the absence of government intervention. The reason is that consumers would be better off with an unregulated imperfectly competitive market than with a regulated market and its attendant costs. Conjecturing, under pipeline deregulation the polar conditions of pervasive monopoly pricing and cutthroat competition are unlikely to exist for the sector as a whole.

STUDIES ON COMPETITIVENESS OF GAS-PIPELINE TRANSPORTATION

Three main approaches have been applied to assessing competitiveness in gas pipeline transportation. An additional approach – the simulation method -- is discussed here. What follows is a review of each of these approaches. The discussion is based on Kleit (1998), McAvoy (2000), Silsbee and Jurewitz (2001), Werden and Froeb (1992) etc.

Co-Integration Approach:

The first approach is essentially a time series approach whose basic idea is to investigate if prices across markets have become more co-integrated with major changes in the gas transportation market. Co-integration means that spatial arbitrage is occurring across different market locations. Arbitrage is important in defining economic markets. At given prices, region B is said to be in the same economic market as region A if, when price in A exceeds the price in B, prices in the two regions are joined by binding arbitrage. Under this condition, if producers in A decide to increase their prices by some small amount, arbitrage from B would take place. Thus, if B belongs to the same economic market as A, the price in A must exceed the price in B by exactly the transaction, or transportation, costs from B to A.[20] With co-integration, city gate markets are not influenced by local conditions, unless transportation bottlenecks exist. A price shock in a local market would send a signal that reroutes the flow of gas throughout the network to dampen the impact. For interregional trade under competitive conditions, the following condition holds: if trade takes place between the regions, the price of the commodity in the region with the higher price must exceed the price in the other region

[20] Co-integration of regional prices confirms the "law of one price;" statistical tests can be applied to test the hypothesis of co-integration. With co-integration, arbitrage is effectively working to narrow regional price differences. Co-integration also means that regional price differences can be attributable largely to transportation and transaction costs. Price behavior at different locations may not follow the law of one price – or at least not for extended periods of time in a growing and changing natural gas market. Reasons for this include the lumpiness of most new major pipeline investments, poor information on capacity available to ship gas, and possible market power of incumbent pipelines and local gas utilities.

by the amount it costs to ship a unit of the commodity from the region with the lower price to the region with the higher price ("arbitrage").

A major change in the gas industry obviously has been that by 1990, all major pipelines had gained open access status (For a description of the deregulatory process see McAvoy (2000) and Spulber and Doanne (1994)). [21] DeVany and Walls (1994; 1996), Walls (1994), and Spulber and Doanne (1994) have attempted to measure the impact of deregulation on pipelines' transaction cost indirectly through a co-integration analysis of different regional markets. For example, Spulber and Doanne (1994) apply correlation, Granger causality, and co-integration tests to data from gas prices in regions such as Appalachia and Texas. Using correlation tests, they find that correlations increased over 1984-1993 period in all 10 pair-wise comparisons available between five regions, namely Appalachia, Louisiana, Texas, Oklahoma, and Rocky Mountain. Also, they find that only 1 in 20 tests between five regions shows Granger causality prior to 1987, while all 20 comparisons show Granger causality after that period. Thus, it is claimed that deregulatory measures during the 1980s have resulted in a more competitive natural gas industry.

The co-integration approach has been criticized by Werden and Froeb (1992) for three reasons. First, spurious correlation may explain the movement in prices. If markets A and B are both affected by the price in Z, and there is variability in Z, markets A and B would appear more correlated. Second, suppose an exogenous shock raises the price in market A; producers in B would be tempted to transport the good to A. With significant transportation bottlenecks, transportation prices along with the flow of goods from B to A

[21] According to MacAvoy (2000), four critical changes to pipeline rate behavior occurred in the transaction years from merchant to unbundled services: (1) actual prices for transport-only services in these years fell below FERC regulated tariff rates, (2) changes in FERC tariff rates had a small effect on changes in actual transport prices – specifically, for a 10-percent tariff reduction, actual prices went down on average by less than 2 percent, (3) the size of discounts on tariff rates did not depend on pipeline concentration at various city gates, but larger discounts were found at hubs in the Midwest, and (4) peak-season transport prices were not much higher, implying that pipelines were not exploiting any market power that they may have had during peak heating periods. MacAvoy interpreted these four changes to support his position that the market, not regulation, was the major driver of prices for gas transportation service in the early to mid-1990s.

would increase, leading to an increase in prices in market B as well. While both markets would be less connected now, a correlation analysis would erroneously show these markets to be more correlated. This scenario could be real in the gas transportation market (See Kleit (1998)).

Another aspect of co-integration analysis deserves some criticism. Generally, as pointed earlier, in the case of gas pipeline transportation market power is more likely to occur when the market is "tight." Therefore, any co-integration approach to assess market competitiveness using data for both off-peak and peak demand periods would obfuscate the ability to accurately conclude whether market power abuse is real or not. In particular, as it was pointed out earlier, during most times the demand for gas is low enough to raise no concerns about pipeline capacity constraints.[22] Thus, when transportation alternatives are plenty (and therefore transportation is competitive enough), prices differ between regions precisely on account of just transportation costs. In this case prices would appear strongly correlated. When we have a "tight" situation, however, transportation bottlenecks (comparable to congestion in the electricity transmission) result, the markets become disconnected, and the supply/demand balance in one market can no longer influence price in the other. Thus, during period of high demand spot prices across markets diverge beyond just transportation costs.[23] The real story on market power abuse lies in the dynamics of market prices during periods of high demand. Co-integration analysis, which relies on the law of one price, does not capture the real picture because the law of one price fails during periods of "congestion." Finally, even in the presence of co-integration, pipelines can operate monopolistically by withholding capacity and marking up price by identical amounts. This could result in "no profitable" arbitrage on the network, but the pipelines could nevertheless earn supernormal profits.

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[22] The characteristics of the markets, or theoretically speaking, their definitions would crucially alter our assessment of capacity constraints. It would be important to clearly identify what are the alternatives to gas pipeline transportation in meeting demand for "energy" in a market.

[23] With transportation constraints, interregional price differences can result from differences in commodity prices, which, in turn, can be attributed to the fact that the law of one price no longer applies because of market non-integration or market independence.

Transaction Costs Approach

We next review the model that Kleit (1998) proposes to study whether deregulation has resulted in lowering transaction costs. Such lower costs would indicate that markets have become more integrated. Suppose that two regions are in autarky, and their prices are

$$P_t^1 = p_1 + e_t^1 \quad (1a)$$

$$P_t^2 = p_2 + e_t^2 \quad (1b)$$

where the p_is represent mean prices in the relevant regions and e_t^is are shocks to the markets. Assume that the price in region 1 is greater than that in region 2, and no autarky exists. Let the arbitrage cost of shipping from region 2 to region 1 in period *t* be T_{t12}. With the possibility of arbitrage, price in region 1 cannot rise above $P_t^2 + T_{t12}$.[24] There are two possible outcomes: when the arbitrage constraint is not binding, the difference between the prices in the two markets is lower than T_{t12}; otherwise, when the arbitrage constraint is binding, the difference is exactly equal to T_{t12}.

Now suppose that the arbitrage cost is a random variable with "geometric mean,"

$$T_{t12} = T * e^{V_t}\ ;\ \log T_{t12} = \log T + V_t \quad (2)$$

where T is a constant representing the geometric mean of arbitrage costs,[25] and V_t is a random variable with mean 0 and variance s_v^2. Let l be the probability that no

[24] Where there are no pipeline capacity constraints, differences in market prices across regions in a competitive market reflect the actual cost of moving gas between locations; where gas flows from region 1 to region 2, the price at 2 must be equal to that at 1 plus the cost of transportation; if the price at 1 were to move out of line with that at 2, traders would arbitrage gas between the two points until prices came back into equilibrium.

[25] As we will see, it would help to assume that T is actual not a constant, and is a function of other factors that may vary across space and time.

arbitrage occurs; that is, prices in the two regions differ by less than the arbitrage cost; mathematically, this can be expressed as

$$Prob\left\{\log\left[P_{1t}-P_{2t}\right]-V_t<\log T\right\}=l \qquad (3)$$

and $1-l$ is the probability that the markets are directly "connected," where prices in region 2 act as a constraint on prices in region 1. When no arbitrage occurs, markets are said to be disconnected. Pipeline capacity constraints can cause a "disconnect" of regional markets. In this situation, the marginal consumer at any given time wherever she is located can no longer affect the demand and supply balance and prices in other regions. This is equivalent to saying that demand and supply within each region, rather than between each region, determines the spot price. Thus, when pipeline capacity between two points in the network is fully utilized, regions become disconnected and demand/supply conditions in one region cannot influence price in the other.

Before proceeding further to describe the model in greater details, an observation is in order. Let us assume that gas pipeline transportation operates in a deregulated environment. The above analysis should make it clear that markets can be "disconnected" when an importing region is faced with both peak demand and off-peak demand situations. When demand is extremely slack in the importing region, prices in that region would be low enough so that the gap between the prices in the two markets may be insufficient to justify unification of the markets through the provision of transportation service. In contrast, when we have a peak demand situation in the importing region, capacity constraints may be so binding that the cost of arbitrage may be extremely high and even though prices in the two markets may greatly differ, markets would essentially be disconnected. In this situation, the value of transportation would be a residual and can be measured as the gap between prices in the two markets; to the extent capacity allows it, transporters would profit from providing service. It is crucial to observe though that in slack demand situations manipulation of prices through withholding of pipeline capacity would be extremely difficult because of excess supply. During peak times, however, transporters may have an incentive to cut capacity to artificially inflate the price that they can charge for the capacity provided to suppliers in the importing region. These observations essentially imply that $\log T$ may closely reflect the mean cost of arbitrage during off peak periods, but for peak demand periods it may reflect market power abuse as well.

Going back to equation (3), many factors can affect l, including the level of arbitrage cost from 2 to 1, the variance s_v^2, and the market dynamics in both regions.

Let us define a positive random variable as

$$U_t = V_t + \log T - \log[P_{1t} - P_{2t}], \qquad (4)$$

which is relevant if the arbitrage constraint is not binding. It is assumed that U_t is a one-sided normal distribution, that it is derived from a normal distribution $N(0, s_u^2)$ truncated below at zero, to account for price differences being truncated above at T. Even though T is truncated below at zero, $\log T$ is not; the same observation applies for $\log[P_{1t} - P_{2t}]$ as well. When the arbitrage constraint is not binding, we find that $\log[P_{1t} - P_{2t}] - \log T$ is the difference between V_t and U_t and, therefore, it has a probability density function

$$f_t^1 = \left[\frac{2}{\sqrt{s_u^2 + s_v^2}}\right] j\left[\frac{\log[P_{1t} - P_{2t}] - \log T}{\sqrt{s_u^2 + s_v^2}}\right] \times \left[1 - \Phi\left(\log[P_{1t} - P_{2t}] - \log T\right)\frac{s_u / s_v}{\sqrt{s_u^2 + s_v^2}}\right], \qquad (5)$$

where $j(.)$ and $\Phi(.)$ are the standard normal density and distribution functions. Similarly, if the arbitrage constraint is binding, $\log[P_{1t} - P_{2t}] - \log T$ would be exactly equal to V_t and its distribution function would be

$$f_t^2 = \left(\frac{1}{s_v}\right) j\left(\frac{\log[P_{1t} - P_{2t}] - \log T}{s_v}\right). \qquad (6)$$

Indeed, we could hypothesize that $\log T$ depends on market concentration especially during peak demand periods, and may model it as follows:

$$\log T_t = a_0 + \vec{a}_1 \vec{X}_t \tag{7}$$

where $\vec{X}$ is a column vector of variables believed to impact the arbitrage cost, with some of the variables, including market concentration, purporting to capture market power, and $\vec{a}_1$ is a row vector of coefficients associated with these variables. Given this, one could maximize the log likelihood function

$$\sum_t \log L_t(l, s_u, s_v, a_0, \vec{a}_1) = \sum_t \log\left[l f_t^1 + (1-l) f_t^2 \right] \tag{8}$$

with respect to the parameters to be estimated, l, s_u, s_v, a_0 and $\vec{a}_1$. Ideally, we could gather data on relevant variables, including prices for n markets, and conduct the study on $\frac{n(n+1)}{2}$ pairs of gas markets.

The transaction-costs approach would presumably have the advantage of identifying pairs of markets, wherein transportation service may be subject to market power abuse. It should be pointed out that Kleit (1998) used the above framework to test whether deregulatory landmarks had led to increases or decreases in transaction cost for specific pairs of markets. He concluded that while deregulation had made the Louisiana-Texas-Oklahoma region close to one large pool of natural gas, transaction cost actually went up in the Rocky Mountain region. The author suggests that the culprit may have been a limited supply of pipeline capacity in that region.

Descriptive Approach

The above approach ties closely with an approach that we may conveniently call the "descriptive approach." This approach again relies on estimating the price difference in spot gas prices at a receipt and a delivery point, i.e., a market center and a city gate, by conducting regression analysis on price differences. The objective of this approach is to explain price differences using explanatory variables like distance between the upstream market center and the downstream city gate, the Herfindahl-Hirshman transport concentration index, projected tariff for firm capacity, and weather. This approach, which has been adopted recently by MacAvoy (2000), makes no attempt to estimate transaction costs. Instead, it estimates the correlation between gas price differences and the regulated tariff transport rates. According to MacAvoy, a strong and significant positive correlation would suggest limited competition in transportation between a city-pair.

MacAvoy (2000) estimated a Box-Cox model as follows:

$$(P_d - P_u)_t^l = b_1 + b_2 (P_d - P_u)_{t-1}^l + b_3 D^l + b_4 HHI^l + b_5 \mathrm{Tariff}^l + b_6 \mathrm{Winter}^l + e \quad (9)$$

where l is the coefficient of Box-Cox transformation, P_d is the spot gas price at the downstream city gate, and P_u is the spot gas price at the upstream field or delivery point. D is the distance between the upstream market center and the downstream city gate, HHI is the Herfindahl-Hirschman transport concentration index, equal to the sum of the squares of pipeline market capacity shares for delivery at that location, and Tariff is the regulated tariff projected firm capacity charge, at full capacity. Winter is the dummy for winter months. Incidentally, the data sources used by MacAvoy (2000) can provide a good starting point for a future investigation. Gas prices at selected city gates and hubs were obtained from *Natural Gas Week* and *Natural Gas Intelligence*. Distances were obtained from *Pennwell Books'* maps of natural gas pipelines of the United States and Canada. The Herfindahl-Hirschman Index for each city gate was estimated from peak day deliveries as reported in annual *FERC Form 2 Reports* of the individual pipelines.

MacAvoy (2000) finds no support for the hypothesis that market power abuse may be prevalent in the U.S. gas pipeline transportation business. But some comments on his approach and results are in order. First, it would be more appropriate to conduct the study separately for peak demand periods and off-peak demand periods; as has been indicated in the previous sections, market power abuse is almost certainly a phenomenon that occurs only during peak demand periods. By conducting the above regression without differentiating how market concentration may impact price differently during off-peak and peak demand periods, and given that observations from off peak demand periods overwhelm the data, a poor and insignificant relationship between market concentration and price differences is hardly surprising. Thus, the regression should be appropriately modified. Also, given the nature of annual cost-of-service based tariff setting in gas pipeline transportation, it is only natural that much of the time with demand for gas being slack, with more alternatives for shipping gas, the differences in prices between city gates and hubs would be lower than the regulated rate. Therefore, such differences are fundamentally uncorrelated with the regulated rates. Also, when demand for gas is at a peak, congestions in gas transportation (which is only exacerbated by the requirement that transportation rates cannot be higher than the regulated rates) lead to the decoupling of differences in spot prices (as these are influenced by unregulated shippers) and the regulated rates. Overall, it is not surprising at all that the above regression produces a poor and insignificant correlation between Tariff and city-pair price difference.

It would be premature, therefore, to interpret the MacAvoy results as giving support to the idea that the market for gas pipeline transportation is comfortably competitive. A more appropriate approach would be to estimate the impact of market concentration (and probably other proxy measures for market power abuse) on price differentials during just peak demand periods, after adjusting for necessary control variables. Also, for some city-pairs, the impact of market concentration on price differential may be significant, while for others it may not be. We have seen that the transaction cost approach could provide such a determination; but even under the descriptive approach, if the regression analysis were conducted carefully, the analysis could identify some city-pairs as being vulnerable to market power abuse.

Simulation Approach

This approach as the name would suggest investigates market power abuse within the confines of a model that tries to simulate the behavior of economic agents given specific characteristics of the market in question. Given the similarity between the natural gas industry and the electricity sector, some lessons can be drawn from experiments conducted for electricity markets. Studies of electricity markets include those conducted by Sweester (1998), Zarnikau and Lam (1998), Bushnell (1999), Wilson (2000), and Silsbee & Jurewitz (2001). In particular, Silsbee and Jurewitz (2001) are discussed below. Their paper basically demonstrates that even electricity suppliers with relatively small market shares may be able to drive up market prices. The authors in particular model a non-cooperative game to simulate the experience of the power sector in California during the summer of 2000.

In their model, Silsbee and Jurewitz represent wholesale generators as five individual power plant owners owning capacities that were roughly equivalent to the capacities owned by the five major generators in California. A 10-percent outage rate corresponded to the highest possible availability and a 90-percent outage rate to the lowest possible availability. The units held out of service are done probabilistically, and a significant portion of electricity is assumed to be bought from out-of-state markets under the condition of severe capacity constraints, with the result of significant increases in prices. Repeat trials allowed the wholesale generators to test outage strategies and to engage in mutual non-cooperative strategies with a Cournot-Nash equilibrium. A crucial element of the model assumes that buyers face a kink supply curve, with the slope rising significantly for supplies above the capacity available in California (this condition is consistent with the *modus operandi* of the California wholesale market); in general prices paid by different buyers were quite uniform).

For our purpose, it is important to note that the model demonstrate that even for a fairly large number of (relatively) uniformly sized sellers, the market price is significantly higher in the case of a severe supply shortage, as opposed to a case of relative abundance of supply. Also, the higher the market concentration is, the more severe is the rise (proportional) in price during a “tight” period as compared to that during an off-peak period. It is also important to note that this model would need to be modified to address the peculiarities of the gas industry. In general the model corroborates the observation made earlier that market power abuse is a matter of concern mainly during “tight” periods.

Overall, simulation models are extremely useful in explaining actual outcomes, but they are a somewhat inferior substitute for the descriptive approach, where analysts use actual data to investigate the validity of a particular hypothesis. The experiments with the electricity sector seem to verify the fear that shippers may have real incentives to manipulate capacities during periods of peak demand to extract monopoly profits.

CONCLUSION

Liberalization of gas pipelines transportation was motivated largely by the evolution of deregulation in the natural gas industry. This paper looks at different approaches to investigate whether pipelines would be prone to abusing market power if they are completely deregulated. In the literature, essentially four approaches have been used to investigate whether utility markets have become more or less competitive during any period compared to some other period.

Our investigation suggests that since transportation is essentially associated with pairs of supplier and buyer, the most suitable approach may be to determine how the transaction cost of provisioning gas between markets depends on market power abuse (a good proxy of which would be the HHI). Important, the model must be able to distinguish behavior during off peak and peak periods of demand, and the transaction cost approach, to some extent, naturally does that. Also, the selected model should be able to identify city pairs where market power abuse might be a serious problem. This would allow regulators to address these concerns more effectively. The transaction cost approach allows us to model differences in behavior across city-pairs quite conveniently.

The descriptive approach is less sophisticated than the transaction cost approach; but it could do a fairly good job in addressing the same issues as pointed above; but regression analysis -- for example, akin to that conducted by MacAvoy -- would have to be carefully modified. The co-integration approach has severe disadvantages that may render it less attractive to specifically address the issue of competitiveness in the gas transportation sector. Simulations, as has already been pointed out, throw light on how markets might be working. Addressing the question of whether or not market power abuse actually exists being the core of the investigation, however, the transaction cost approach may be the most suitable starting point for a detailed investigation.

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