Indexing Interstate Gas Transportation Rates

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INDEXING INTERSTATE GAS TRANSPORTATION RATES

Final Report

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EXECUTIVE SUMMARY

INTRODUCTION

The INGAA Foundation retained Christensen Associates in May of 1990 to study the indexing of interstate gas transportation rates. The eight-month project has included a number of tasks. First, we developed a statement of the public policy arguments favoring gas transport rate indexation. We next identified the major options in the design of a rate adjustment index. The third task was to develop and calculate supporting indexes of industry input price and productivity trends. We then calculated a representative rate adjustment index. This is the final report on our research.

THE CASE FOR RATE INDEXING

Gas Transportation in the Turn-of-the-Century Economy

Interstate natural gas companies are destined to play a major role in the turn-of-the century U.S. economy. Low cost gas supplies are needed to improve air quality, trim oil imports, bolster the living standards of low income groups, and help sustain the competitiveness of American industry. The performance of interstate gas companies is a key determinant of gas availability and price.

One measure of industry performance is the level of rates for gas transport services. But performance also means providing the market-responsive array of rate and service options that are the hallmark of modern service industries. These industries have figured prominently in the continuing productivity edge of the U.S. economy.

Barriers to Improved Performance

The ability of interstate gas companies to respond to these challenges is hampered by current regulation of its rates and services by the Federal Energy Regulatory Commission (FERC). The industry does not yet offer a market-responsive array of transport rates and services. The need for improved offerings is especially urgent now, since the industry is undergoing a major restructuring.

The federal government has recognized the need for extensive revisions in the rate and service offerings of interstate gas transport companies. Current FERC chair Allday has voiced the goal of "designing and implementing pipeline rate designs that reflect the competitive realities of the natural gas market." Two workshops on gas transport rates have recently been organized by FERC staff.

Unfortunately, there is serious doubt as to whether the FERC can accommodate the present need for change if it continues to rely exclusively on traditional review procedures. The FERC regulates gas transport rates and services using a cost of service method. This is the traditional method by which U.S. regulators enforce legally prescribed fairness standards such as those in the Natural Gas Act. Controls on profits limit monopolistic pricing. Prudence reviews limit the cost of service. Cost allocation procedures limit undue rate discrimination.

The efficiency of traditional rate regulation has been increasingly questioned by economists in recent years. One problem is its high direct cost. Regulators typically know far less than managers about the affairs of regulated utilities. Judgments regarding cost allocations and the prudence of management decisions are difficult even if extensive information is at hand. Proceedings are contentious since intervention can yield large economic rewards. Efforts to learn about company operations and to resolve disputes are costly. Significant economic resources are thus expended on traditional rate regulation that have no counterpart in unregulated markets.

The parties to regulatory proceedings take a number of measures to reduce these direct costs. The frequency of reviews is reduced. Familiar, rule-of-thumb methods are used in cost allocation and rate design. Prudence reviews are confined to conspicuous examples of dishonesty, incompetence, or misfortune. Companies scale back the array of rates and services which they would otherwise offer.

These economy measures unfortunately have their own costs. Lessened prudence vigilance combined with profit controls reduce incentives to trim input prices and boost productivity. Between rate reviews, companies can increase profits by improving performance since current rates are unaffected. However, an improved performance today can produce lower rates and higher performance standards tomorrow. Weakened performance incentives mean poorer performance. Rates may be higher than their lowest possible level. Rates and services are not offered that would be mutually beneficial to the company and its customers.

The Rate Indexing Option

Regulators frequently confront the conflicting needs to accommodate change and enforce standards of fairness. The rational response is to seek departures from traditional rate regulation. In the 1960's the Federal Power Commission resolved the problem of setting prices for sales from myriad natural gas wells by setting area rates based on the cost conditions of typical producers. More recently, regulators have sought to reconcile the needs for change and fairness with rate indexing. A rate indexing program has been operating for class I line-haul railroads since 1981. Additional companies with rates currently subject to indexing include AT&T, Pacific Bell, British Telecom, British Gas, and the new British electricity transmission and distribution companies.

The FERC has long held an interest in incentive regulation programs such as rate indexing. It commissioned a study of incentive regulation for electric utilities in 1983. The FERC Office of Economic Policy (OEP) released two studies of incentive regulation in 1989. One proposed a specific, voluntary scheme for indexing gas transport rates. On December 31, 1990, the FERC approved a rate indexing scheme for Buckeye Pipe Line Company, a refinery products carrier.

What is Rate Indexing?

Rate indexing is a method for adjusting maximum rates for public utility services. In a typical scheme, base rates are first set by the traditional method. Thereafter, they are adjusted periodically—usually quarterly or annually—using an automatic rate adjustment index. Companies retain an obligation to provide the indexed services unless released from obligation in an abandonment proceeding.

The rate adjustment index tracks general trends in the cost of service. However, it is insensitive to the current performance of the companies to which it applies. Reviews of indexing schemes commonly occur much less frequently than reviews under traditional regulation.

Benefits of Rate Indexing

Rate indexing can produce a number of benefits for interstate gas companies and their customers.

A company's rates are generally far less sensitive to its own performance. Incentives are thus strengthened to cut costs and devise market-responsive rates and services. The improved performance makes it possible for companies to enjoy higher earnings with rates below those they would charge under traditional regulation. Indexes can be designed that promote this outcome. That is, indexes can confer the expectation that rates will be as low or lower than those that would occur under traditional regulation.

The insensitivity of rates to a company's own performance makes it difficult to cross-subsidize initiatives in competitive markets from the high prices charged in non-competitive markets. Similarly, new rate and service offerings to any customer class can only benefit customers (if accepted) or have no effect (if rejected).

Rate indexing thus commonly coincides with greatly increased marketing freedoms for utilities. Companies commonly have freedom to offer discounts from the indexed base rates. The base rates are for this reason often called price caps. Certain services may no longer be subject to rate restrictions. That is, indexing often coincides with a partial decontrol of rates. Streamlined approval of new rate and service offerings is also common.

These freedoms are all the more impressive when we consider that they are accomplished without a formal division of the rate base into core and non-core segments. Rate base divisions are inherently arbitrary and have proven awkward where attempted.

RATE INDEXING IN THE U.S. RAILROAD INDUSTRY

The inability of traditional regulation to accommodate market-responsive rates and services threatened the viability of U.S. railroads in the late 1970's. Congress responded with the Staggers Rail Act of 1980. Rates for competitive services were decontrolled. Maximum rates on traditional services to captive shippers were initially set by traditional methods. They are now adjusted by an Index of Railroad Costs.

The effect of the Act on general rate levels has not been clear-cut. However, the market-responsiveness of rail rates and services has improved considerably, to the benefit of consumers.

Productivity growth has accelerated. The rate indexing program helps captive shippers benefit from these changes.

ALTERNATIVE RATE ADJUSTMENT INDEXES

Two kinds of rate adjustment indexes predominate in current rate indexing programs. The index used by class I line-haul railroads measures trends in the input prices and productivity of the railroad industry. A "railroad-style" index was featured in the FERC OEP proposal.

A different kind of index is used by telecommunications companies and the British gas and electric utilities. Rate adjustments are based on the current rate of economy-wide inflation and an additional percentage offset. The percentage offset depends in principal on the expected difference in the productivity trends of the company and the economy under rate indexing.

Both of these indexes have advantages worth considering in the gas transport context. Railroad-style indexes track industry-specific cost trends using published data. "Telecommunications-style" indexes are simple to administer once the percentage offset has been determined. The percentage offset can be tailored to the circumstances of individual companies.

INDEXES FOR INTERSTATE GAS TRANSPORTATION RATES

Input price and productivity indexes were developed and calculated for an aggregation of interstate gas transporters in the 1977-88 period. We found that an output index like that used to adjust rail freight rates cannot be constructed from currently published data. The FERC OEP proposed the total throughput of major interstate gas companies as an output measure. This index exaggerated the output of the industry during the sample period since it was insensitive to the decline in the average distance shipped. Our alternative, "price-distance" output index indicated substantially slower output growth over the same period.

Three alternative treatments of capital cost were considered in the indexing work. The treatment including capital gains and losses as capital costs produced substantially different results than the two that did not. Rates are not adjusted for capital gains and losses under traditional regulation.

The indexes provided the basis for railroad-style rate adjustment indexes such as would have been applicable in the 1983-88 period. One such index was calculated for illustrative purposes. The indexes also shed light on the appropriate productivity offset for a telecommunications-style index.

SUMMARY

Rate indexing can boost utility incentives to cut costs and develop market-responsive rates and services while protecting the interests of disadvantaged customers. Its potential benefits are largest where innovation is urgently needed and the competitive sector is substantial. Both of these conditions are characteristic of the contemporary interstate gas transportation industry. Indexing of gas transport rates would then seem to be an option worth serious consideration by interstate gas transporters and their customers. The empirical work undertaken in this study provides a solid foundation for the design of indexing programs.

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ACKNOWLEDGEMENTS

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Section 1
INTRODUCTION

Interstate natural gas companies are destined to play a major role in the turn-of-the century U.S. economy. Low cost gas supplies are needed to improve air quality, trim oil imports, bolster the living standard of low-income households, and more generally, to help sustain the competitiveness of American industry in world markets. While interstate gas companies have a major impact on the availability and price of gas, their ability to respond to these challenges is hampered by FERC regulation. The industry does not yet offer the market-responsive array of rates and services that are common in modern service industries. The need for improved offerings is especially urgent now, since the industry is undergoing a restructuring of unprecedented dimension.

The Commission has a statutory responsibility under the Natural Gas Act (NGA) to ensure that changes in rates and services conform to certain fairness standards. Traditional review procedures are intended to ensure conformance. Unfortunately, these procedures may not accommodate the rapid changes that current circumstances demand.

Regulators frequently confront the conflicting needs to accommodate change and enforce fairness standards. A departure adopted with increasing frequency is rate indexing. The FERC has made a preliminary investigation of rate indexing and has invited interstate gas companies to propose indexing schemes. On December 31, 1990, the FERC approved an indexing scheme for a refinery products pipeline company.

The INGAA Foundation retained Christensen Associates in May of 1990 to study the indexing of interstate gas transportation rates. The eight-month project has included a number of tasks. Our first was to develop a statement of the public policy arguments for indexing gas transport rates. We then identified the major options in the design of a rate adjustment index. Next, we developed input prices and productivity indexes that rely exclusively on published data. We then calculated actual indexes using data from 39 companies in the 1977-88 period. Such indexes provide the basis for the construction of rate adjustment indexes. A representative rate adjustment index was constructed that could have applied during the 1983-88 period.

This is the final report on the research project. In the next section, we describe in greater detail the regulatory dilemma facing the interstate natural gas industry. Section 3 outlines the rate indexing option and its potential worth in resolving the dilemma. In Section 4, we present a case study of rate indexing in an industry with many similarities to the interstate gas transport industry:

class I line-haul railroads. We then consider some major issues in the design of a rate indexing program. A discussion of our work to produce rate adjustment indexes and the supporting input price and productivity indexes is found in Section 6. Results of the indexing work are reported in the final section.

Section 2
THE DILEMMA IN GAS TRANSPORT POLICY

A. GAS INDUSTRY CHALLENGE

In 1991, the United States faces extraordinary challenges in its effort to sustain its leading position in the world economy. US producers are subject to intense foreign competition. Efforts to boost cost competitiveness are constrained by a public commitment to environmental quality. The economy continues to be destabilized by reliance on price-volatile petroleum. Continued growth in the living standards of low-income households is increasingly difficult.

The natural gas industry can help to mitigate these problems. Thanks to abundant gas supplies, the U.S. is less reliant on oil than most industrialized nations. Gas-based engine technologies are a clean-burning alternative to oil-based technologies and restrain longer-run increases in oil prices. Gas-based power generation technologies have special attributes needed by electric utilities to meet growing demand, improve air quality, and develop a more competitive structure. Natural gas is an important part of the budget of low-income households.

The gas transportation industry will play a key role in helping natural gas realize its potential in the turn-of-the century economy. In most states, transportation accounts for more than half of the delivered cost of gas. The performance of gas transporters therefore has a major bearing on the price and availability of gas.

One measure of industry performance is the level gas transport rates. Performance also means providing the market-responsive array of price and service options that are the hallmark of modern service industries. These industries have figured prominently in the continuing productivity edge of the U.S. economy.[1]

Market-responsive transport rates and services have long been needed (and, to an extent, achieved) in the gas industry. Demand for gas in space heating and power peaking is highly seasonal and sensitive to weather conditions that are hard to predict. Demand for gas as a boiler fuel in base-load electric, industrial, and enhanced oil recovery operations is sensitive to oil price swings. The industry must respond to these changes if it is to keep capacity utilized when demand is slack, and to allocate capacity to high-valued uses when demand peaks.

[1] F. Gluck, "Europe, Japan Would Lose Trade War" (1990).

The current restructuring of the interstate gas industry has greatly increased the need for market-responsive transport rates and services. Before 1978, interstate gas companies as limited-access private carriers were the primary merchants of gas sold in interstate commerce. For most companies, the bulk of transported gas was company-owned and delivered from fields to end-use markets in company lines. Competition to secure gas supplies was limited by wellhead price controls. Supplies were obtained from producers primarily by long-term contracts. Most buyers of interstate gas were directly served by just one interstate carrier.

Since 1978, a number of federal policy initiatives have promoted change in the industry's structure. The Natural Gas Policy Act of 1978 removed ceilings on wellhead prices for new gas. A series of FERC orders has encouraged interstate lines to admit competition for their merchant services by offering "unbundled" transport services. The FERC has also promoted increased integration of the interstate system to alleviate take-or-pay problems and increase competition.

Today, the bulk of interstate gas transportation occurs on an unbundled basis. Much more gas is sold under spot or medium-term contracts that permit shippers to change trading partners on short notice. New construction has increased system integration substantially.

Structural change will be furthered by current efforts to expand transport services from areas of surplus gas production capacity. For example, Pacific Gas Transmission is greatly expanding its previously modest capacity to ship gas from Canada to California. Non-traditional suppliers are now constructing a pipeline to ship Wyoming gas directly to California. As a consequence of such developments, interstate gas companies face major shifts in North American gas flows that will reduce long-run demand for transportation on some routes while boosting it on others.[2]

Changes such as these have greatly increased the transportation options of natural gas buyers. Many regional end-use markets for gas are now directly served by two or more transmission companies. Customers in end-use markets are less dependent on their direct-service carrier to provide the complete field-to-end-use-market haul. The gas distributor serving Indianapolis, for example, was traditionally reliant on Panhandle Eastern Pipe Line Co. for transmission service. It will soon have the additional option to receive gas from Texas Gas Transmission Corp. The distributor will be able to use Texas Gas for a long haul from gulf coast fields, or to relay gas delivered to the Texas Gas system from the Arkoma basin.

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[2]See, e.g. E. Spiegel et. al., "New U.S. Gas Lines Will Restructure North American Grid Flows" (1990).

The transportation options of gas producers have also expanded. Consider the case of a gulf coast producer that previously had committed its supplies to Texas Gas. The producer now has the additional options of reaching Atlanta on the Southern Natural Gas system, or Detroit on the ANR system.

Increasing options for shippers means more vigorous competition among gas transporters. Pipelines serving the same field vie to determine which end-use market receives the gas. Discounts by pipeline companies serving midwestern end-use markets, for instance, have been noted to divert gas supplies from the California market. In the future, midwestern and eastern lines will compete more vigorously for Gulf Coast gas, and California and midwestern lines for Wyoming gas.

Pipelines serving the same end-use market will increasingly vie to determine the source of gas supplies. Vigorous competition for the California market will develop between transporters serving Alberta, Wyoming, New Mexico, and Texas fields. Competition for the northeast market will emerge between suppliers serving gulf coast, midcontinent, and Canadian fields.

Increased competitive pressures encourage transporters to offer more market-responsive rates and services. However, interstate gas transportation markets will continue to differ greatly in their competitiveness. In particular, many end-use markets, and a few field markets, will continue to be directly served by only one transmission company.

Another important force for revision of rate and service offerings is the demand by gas industry customers for the full array of transportation services that were previously bundled with merchant services. Shipper demands for change are backed by claims that failure to provide such services gives interstate gas companies unfair advantage as gas merchants.

In addition to unbundled transmission, there are now frequent calls for firm and interruptible gathering and storage, and for such coordination services as supply aggregation, exchanges, and backhauls. To be comparable to other service industries, the gas transportation industry must also offer variations on its basic services. For example, shippers may prefer a type of interruptibility that differs from a "chocolate-and-vanilla" choice between firm and interruptible service. They may also want unconventional combinations of services such as interruptible transportation and firm storage. Each of these variations involve different costs for natural gas transporters.

Changes in rate design are also requested by customers. Most obviously, discounts from regulated maximum rates can benefit all parties so long as revenues exceed variable cost so that a contribution is made to fixed costs. Certain customers may benefit from complex rate designs. For example, mileage based rates are desirable for shippers using routes that require the services of multiple pipeline companies.

B. BARRIERS TO REGULATORY REFORM

INADEQUACY OF CURRENT RATE AND SERVICE OFFERINGS

The array of rates and services currently offered by the industry is, unfortunately, far short of current market needs. Most interstate companies offer a fairly limited array of unbundled transport services. Unbundled storage service, for example, is only now becoming common.

Established rates often fail to maximize throughput in periods of low demand. Without discounting, off-peak loads that could boost throughput would be missed. When demand for transport services peaks, regulated rates often fail to allocate capacity to its highest-valued use. Capacity must then be rationed, and is usually allocated on a first-come, first-served basis. The companies valuing capacity rights most highly do not always possess them. Yet trade in capacity rights is still quite limited.

The federal government has recognized the need for extensive revisions in the rate and service offerings of interstate gas transporters. Successive FERC chairs have emphasized the point. In its Notice of Proposed Rulemaking of June 7, 1985, the FERC stated:

> In those areas where competitive forces are adequate, the regulatory framework should allow all participants in the industry greater flexibility to adjust to market conditions so long as the adjustment does not involve cross subsidization or the involuntary shifting of costs among customers.

Current FERC chair Allday has voiced the goal of "designing and implementing pipeline rate designs that reflect the competitive realities of the natural gas market."[3] Two workshops on rate reform have
recently been organized by FERC staff. Reform of gas pipeline rate design was one of the National Energy Strategy options recently presented by the DOE to the Council of Economic Advisors.

Unfortunately, there is serious doubt as to whether the FERC can accommodate the present

[3] Reported in The Energy Report, November 13, 1989.

need for change relying only on traditional review procedures. To see why, we must first review the manner in which interstate gas companies develop transport rates and services.

TRADITIONAL FERC REVIEW PROCEDURES

Under the NGA the FERC, as successor to the Federal Power Commission (FPC), has jurisdiction over the activities of interstate gas transporters. The companies need certificates of public convenience and necessity in order to construct or operate facilities under FERC jurisdiction. Certificate holders must comply with certain performance standards.

Under Section 4(a) of the NGA, the rates and charges for jurisdictional services shall be "just and reasonable." Section 4(b) states:

> No natural gas company shall, with respect to any transportation or sale of natural gas subject to the jurisdiction of the Commission, (1) make or grant any undue prejudice or disadvantage, or (2) maintain any unreasonable differences in rates, charges, services, facilities, or in any other respect, either as between localities or between classes of service.

The FERC has extensive powers to enforce these standards. Under Section 4(d), changes in rates, charges, classifications, or service may only take place after proper notification to the Commission. Section 16 states that "The Commission shall have the power to prescribe, issue, make, amend, and rescind such orders, rules, or regulations as it may find necessary to carry out the provisions of this act."

Under Section 5(a), the FERC may, upon its own motion or the complaint of interested parties, investigate whether "any rate, charge or classification demanded, observed, or charged ... is unjust, unreasonable, unduly discriminatory, or preferential." If the standards are violated, "the Commission shall determine the just and reasonable rate, charge, classification, rule, regulation, practice or contract to be thereafter observed and shall fix the same by order."

The Commission has had to develop operational procedures for enforcing these standards. The common approach around 1940 was the cost of service method. This evolved from regulatory practice in a number of industries and was sanctioned by the U.S. Supreme Court in a series of historic decisions. The FPC interpreted the NGA as calling for a cost of service method. Their approach was supported by the 1944 U.S. Supreme Court in Federal Power Commission v. Hope

Natural Gas Co.[4]

In cost of service ratemaking, rates are set to recover allowed costs. The allowed costs consist of prudent operating costs plus a return on the value of prudent investments. The allowed rate of return is that typical of unregulated businesses facing a comparable degree of risk. Allowed costs are allocated to customer classes based on estimates of the costs incurred by each class. The rates approved for each class are intended to recover the portion of the revenue requirement allocated to that class.

The standard cost allocation procedure used by interstate gas companies begins by dividing total costs between those that are variable (ie that vary with service volumes) and those that are fixed. Variable costs are apportioned among general customer classes on the basis of annual delivery volumes. Fixed costs are apportioned on the basis of both volumes and the average class coincidental demands during a three-day continuous peak period on the system. The proportions of costs allocated on a volumetric and a demand basis has been a contentious issue and treatment has changed over time. The "modified fixed-variable method" is most widely used at present. This allocates all fixed costs except return on equity and income taxes on a demand basis.

Methods for allocating costs between jurisdictional customers receiving transportation service between different receipt and delivery points is more varied. Typically, the service area of a pipeline is divided into rate zones. Costs are then allocated between zones using a certain rule of thumb.

When a company offers new services, it must provide the FERC with the reasons for the schedule, the basis of the proposed rate, and an estimate of expected sales and revenues. The service must be certificated under Section 7. Regulations require less data in support of small tariff adjustments and changes in terms and conditions that do not increase rates. However, major rate increases require extensive and time-consuming data filings.

While rate increases are usually permitted to take effect, years may pass before the offerings are officially approved by the FERC. Approval may involve examination of the company's books and records, a hearing, the filing of briefs, an Administrative Law Judge's decision, the filing of exceptions, oral arguments, and the rendering of a final decision. Approval may be further delayed if a party to the proceeding requests a court review of the FERC's decision.

The process can be expedited by a settlement conference in which the pipeline company, its customers, and other intervenors (e.g. state regulatory commissions) reach a compromise on key

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[4] 320 U.S. 591.

issues. Settlements are submitted to the FERC for approval. Settlement conferences afford cost savings over formal review procedures but are still quite costly.

Some steps toward streamlining this process occurred in the mid-1980's. Most notably, Order 436 permitted interstate gas companies to offer discounts from maximum rates as long as they are not unduly discriminatory and are filed at the Commission. The FERC has ruled that discounts to individual customers do not constitute undue discrimination given the assurance of fair prices provided by maximum rate regulation.

To summarize, the traditional, cost-of-service approach to ratemaking is intended to fulfil the fairness standards of the NGA in three ways. Controls on profits limit monopolistic pricing. Prudence reviews limit the costs incurred in providing service. Cost allocation procedures limit undue discrimination by basing differences in the rates charged to different customer groups on differences in the cost of serving them.

THE HEART OF THE PROBLEM

An extensive literature has developed in economics to explain why this review procedure is not ideal when rapid and extensive changes in industry practices are needed. In this section we briefly review some major findings of this literature.

Cost of service regulation involves high direct costs for utilities and their customers. These costs result from a set of related problems. One problem is asymmetric information. Regulators need extensive information to ensure conformance with legally prescribed performance standards.

Another problem is the conceptual difficulty of allocating costs between customer classes. For example, the cost of a gas transportation service depends greatly on which facilities are used to provide it, and when. It also depends on the distance shipped. The allocation of common or joint costs is a further complication. These are costs that are not incurred in the provision of specific services. Hence their allocation is inherently arbitrary.

Evaluation of the prudence of actions taken by utilities is also problematic. The proper standard is the prudence of actions undertaken given the information that was available to managers when decisions were made. It is difficult to recreate this information set and to ascertain the prudent behavior that should have followed from it.

Decisions are complicated to the extent that utilities have incentives to distort cost information to enhance profits. The utility may benefit from efforts to allocate additional costs to captive (price inelastic) customers, especially if some markets are non-jurisdictional. It may also have incentives to raise cost projections, lower volume projections, and withhold unfavorable information during prudence investigations.

The contentiousness of proceedings is another problem. Intervention in proceedings can yield significant economic rewards. Major decisions of the FERC are routinely challenged in the federal court system.

Efforts to learn about company operations and to resolve disputes are costly. Significant economic resources are thus expended on traditional rate regulation that have no counterpart in unregulated industries.

In view of these costs, it is not surprising that the parties to traditional rate regulation take steps to reduce them. The frequency of reviews is diminished. Familiar, rule-of-thumb methods are used in cost allocation and rate design. Prudence reviews are confined to conspicuous examples of dishonesty, incompetence, or misfortune.

These economy measures unfortunately have their own costs. The prudence standard can in principle require penalties for any performance less satisfactory than would occur in a competitive market. To the extent that prudence vigilance is removed, however, performance incentives are eroded by the controls on profits if profits are close to their maximum level. Between rate reviews, companies can boost profits by improving performance since current rates are unaffected by current performance. Economists call this the regulatory lag effect. However, an improved performance today can produce lower maximum rates and higher performance standards tomorrow.

The case of discounting from established rates is salient in this regard. Facing excess capacity, gas transporters can often cut rates and still earn a return over variable cost. Profits are boosted with no effect on current maximum rates. When rates are revised, however, the discount-augmented volume may inflate expectations of future volumes, producing lower maximum rates.

It is important to note that the notion of performance that is relevant here is broad. It includes the provision of market-responsive rates and services. It also includes efforts to minimize the cost of offered services by trimming input prices, using traditional inputs more shrewdly, and developing and adopting new technologies. We have chosen to emphasize marketing performance since it is here that requests for change are currently greatest. However, a long memory is not needed to recall instances in which cost minimization was an issue in the interstate natural gas industry.

In summary, customers of interstate gas companies pay a significant cost for the control of profits achieved by traditional cost of service regulation. Large regulatory costs are incurred.

Desired rates and services may not be offered. Rates for offered services may be higher than their lowest possible levels.

Section 3

THE CASE FOR RATE INDEXING

Regulators frequently confront the need to accommodate change while enforcing standards of fairness. A rational response has been to seek departures from traditional regulation. In the interstate natural gas industry, a dilemma of this type from earlier times was the regulation of wellhead prices.

In its 1954 Phillips decision[5], the Supreme Court ruled that the NGA required FPC review of the wellhead prices of gas sold in interstate commerce. Large differences existed then as now in the cost conditions of individual gas producers. However, the use of traditional review procedures to approve price increases requested by individual producers involved high direct costs.

In 1960, the Commission elected in its Phillips II opinion to divide the nation into five regions and set common prices for wellhead sales in each region. The resulting area rates were based on the costs of typical area producers. Despite vigorous producer protests, this decision was supported by the high court in the Permian Basin Area Rate Cases[6] decision.

A. THE RATE INDEXING OPTION

In more recent years, a common means of accommodating change has been rate indexing. In the U.S. railroad industry, restrictions on abandonment and on rate and service offerings for many years limited the ability of class I line-haul railroads to respond to intermodal competition. The result was chronically low rates of return and the bankruptcy of several systems. Yet railroads continued to wield market power in providing some services. A series of regulatory reforms culminated in a program under which rates for competitive services have been decontrolled whereas rates for non-competitive services are subject to indexing.

In the telecommunications industry, rapid technical change has created competitive market conditions for some services (eg long-distance) and a proliferation of desired services. Market power is still substantial in the provision of other services (eg local access). The privatization of British

[5] Phillips Petroleum Co. v. Wisconsin [347 U.S. 672 (1954)].

[6] 390 U.S. 747.

Telecom[7] in 1984 created a company with a monopoly on local access but one facing imminent long-distance competition. The Director General of Telecommunications decontrolled rates for many services and instituted rate indexing for the less competitive services.

In 1989, the Federal Communications Commission approved rate indexing for AT&T, the dominant interexchange carrier but one facing growing competition. Since then, indexing has been applied to rates of several U.S. local exchange carriers. These include Pacific Bell, U.S. West, and Rochester Telephone.

The privatization of British Gas in 1986 created a company with a virtual monopoly on gas transmission and distribution in Britain but imminent competition in merchant service to large commercial and industrial customers. The Director General of Gas Supply established an index to adjust rates for non-gas services to tariff customers for the 1987-92 period. The British Gas experience with rate indexing was the subject of an article by Branko Terzic prior to his appointment as a FERC Commissioner.[8]

Britain is now in the process of privatizing its electric power industry. Companies have been established with monopolies on power transmission and distribution. The distribution companies face imminent competition in power merchandising. Charges for transmission and distribution services will be subject to rate indexing.

The Federal Energy Regulatory Commission has long held an interest in incentive regulation schemes such as rate indexing. It commissioned a report on incentive regulation for electric utilities that was released in 1983.[9] In 1987, then FERC chairman Martha O. Hesse announced an interest in incentive regulation for the interstate natural gas industry. The Hesse initiative included an acceleration of research on incentive regulation by FERC's Office of Economic Policy (OEP). The OEP released two papers on incentive regulation in 1989.[10] One proposed a specific, voluntary

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[7] For discussions of the British rate indexing schemes see J. Vickers and G. Yarrow, Privatization: An Economic Analysis (1988) and T. Weyman-Jones, RPI -X Regulation: The Price Controls Used in UK Electricity (1990).

[8] Branko Terzic and James McKinnon, "Gas in Britain: Regulation of a Privatized Former State Monopoly" (1988).

[9] D. Goins et. al., Incentive Regulation in the Electric Utility Industry (1983).

[10] Office of Economic Policy, "Incentive Regulation for Natural Gas Pipeline Companies: A Specific Proposal With Options" and Lorenzo Brown, Michael A. Einhorn, and Ingo Vogelsang, "Incentive Regulation: A Research Report."

scheme for indexing gas transport rates and calculated a representative index with industry data.

On December 31, 1990, the FERC approved a rate indexing scheme for the Buckeye Pipe Line Company, L.P.[11] Buckeye is a large, independent oil pipeline company. This program does not call for the decontrol of its rates for competitive services.

B. WHAT IS RATE INDEXING?

The rate indexing programs used in different industries vary widely but have common attributes. In a typical scheme, base rates are set by the traditional method at the start of the indexing program. Thereafter, they are adjusted periodically — usually quarterly or annually — using an automatic rate adjustment index. Companies retain an obligation to provide traditional services unless released from obligation in an abandonment proceeding.

The formulas used to generate rate adjustment indexes are insensitive to the performance of the individual companies to which they apply. Since indexes track trends in the cost of service, reviews of indexing schemes commonly occur much less frequently than reviews under traditional regulation. Despite the diminished importance of reviews, regulators and the companies they regulate usually retain certain rights to seek modifications of the indexed rates or to abandon rate indexing.

C. BENEFITS OF RATE INDEXING

We have seen that indexing is now used to revise the rates of some of the world's largest companies. It is important to understand the benefits that regulators foresee in implementing such programs. Fortunately, rate indexing has been discussed extensively in the economics literature. We rely on this literature in the discussion that follows.

Of the many benefits theorized to flow from rate indexing, the most obvious is a reduction in the direct costs of regulation. The extent of this gain is apt to be limited initially. Large direct costs will be incurred in implementing an indexing program. Moreover, much of the apparatus for

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[11] FERC Opinion No. 360, Buckeye Pipe Line Company, L.P. Docket No. IS87-14-000, et. al., and OR88-3-000.

traditional regulation may be preserved for some time to review the impact of indexing. A case in point is the close scrutiny planned for the Buckeye Pipe Line program in its first three years. Finally, parties to regulation may still exercise their rights to challenge particularly onerous consequences of indexing.

The main benefits of indexing flow from the fact that a company's rates are substantially less sensitive to its ongoing performance than under traditional rate regulation. Managers will have stronger incentives to trim costs and to boost capacity utilization by offering market-responsive rates and services. To the extent that performance improves, it is possible for companies to enjoy higher earnings with rates below those that they would charge under traditional regulation. Indexes can be designed to promote this outcome. That is, indexes can confer the expectation that rates for traditional services will be as low or lower than those that would occur under traditional regulation.

The insensitivity of rates to a company's own performance also makes it difficult to cross-subsidize initiatives in competitive markets from the high prices charged in non-competitive markets. Moreover, new rate and service offerings to any customer class can only benefit customers (if accepted) or have no effect (if rejected).

This feature of rate indexing, together with the continuing obligation to serve, makes it possible to streamline regulation of new rate and service offerings, and of all offerings for competitive markets. Rate indexing therefore typically coincides with increased marketing freedoms for utilities. Most commonly, companies have freedom to offer discounts from the indexed ceilings. Rate indexing programs are for this reason often called *price cap* programs. Certain services may no longer be subject to rate restrictions. That is, indexing often coincides with a *partial decontrol* of a utility's rates. Approval of new rates and services may be streamlined even if they remain subject to controls.

Marketing freedoms such as these are all the more impressive when we consider that they are accomplished without dividing the rate base into core and non-core segments. Rate base divisions are inherently arbitrary and have proven difficult where attempted. The experience of the gas companies subject to the jurisdiction of the California Public Service Commission is illustrative.

From this recounting, it is easy to see why regulators have turned to rate indexing as an alternative to traditional regulation. Indexing can boost industry incentives to innovate and meet competitive challenges while protecting the interests of disadvantaged customers. Its potential benefits are largest where innovation is urgently needed and the competitive sector is substantial. Both of these conditions are characteristic of the contemporary interstate gas transportation industry. Indexing of gas transport rates would then seem to be an option worth serious consideration by interstate natural gas companies and their customers.

Section 4

RATE INDEXING IN THE U.S. RAILROAD INDUSTRY

A. BACKGROUND

Regulation of class I line-haul railroads has evolved in a manner similar to that of gas transportation.[12] Both industries began in the early nineteenth century. A local gas distribution system was established in Baltimore in 1816. The first railroad to offer regularly scheduled passenger and freight service began construction from Baltimore in 1828.

Early companies in both industries were established with the aid of charters from state or local governments. These franchises had a legal foundation in medieval British common law. Franchise holders held certain privileges and were subject to certain performance standards. These included an obligation to serve, to set reasonable prices, and to provide equal treatment to comparable customers. Governments were empowered to enforce these standards, and were granted authority over service abandonment.

In the late nineteenth and early twentieth centuries, state legislators strengthened enforcement of such standards by establishing state regulatory commissions. Regulation of interstate services required the establishment of analogous agencies at the national level. The Interstate Commerce Act of 1887 established the Interstate Commerce Commission (ICC) to regulate interstate rail freight and passenger service.

Like the NGA, the ICA contained explicit language prohibiting undue discrimination in rates and services and requiring just and reasonable rates. However, the ICA language on price discrimination was considerably stronger. In particular, the Act prohibited discrimination against persons or shippers, undue preference among regions, and the practice of charging more for a short haul than a long run.

The ICC has faced many difficulties in enforcing the ICA in the more than 100 years since its passage. The main problem has been the emergence of intermodal competition. Before 1900, railroads faced significant intermodal competition only from waterborne carriers. Subsequently, the construction of an extensive pipeline system greatly reduced the large demand for rail services by the

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[12] For more background information on rail freight regulation see T. Keeler, Railroads, Freight, and Public Policy (1983), C. Barnekov, "The Track Record" (1987), and C. Winston et. al., The Economic Effects of Surface Freight Deregulation (1990).

petroleum industry. The inland waterway system was significantly upgraded. The emergence of a large aviation industry reduced the demand for railroads as carriers of passengers and high-value goods. Even the gas industry played a role by reducing the demand for coal.

Of greatest importance, perhaps, has been the combined effect of advances in motor vehicle technology, low fuel prices, and the construction of an extensive, quality road system. Motor vehicles further reduced the potential demand for railroads as carriers of passengers and high-value goods. Truck competition was restrained by ICC regulation of trucking rates under the Motor Carrier Act of 1935. However, important classes of motor carriers (eg agricultural carriers, owner-operators, and private carriers) were exempt from ICC jurisdiction.

These developments had major cumulative effects. Demand on many routes served by railroads — particularly local ones — fell precipitously. The elasticity of demand for many services grew substantially.

The railroads needed three freedoms to respond rationally to these developments. One was to downsize the system by abandoning routes on which revenues could not cover variable costs. The second was to cut costs. The third was to market services aggressively in contested markets.

All three of these strategies were frustrated in various degrees by government policy. The ICC and state agencies were slow to approve the abandonment of passenger services and low-density routes. Before 1976, the ICC would not even approve abandonments by financially troubled carriers if they were vigorously opposed by shippers or local governments.

As for cost cutting, the industry was saddled with labor unions that aggressively fought efforts to achieve the kinds of labor economies that have occurred in most industries since World War II. Labor has responded to economy initiatives with threats of nationwide strikes. The White House and Congress have pressured the industry to avoid such strikes and have sometimes required compulsory arbitration. While significant progress occurred, the industry continued to suffer from overstaffing and outmoded work rules.

Regarding rate flexibility, the ICC for many years discouraged rail rate cuts as a violation of the just and reasonable standard of the ICA. Policy on rate cuts moderated in the 1950's. In the inflationary 1970's, cuts in real rates could be affected by requesting small rate increases. However, seasonal and other short-run discounting from maximum rates was uncommon.

The ICC continued to discourage revisions in relative rates to reflect differences in the cost of service. Each change in relative rates had to be justified by extensive cost evidence. Cost allocation is at least as problematic for railroads as for gas transporters. Simple cost allocation methods were the norm. Proceedings to change rates were typically long and costly. Rate changes could not be implemented until all challenges were overcome.

These regulatory barriers had the result that rate increases were generally across the board. Relative prices were thus frozen into historic relationships bearing little resemblance to costs. In particular, rates on low density routes were commonly well below the cost of serving these routes. Railroads often charged the same rates to exporters regardless of which port they used. Similar rates were charged to grain elevators of different size despite large differences in the cost of service.

Unfortunately for railroads, the array of rates resulting from these policies was insufficient to recover their cost of service despite significant productivity growth. By the mid-1970's, the KATY, Penn Central, and several smaller northeastern carriers were bankrupt. The Rock Island and Milwaukee Road were nearing bankruptcy.

The federal government has instituted a number of measures since World War II in response to this gathering crisis. The Transportation Act of 1958 liberalized restrictions on rail rate cuts and guaranteed loans for troubled carriers. A liberalized abandonment policy for passenger services culminated in the Rail Passenger Service Act of 1970, which created Amtrak. The Regional Rail Reorganization Act of 1973 created a support structure for northeastern railroads that led to the creation of Conrail. The Railroad Revitalization and Regulatory Reform Act of 1976 provided additional subsidies and encouraged more relaxed regulation of rates and abandonment. The ICC provided additional assistance with a merger policy that supported survival of rail services at the expense of competition. In particular, parallel mergers were approved between large carriers that greatly increased rail service concentration in some regions.

A climate for more dramatic reform in rail freight regulation developed in the late 1970's, for several reasons. Bankruptcies and low earnings continued. The ICC's interpretation of the 4-R Act greatly limited its potential impact on rate flexibility. At the same time, the political climate for deregulation was improving. Deregulation of domestic air transportation in 1978 was well received.

The Carter Administration appointed two pro-deregulation economists to the ICC in 1979. The new Commission instituted a number of reforms, including greater use of contract rates. Recognition of the benefits of liberalized rail freight regulation was widespread. The main opponents were politically powerful coal shippers who feared adverse consequences from total rate control.

B. THE STAGGERS RAIL ACT

In 1980 the Staggers Rail Act was passed by Congress. Its basic premise, stated in Section 2, is that ICC regulation had reduced the efficiency and threatened the financial viability of class I line-haul railroads despite a major decline in their monopoly power. The Act rectified this situation by providing the necessary authority for greatly relaxed regulation of abandonments and rates.

The most striking feature of the Staggers Act is the high degree of rate flexibility that it allows. Railroads now have complete price flexibility in competitive markets. That is, the Act effected a partial decontrol of rail service rates. To limit ICC discretion in determining which markets are competitive, the Act specifies a test for determining conclusively when market dominance does not exist. The test is based on the ratio of Total Revenue to Total Variable Cost. In 1980, the first year of the Staggers Act, any ratio less then 1.6 precluded a finding of market dominance. The ratio increased gradually to 1.75 in 1984, where it has remained.

A rate exceeding the 1.75 ratio does not imply that the railroad has market dominance. But in such a case the burden of proof is on the railroad to demonstrate that it does not have market dominance. The ICC must then determine whether market dominance exists. Only if market dominance is found does the reasonableness of the rate become an issue.

The Act called for continued ICC review of changes in rates for services where market dominance persisted. A level is specified below which no rate can be found unreasonable. (Above that level unreasonableness is not presumed.) The zone of presumed reasonableness relies on the notion of a base rate. Any rate that was in existence at the promulgation of the Act, and was not challenged during the ensuing 6 months, became a valid base rate. The ICC was charged with developing an Index of Railroad Costs. The rate of change in this index, called the Rail Cost Adjustment Factor (RCAF), has been multiplied by each base rate to obtain an "adjusted base rate." Any rate that does not rise above the adjusted base rate is free from the threat of Commission suspension.

Rail carriers are prohibited from setting rates below a "reasonable" minimum level. But we are not aware of any instance in which this provision has been binding. Any rate that contributes to the going value of the firm (i.e., above short-run marginal cost) is presumed to be reasonable. The burden of proof is on the party challenging a rate to demonstrate that it is too low. Thus, this provision does not appear to be any more restrictive than the provisions of the antitrust laws that prohibit predatory pricing.

The Act contained other provisions for increasing rates for captive shippers more rapidly than increases in the RCAF Index. These provisions applied to any railroad that was deemed to be "revenue inadequate" (i.e. a railroad with a rate of return that was less than its cost of capital). However, these increases are not immune from challenge.

The Act also grants extensive freedoms regarding the structure of rates. In particular, contract rates are allowed for all services, including those to captive customers. These are described below.

C. OPERATION OF THE RATE ADJUSTMENT INDEX

The initial RCAF Index was essentially an input price index. The rate of change in the index was a weighted average of the rates of change in the prices of labor, capital, and materials purchased by U.S. railroads.[13] The price increases were measured on a nation-wide basis, and the Index was updated quarterly.

Shippers complained that the index was inequitable since it did not reflect improvements in railroad productivity. They argued that a productivity adjustment was needed to make the RCAF an index of railroad cost. The railroads resisted this notion. The ICC did not seem inclined to re-examine the issue until ordered to do so by the D.C. District Court. Beginning in 1982 the ICC conducted a series of hearings on the productivity issue. These culminated in a 1989 order[14] creating an "adjusted" RCAF Index. The adjustment is based on the Index of Railroad Productivity first proposed in 1982 by Douglas W. Caves and Laurits R. Christensen. To a first approximation the index reflects nationwide changes in railroad ton-miles per unit of total railroad resource use (capital, labor, and purchased inputs combined).

Under the revised index, increases in industry productivity produce a downward adjustment in maximum rates. Since all companies in the industry are subject to indexing, the index effects a sharing of the benefits of improved the performance from rate indexing with captive

[13] Data on railroad prices prior to the passage of the Staggers Act were not required to implement the RCAF Index. The RCAF Index simply reflects the ratio of this quarter's costs to those of the previous quarter.

[14] <u>Ex Parte</u> No. 290 (Sub-No. 4), Railroad Cost Recovery Procedures - Productivity Adjustment.

shippers.

D. IMPACT OF THE STAGGERS ACT ON INDUSTRY PERFORMANCE

We have seen that the Staggers Act allowed railroads virtually complete pricing freedom in competitive markets and established an index to adjust rates in less competitive markets. The railroads responded by turning their focus from fighting regulatory battles to competing in the transportation marketplace. The results have been striking.

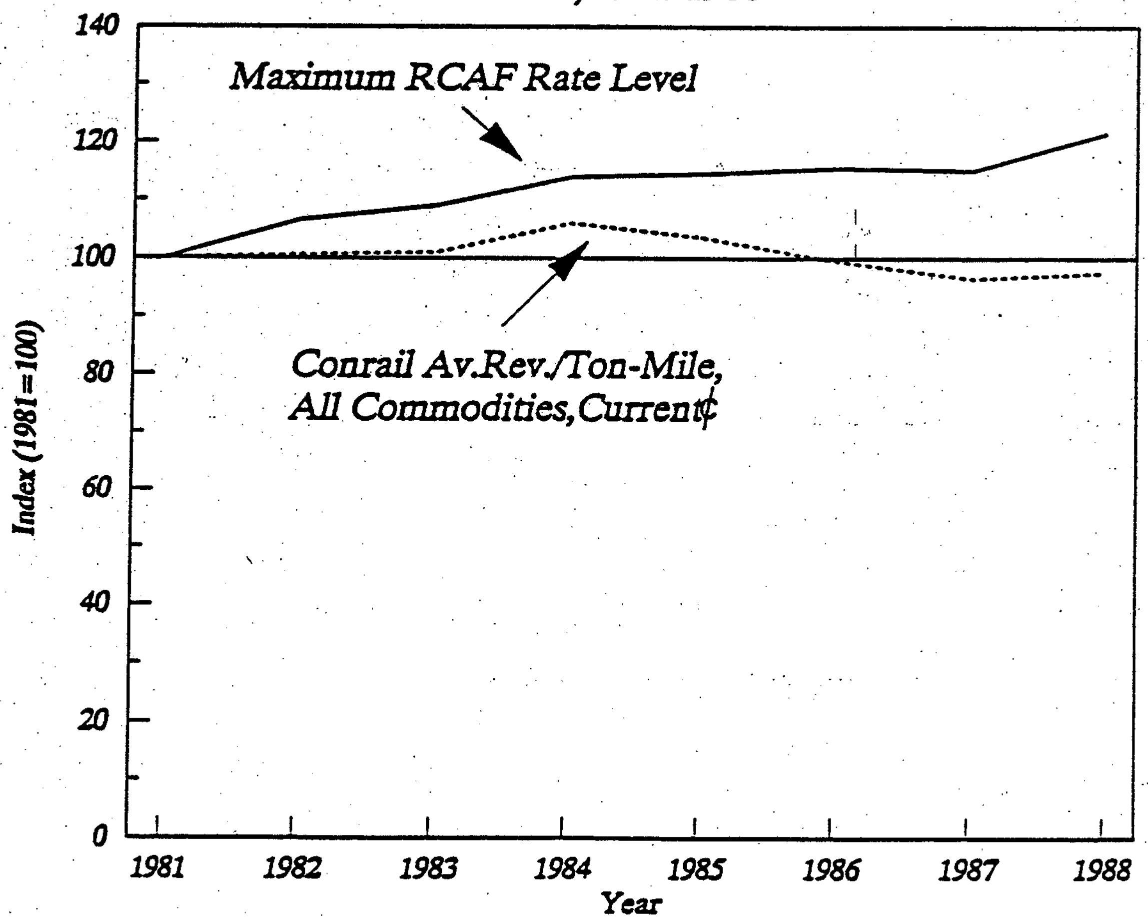
Most dramatic, perhaps, has been the move away from traditional rates toward contract rates for both rate-regulated and competitive services. More than half of all rail traffic now occurs under contracts. These frequently contain provisions governing such quality-of-service attributes. Provisions for timely service that are essential for "just-in-time" inventory management are now common. Minimum and maximum volume provisions for specified time periods help railroads effect cost-reduction plans. Contracts have also encouraged the construction of specialized loading facilities.

The effect of the Staggers Act on rate levels is difficult to assess due to the proliferation of contract rates and changes in the commodity-composition and average distance of hauls. Apparently, rates for coal traffic have risen on average while rates for grain traffic have fallen. One study found that the effect of the Act on the overall level of rates has been insignificant.[15] This finding is fairly remarkably when we recall that the RCAF operated without a productivity offset until 1984. One certainty is that the average rates for most railroads (including competitive and market dominant traffic) have grown far less than the RCAF Index. See, for example, Figure 1, which was submitted by Conrail in 1989 testimony to the ICC.

In evaluating the benefits of the Staggers Act to shippers we must also consider changes in the

[15] H. McFarland, "The Effects of United States Railroad Deregulation on Shippers, Labor, and Capital" (1989).

Figure 1
CONRAIL AVERAGE RATES, ALL COMMODITIES VS. RCAF, 1981-1988



quality of service. One study[16] reports that rail's mean transit time has decreased as a result of the Staggers Act by nearly 30%. The authors valued the benefits to customers from the better service that would have occurred from instituting reforms earlier at almost $5 billion in 1977 alone. This result is striking since the study did not consider the full range of service improvements. For example, it did not quantify the benefit of reported improvements in the time between a shipper's request for service and the arrival of a carrier.

The impact of the Staggers Act on the efficiency of the railroad industry has been evaluated in productivity studies. A productivity index for the railroad industry is depicted in Figure 2. A rising productivity trend can be noted during the 1970's, as was mentioned previously. All productivity growth during the 1980's can therefore not be viewed as a benefit of the Staggers Act.

Figure 2 suggests, however, that since passage of the Staggers Act railroad productivity growth has accelerated. From 1980 through 1988 the compound annual rate of increase was 3.5% per year. From 1982 through 1988 the rate was 5.5% per year. These figures are very high by any standard; productivity growth for the entire U.S. economy is typically less than 1% per year. In fact, in the 1980's railroad productivity growth has been similar to that of the telecommunications industry.

Labor economies appear to have been one reason for the productivity growth. The decline in railroad labor is depicted in Figure 3. A study by the Association of American Railroads estimates that work rule concessions and other labor economies resulting from the Staggers Act have reduced average labor costs by at least 20%. Employment has fallen substantially. Almost half of the decline in the operating expenses that occurred between 1980 and 1985 was due to lower labor expenses.[17] Despite these gains, it is important not to exaggerate the importance of labor economies in the industry's productivity growth since the Staggers Act. Chronically low rates of return gave the industry strong incentives to cut labor costs prior to the Act. The rate of labor force decline after 1980 is very much in line with the rate before 1980.

Figure 4 depicts the change in ton-miles of Class I railroads from 1948 through 1988. It can be seen that the industry rebounded from the recessions of the early 1980's to post traffic gains very much in line with the trends of the 1970's. This is an impressive accomplishment, since the Motor Carrier Act of 1980 removed many barriers to trucking industry competition. The ability to increase

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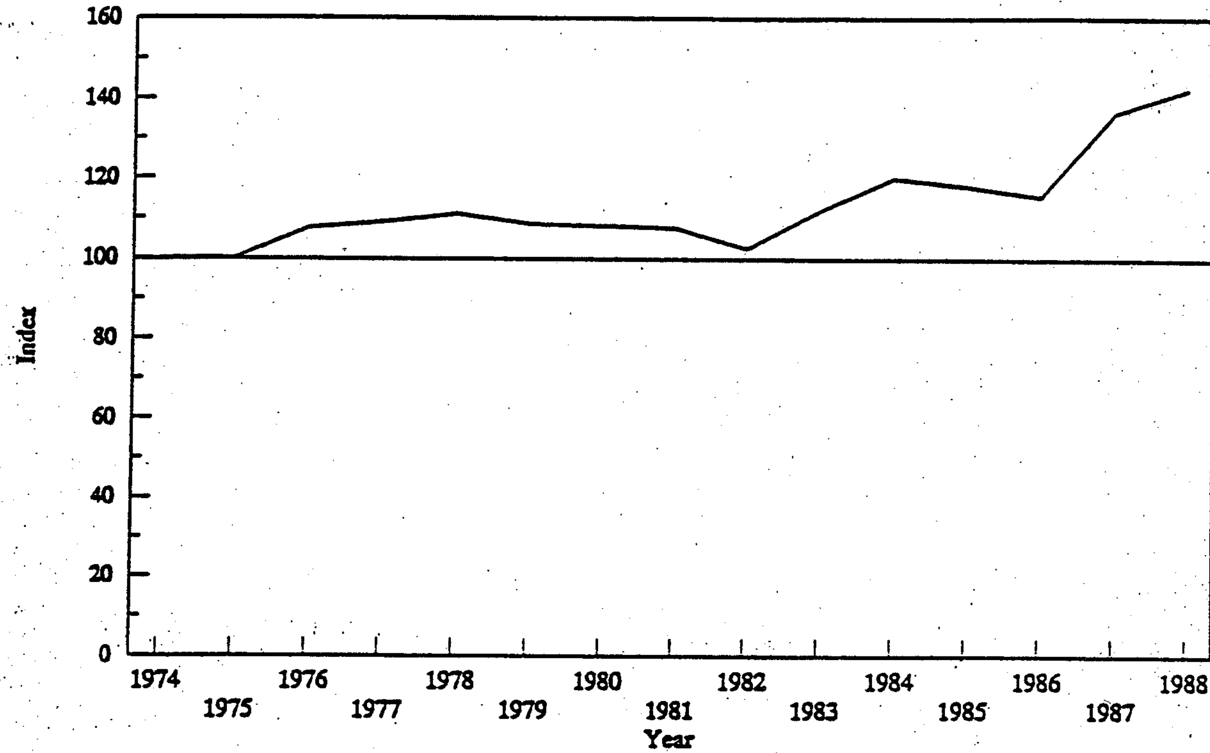
[16] Winston et. al. ibid.

[17] C. Barnekov, ibid.

Figure 2

PRODUCTIVITY INDEX
CLASS I U.S. RAILROADS



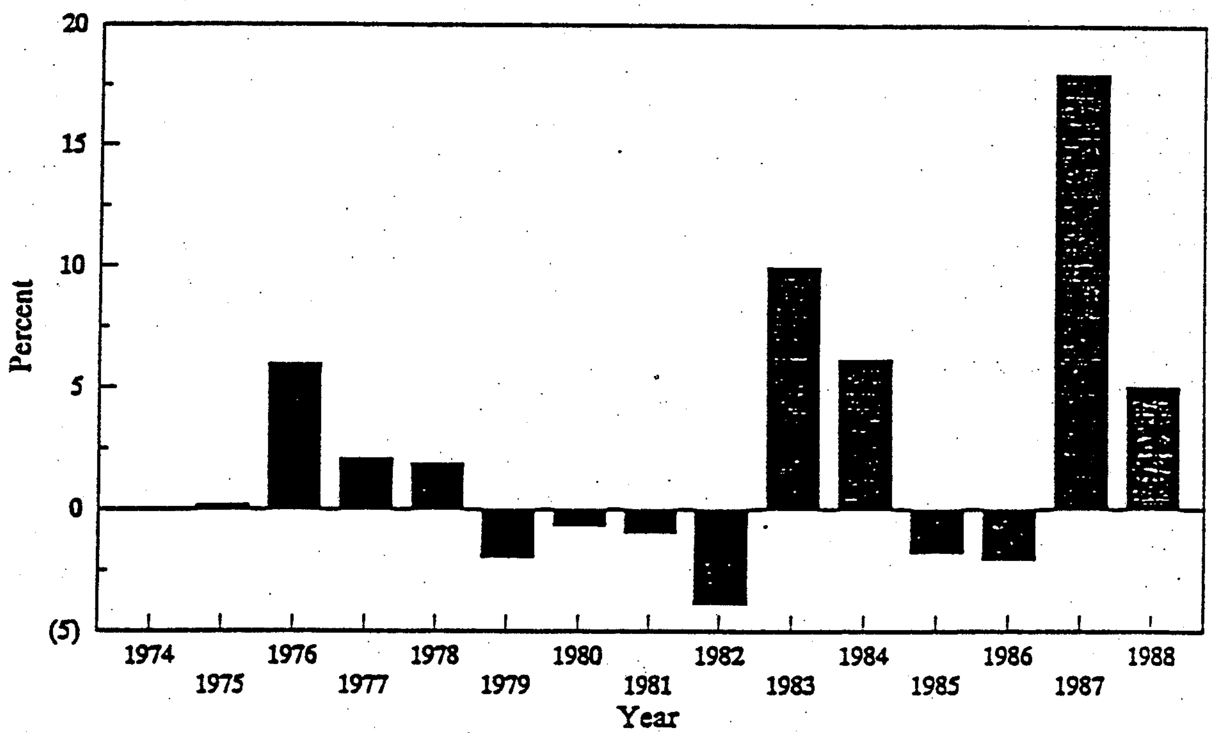


Figure 3
FULL-TIME-EQUIVALENT EMPLOYEES-U.S. RAILROADS

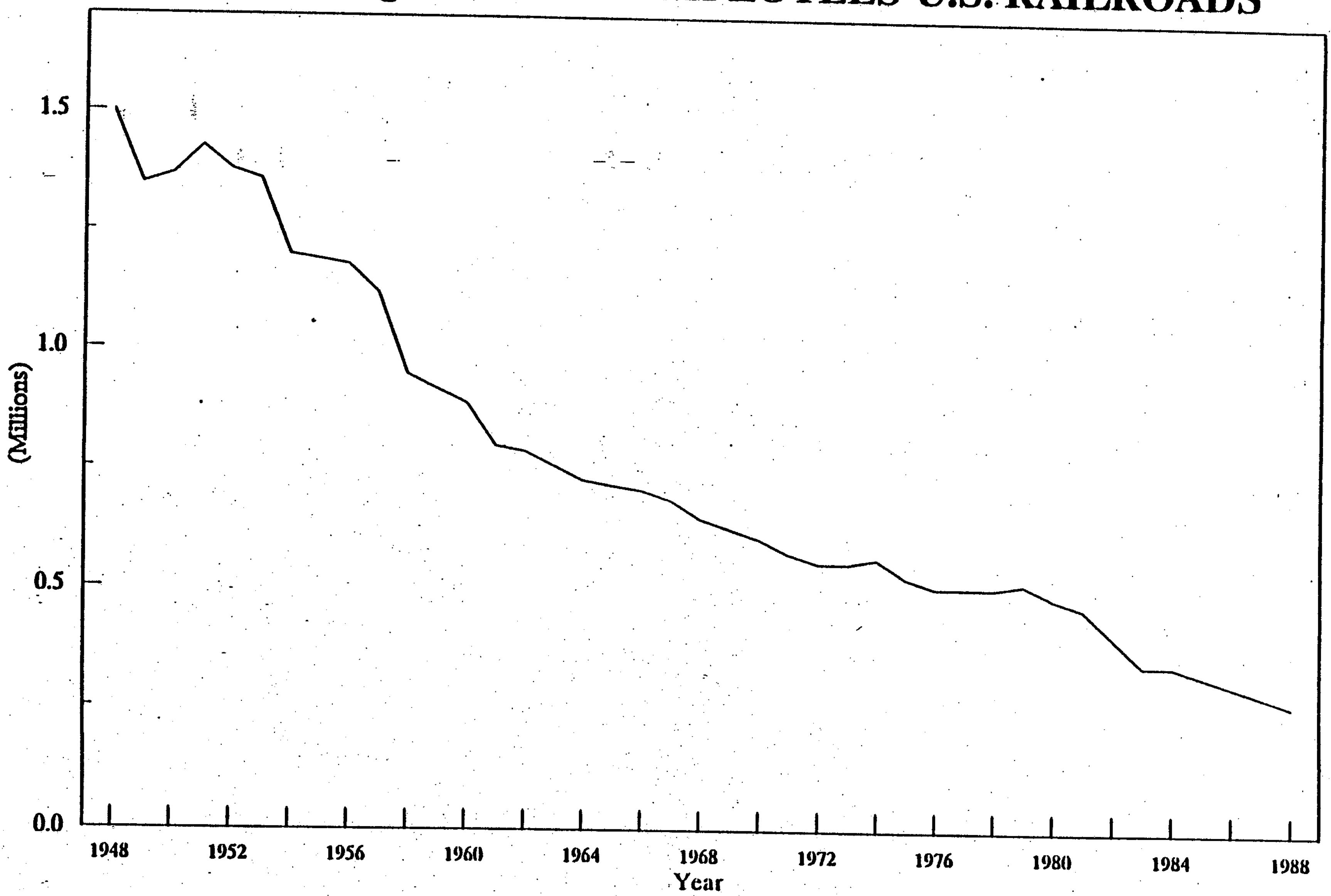
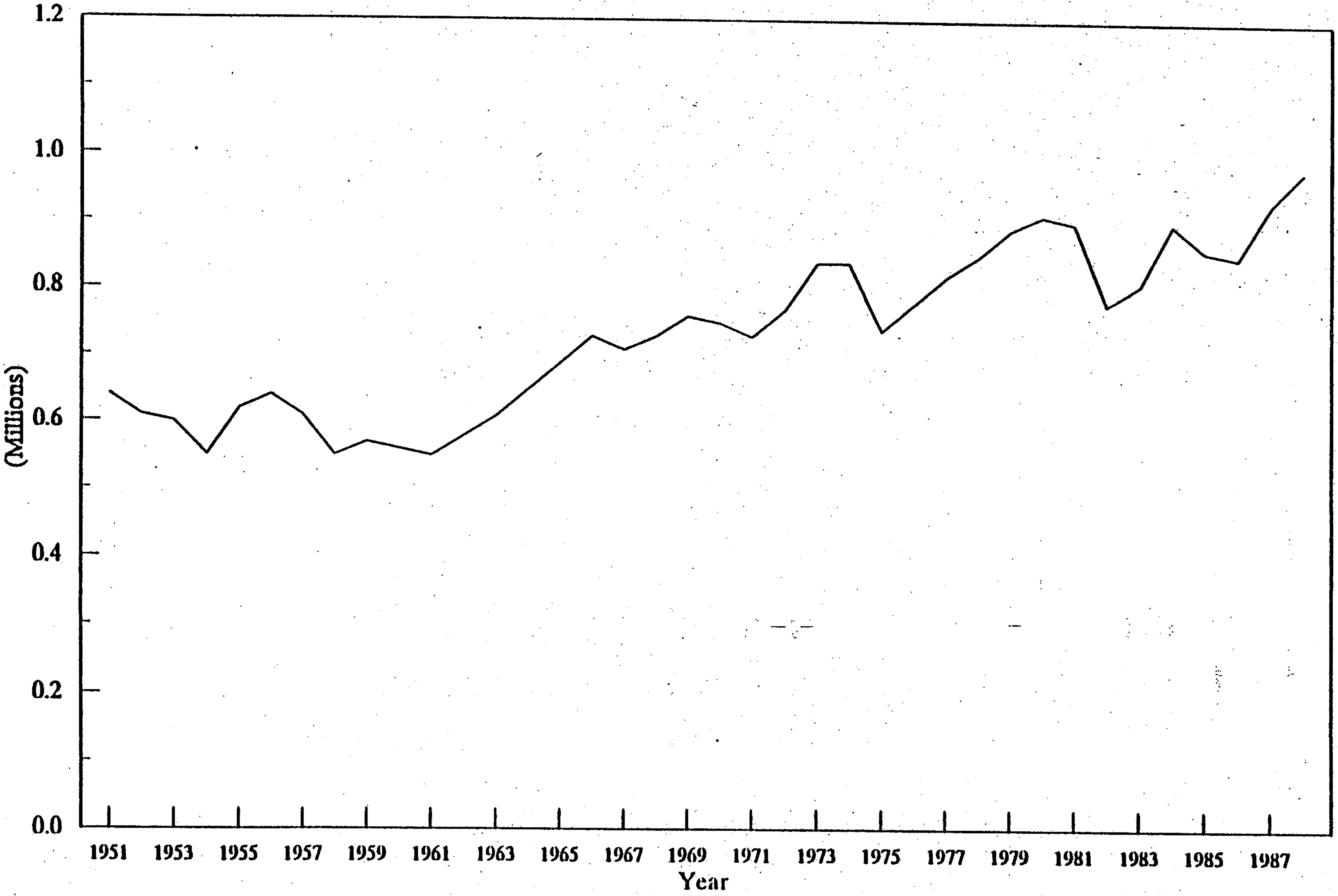


Figure 4
TON MILES OF CLASS I U.S. RAILROADS



traffic can be attributed in part to the lower rates made possible by labor force economies. However, a major factor has been improvements in service and more aggressive marketing.

To summarize, the Staggers Act instituted a comprehensive reform of rail freight regulation in an effort to boost industry profitability and unleash competitive market forces. While the effect of the Act on general rate levels is unclear, railroad customers have benefitted substantially from a more market-responsive array of rates and services. The rate indexing schemes, as revised, will ensure that these changes will not occur at the expense of captive shippers.

Section 5

ISSUES IN THE DESIGN OF RATE INDEXING PROGRAMS

Regulators confront a number of issues in the design of a rate indexing program. The resolution of these issues has an effect on program success. We identify here some of the important issues and provide a critical discussion of the options. We also indicate how these issues have been resolved in some operating indexing programs and in the FERC OEP proposal.

A. RATE INDEX FORMULA

Two kinds of rate adjustment indexes are presently in large-scale use. The first, which we will call a "railroad style" index, is that used by class I line-haul railroads. This approach was also used in the FERC OEP proposal to index interstate gas transportation rates.

We will call the second kind of rate adjustment index in large scale use a telecommunications-style index. It was first used in the indexing program for British Telecom and has since been used in the programs for British Gas and the British electric utilities. In the United States, it is used in virtually all of the programs for telecommunications companies.

While these indexes differ fundamentally, they are both rationalized by a basic theoretical result: that the traditional rate adjustment process can be approximated by an internal rate adjustment index. We now consider this line of reasoning. There follows an explanation of how the established indexing approaches follow from this reasoning.

HOW INDEXES APPROXIMATE TRADITIONAL RATE ADJUSTMENTS

Under traditional cost of service regulation, a utility earns only a competitive rate of return on its capital investment. This is achieved by setting rates to recover a revenue requirement that equals its cost of service. The cost of service includes a return on capital at a rate like that earned in the long run in comparable unregulated industries. It is then approximately true that the percentage change in the revenue requirement of a utility equals the percentage change in its cost of service in each period, t:

$$\%\ \text{change in revenue}_t \cong \%\ \text{change in cost of service}_t \tag{1}$$

A period may be taken to mean a quarter or a year.[18]

Consider, now, that the cost of each kind of input used by a utility is the product of the quantity used and the price (unit market value) of the input. It follows that the cost of service can be decomposed into an input price index and an input quantity index[19] such that:

$$\begin{aligned}&\%\ \text{change in cost of service}_t\\ &\quad = \%\ \text{change in input price index}_t + \%\ \text{change in input index}_t\end{aligned} \tag{2}$$

The percentage change in the cost of service is the sum of the percentage changes in the input price and quantity indexes.

Similarly, the revenue from each kind of service offered is the product of the volume sold and the unit price of the service. It follows that the total revenue requirement can be decomposed into a rate (output price) index and an output quantity index such that:

$$\begin{aligned}&\%\ \text{change in revenue requirement}_t\\ &\quad = \%\ \text{change in rate index}_t + \%\ \text{change in output index}_t\end{aligned} \tag{3}$$

The rate of change in the revenue requirement is the sum of the rates of change in the output price and quantity indexes.

Relations (1), (2), and (3) imply that adjustments in output prices conform to the following relation:

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[18] Here "≅" denotes "approximately equals".

[19] Relations (2) and (3) hold exactly for indexes of the Divisia form. They are derived by taking the logarithm of the revenue requirement (or cost of service) and differentiating with respect to time. In practice, these continuous-time indexes must be replaced by discrete-time indexes that measure the percentage change between discrete periods of time such as a quarter or year. The percentage change in the value of a variable is taken to mean the logarithmic rate of change between its value this period and last.

% change in rate index$_t$

$$\cong \text{\% change in input price index}_t - (\text{\% change in output index}_t - \text{\% change in input index}_t). \quad (4)$$

The difference between percentage changes in an output and input index is the percentage change in a *total factor productivity* index. It follows that

% change in rate index$_t$

$$\cong \text{\% change in input price index}_t - \text{\% change in productivity index}_t. \quad (5)$$

Relation (5) tells us that the percentage change in the rate index is approximately equal to the difference between the percentage changes in an input price index and a productivity index. It follows that the traditional rate adjustment process can be approximated by a index consisting of subindexes for input prices and productivity.

RATE ADJUSTMENT INDEXES

The index just described is *internal* in the sense that it adjusts a utility's rates on the basis of its own input price and productivity performance. Success in trimming input prices or in boosting productivity would cause an internal rate adjustment index to turn down. A rate adjustment index used in incentive regulation must, in contrast, be insensitive to the current performances of individual companies. It must also confer the expectation of rate adjustments that utilities and their customers can live with. The railroad and telecommunications-style indexes accomplish this in different ways.

Railroad-Style Indexes

We have noted that the Staggers Act of 1980 decontrolled rates for many rail services and gave railroads a free hand in offering new rates and services. Indexing was instituted for the rates of services offered in less competitive markets. The RCAF can be summarized in the following relation:

$$\% \text{ change in rate ceiling}_t^{company}$$

$$= \% \text{ change in input price index}_t^{industry}$$

$$- \% \text{ change in productivity index}_t^{industry} \, . \tag{6}$$

Although similar to the index in relation (5), the input price and productivity indexes for the company are replaced with those for the entire railroad industry. The index thus insures that changes in the indexed maximum rates of individual companies are consistent with normal long-run profits for the *industry*.

As noted earlier, a key feature of the RCAF Index is that it measures the input price and productivity performance of companies that are subject to rate indexing. Improved industry performance due to stronger incentives thus results in a higher productivity offset that slows the increase in maximum rates to captive shippers. The RCAF Index thus helps captive shippers to share in the benefits of the Staggers Act.

An issue in the design of railroad-style indexes is the timeliness of the productivity adjustment. In principle, the productivity index can measure the change in productivity occurring during the same period as the input price index. This approach results in what we will call an unsmoothed rate adjustment index.

Unsmoothed indexes are not used in practice for several reasons. Most notably, much of the data needed for a good productivity index is available only with a two-year lag. Good input price indexes, on the other hand, can be constructed from more recent data. It is common, then, to adjust maximum rates with indexes of current input price changes and prior productivity changes.

Since productivity is volatile, it is also common to smooth the productivity index by using a moving average of the annual percentage changes in productivity in recent years. The RCAF Index, for instance, now uses as a productivity offset a two-year old average of productivity growth over the previous seven years. This approach has an added advantage to shippers of delaying the pass-through to rates of the productivity gains from rate indexing.

"Telecommunications-Style" Adjustment Indexes

We begin our explanation of the telecommunications-style indexes by noting that some utilities (eg AT&T, British Gas, and British Telecom) do not coexist with a large number of comparable firms, as U.S. railroads do. Accordingly, a different kind of rate adjustment index was needed that did not require comparable-firm data.

Think of a national economy like that of the U.S. as a huge competitive industry. As such, it earns only a competitive rate of return in the long run. We may then posit that inflation in the economy's output prices conforms to the following relation, which is analogous to relation (5):

$$\begin{aligned}&\%\text{ change in output price index}_t^{US}\\ &\quad\cong \%\text{ change in input price index}_t^{US}\\ &\qquad - \%\text{ change in productivity index}_t^{US}\end{aligned} \tag{7}$$

Suppose, now, that the rate of input price inflation in the U.S. economy is similar to the percentage change in a company's input prices.

$$\%\text{ change in input price index}_t^{company} \cong \%\text{ change in input price index}_t^{US} \tag{8}$$

Relations (7) and (8) then imply that:

$$\begin{aligned}&\%\text{ change in input price index}_t^{company}\\ &\quad\cong \%\text{ change in output price index}_t^{US}\\ &\qquad + \%\text{ change in productivity index}_t^{US}\end{aligned} \tag{9}$$

Moreover, the rate of change in the rate index of the company would conform to the following relation:

$$\begin{aligned}&\%\text{ change rate index}_t^{company}\\ &\quad\cong \%\text{ change output price index}_t^{US}\\ &\qquad - (\%\text{ change productivity index}_t^{company} - \%\text{ change productivity index}_t^{US})\end{aligned} \tag{10}$$

The percentage change in the rate index of the company is approximated by the difference between the percentage change in an economy-wide inflation index and a certain percentage productivity offset. The percentage productivity offset is the difference between the current productivity growth rates of the company and the economy.

We seek now a rate adjustment index that confers an expectation of future rate adjustments that the company and its customers can live with. A telecommunications-style index can accomplish this by replacing the productivity offset in (10) with a *fixed* percentage offset. This offset reflects the expectation at the start of the indexing program of the difference in the average productivity growth of the company and the economy during the rate indexing program. An expectation of this type is often based in on the measured difference in the productivity trends of the company and the economy in recent years. An adjustment may then be made for expected acceleration in the company's productivity growth under the stimulus of rate indexing.

A major issue in the design of a telecommunications-style index scheme is the choice of a subindex for U.S. output prices. The following are obvious candidates:

- Fixed-weight price index for GNP
- GNP price deflator
- Consumer (retail) price index
- Producer price index

The fixed-weight price index for GNP provides the basis for the AT&T rate indexing program. The GNP price deflator is used in the Buckeye Pipe Line program. Retail price indexes are used in the British programs. In our view, the GNP price indexes best represent the general trend of output prices in the U.S. economy.

A COMPARISON OF THE MAJOR INDEXING APPROACHES

A comparison of the major indexing alternatives reveals that neither is decidedly more appropriate for the interstate gas transportation industry. The main advantage of a railroad-style index is that it would be expressly designed to track trends in the costs of the gas transportation industry. The input price index would be specific to the industry. The productivity offset would respond over time to change in the industry's productivity performance.

One shortcoming of the railroad-style index is its complexity. The ongoing measurement of input price and productivity trends is a non-negligible task. Small details of the indexing approach may be disputed by interested parties.

Another shortcoming is that it may not be possible to base a railroad-style index for gas transporters on the performance of companies subject to indexing. Absent such a coverage, the index will not reflect an improvement in performance due to the rate indexing incentives. It therefore does not ensure that benefits of indexing are passed through to captive customers.

At the extreme, where only one interstate gas company is subject to indexing, a railroad-style index measures the performance of typical firms under traditional cost of service regulation. While this is a useful benchmark, the volunteer company may be asked to propose an additional rate discount to facilitate sharing. A additional percentage offset like that found in telecommunication-style index is one possibility.

Telecommunications-style indexes are largely free of these faults. Productivity research may be warranted initially to help establish the percentage offset. However, the subsequent operation of the index relies only on widely-published inflation data. Since the productivity offset is specific to the firm, data from other companies subject to indexing is not needed to effect a sharing of indexing benefits.

B. OTHER ISSUES

NATIONAL VS. REGIONAL INDEXES

An important issue in the design of railroad-style indexes is whether they should be regional or national in scope. The RCAF Index is national in scope. So too is the index proposed by the FERC OEP. In principal, however, the "industry" may be defined as a group of companies operating in a certain region.

In the interstate natural gas industry national indexes have an advantage, discussed below, of being more readily calculated from existing data. However, national indexes make rate adjustments consistent with normal long-run profits for the industry nationwide. To the extent that the industry's performance differs across regions, this approach may produce regional windfall gains and losses to companies and their customers.

This issue is not of major concern if the program applies to companies nationwide since gains in some regions will offset losses in others. However, the issue may well surface if volunteer companies propose to adjust rates for indexed services using a national index. They may be challenged to demonstrate why their future price and productivity performance should be like that of the nation. Failing such a demonstration, they may be asked to revise their proposed index in a manner that provides an expectation of shared benefits.

FREQUENCY OF REVIEWS

The frequency of reviews varies substantially among current rate indexing programs. Regularly scheduled rate reviews have been abandoned for class I line-haul railroads. More commonly, an interval of three to five years is scheduled at the start of the indexing program before the program is reviewed.

The frequency of reviews plays a key role in the strength of the regulatory lag effect. As reviews become less frequent, incentives to improve performance strengthen. We are comfortable with a cancellation of scheduled rate reviews, with the exception of occasional refinements to the index itself. We also feel that an interval of less than five years reduces the net benefits of an indexing program substantially. Since three-year intervals between reviews are presently common for interstate gas companies, we propose a minimum inter-review period that is double this, or six years.

REVIEW METHOD

Indexing programs are commonly vague as to the methodology to be used in regularly-scheduled program reviews. The method employed has a major bearing on incentive effects. If companies feel that performance under the first indexing period sets the standard for the next one, incentives will be greatly reduced.

The lack of a clear review procedure gives regulators more discretion during reviews, while giving companies some hope of keeping efficiency gains. On the other hand, inexplicitness may prompt companies to assume that adjustments to the program will be extremely sensitive to their recent performance.

In light of these remarks, we feel that the resolution of the issue contained in the FERC OEP proposal is worth serious consideration. They suggest periodic rate adjustments based on a sharing of cost-saving gains. In their words,

> a fraction of the difference between the indexed and actual costs would be added to other accounting costs to estimate the overall cost of service. Thus, if accounting cost is less than

the indexed cost, the pipeline would share its profits with ratepayers. If actual accounting cost exceeds the indexed cost, then the pipeline would share its loss with ratepayers.[20]

[20]Brown et. al. op. cit, p. .

Section 6
FASHIONING INDEXES FOR INTERSTATE GAS TRANSPORTATION RATES

Rate indexing is a promising alternative to the FERC's current method for regulating gas transport rates and services. The construction of railroad-style and telecommunications-style indexes are based on indexes of industry input productivity trends. In this section we address the practical problem of developing the supporting indexes.

The plan for the section is as follows. In part A we enumerate the basic steps in the calculation of rate adjustment indexes. In later parts we discuss the component output, input price, and input indexes in turn.

A. BASIC STEPS IN INDEX CONSTRUCTION

RAILROAD-STYLE INDEXES

Under railroad-style indexing, we have seen that the percentage change in maximum rates[21] for certain services equals the difference between the percentage changes in an industry input price index and a productivity offset. The productivity offset is based on recent trends in industry inputs and outputs. Thus, a railroad-style rate adjustment index has subindexes for industry input prices, input quantities, and outputs.

The basic steps in the calculation of a railroad-style adjustment index are as follows:

1. Construct the necessary subindexes

   input price index^{industry}
   output index^{industry}
   input quantity index^{industry}.

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[21] We sidestep here the issue of whether the index applies to individual rates or the average rate of the company. An average rate approach permits prices for some services to rise faster than the index so long as prices for other services rise less fast. This flexibility has advantages, but reduces the protection afforded to captive customers.

2. Use the input price index to measure the current percentage change in the industry's input prices.
3. Use the input and output indexes to measure the percentage changes in the industry's productivity over a recent sequence of years.
4. Use the results of step (3) to calculate the <u>average</u> percentage change in productivity during this sequence of years.
5. Calculate the percentage change in maximum rates using the results from steps (2) and (4).

TELECOMMUNICATIONS-STYLE INDEXES

Under telecommunications-style indexing we have seen that the rate of change in the rate adjustment index equals the difference between the current inflation rate and the percentage offset. The basic steps in the construction of such an index are as follows:

1. Select an index of economy-wide inflation.
2. Obtain from this index the current inflation rate.
3. Construct the component indexes for the measurement of company productivity.

$$\text{input index}^{\text{company}}$$
$$\text{output index}^{\text{company}}$$

4. Use these indexes to calculate the percentage changes in company productivity over a recent sequence of years.
5. Compare the results in (4) to the long run growth rate in economy-wide productivity. Adjust as necessary to obtain a percentage offset.
6. Calculate the percentage change in average rates using the results from steps (2) and (5).

B. OUTPUT INDEX

The percentage change in a conventional output index is a weighted average of the percentage changes in the volumes of various services provided. The weight assigned to each output category is the share of that category in total revenues. The construction of a conventional output index thus requires detailed data on revenues and volumes sold.

The desired detail is a breakdown of these variables by important output categories. The main distinctions between the services of gas transporters are between service functions, quality of service, and distance served. The major service functions are gathering, transmission, storage, and merchandising. Interruptibility is the major quality attribute. The distance served differs greatly for gas-field short-hauls and transcontinental shipments.

LIMITATIONS OF FERC DATA

The primary source of data on revenues and service volumes is the Form 2 reports that interstate pipeline companies file with the FERC. Certain data from these reports are published in the Energy Information Administration's (EIA's) Statistics of Interstate Natural Gas Pipeline Companies. Results by kind of service are reported separately in the Statistics only for sales and unbundled transportation deliveries. There is an extensive breakdown of deliveries by customer type for sales but not for transportation services. There is no published breakdown of volumes on the basis of interruptibility or distance shipped. In effect, then, published data do not provide the basis for a detailed output index.

The FERC OEP used interstate throughput as its output index in its rate indexing proposal. Interstate throughput is the sum of sales and unbundled transportation deliveries. This variable is not a desirable measure of interstate gas transportation output. Its most important shortcoming is its insensitivity to change in the average distance shipped. A shipment of one mile counts the same as one of a thousand miles. Throughput also fails to distinguish between deliveries between interstate companies and those to companies outside the interstate system. A shipment involving the services of several interstate companies can thus be counted several times.

The importance of these shortcomings can be illustrated by a look at data for the 1980's. In that decade, take-or-pay problems and FERC's policies to resolve them[22] stimulated shipments involving the use of multiple interstate companies. Interstate throughput has consequently trended upward since 1977 despite a downward trend in consumption. Its use in a rate indexing scheme might then result in price adjustments much less appropriate than would occur using a distance-

[22] Examples are the special marketing programs and Order 436/500.

sensitive index.

A PRICE-DISTANCE MEASURE OF OUTPUT

A major accomplishment of this project has been to devise an alternative output index that adjusts for distance shipped using only regularly published data. The index measures the output of a gas transportation system defined as all gas transporters (except for those in Alaska and Hawaii) that fill out Form EIA-176: the "Annual Report of Natural and Supplemental Gas Supply and Disposition." The respondents include many distribution and transmission companies that are connected with, but not part of, the interstate system.

The output of a gas transporter is defined as the action of receiving gas at one point in the system and delivering gas at another point. This is a reasonable assumption for the transport of a homogeneous commodity like processed natural gas. In practice, gas transporters deliver the same molecules of gas to a requested location that they receive from a customer only by chance. To do otherwise would be to miss opportunities to minimize costs.

Under this approach, a given change in the volume shipped from Texas to New York will have a greater impact on output than the same change in shipments between points in Texas. If a certain flow of Texas gas were diverted from Houston to Buffalo and all other volumes were unchanged, output would rise. More generally, output would be sensitive to fluctuations in shipments to regions far from gas exporting states such as California, the upper midwest, southern Florida, and the northeast. These are regions in which gas consumption is at once large and variable due to its sensitivity to swings in the prices of competing oil products.

Data are not published on shipments between various points in the transportation network. But there are state-level data on the volumes of marketed production and on deliveries by gas transporters to residential, commercial, industrial, and electric utility customers. We also have state-level proxies for the market value of a unit of gas at delivery and receipt points. The average wellhead price of gas is a good proxy for market value at receipt points. The average price of gas delivered to consumers (the so-called burner-tip price) is a good proxy for the market value at delivery points.

We have proven that under reasonable assumptions these data permit us to construct an index of the output of all gas transporters without data on volumes shipped between points in the system. We will call this a price-distance approach to output indexing. The price-distance output index is based on the fundamental theoretical result that the difference in gas prices at receipt and delivery points linked by trade roughly equals the unit transportation charge. It can then be shown that the percentage change in an index of output is the difference between the rates of change in indexes of deliveries and receipts.

The percentage change in the receipt index is a weighted average of the percentage changes in importation and marketed production in each of the lower-48 states. The shares of the states in the total value of gas importations and marketed production serve as weights. A unit increase in receipts will then have a greater impact on output in states with lower supply prices.

The percentage change in the delivery index is a weighted average of the percentage changes in deliveries to residential, commercial, industrial, and electric utility customers in each of the lower-48 states. The shares of the states in the total market value of gas at the burner tip serve as weights. A unit increase in deliveries will then have a greater impact on the output index in states with high burner-tip prices.

To better understand this approach, suppose as before that a certain flow of gas from Texas wells is diverted from Houston to Buffalo. The receipt index is unchanged since the Texas producer is marketing the same flow of gas as before. The delivery index registers a decline in Texas deliveries and a rise in New York deliveries. Since the burner-tip price of gas is higher in New York than in Texas, there is a rise in the delivery index. It follows that the output index rises as before.

Some limitations of the proposed output index merit note. An obvious one is that it measures the output of the entire gas transport system, not just that of the interstate system. It is then accurate only to the extent that rates of change in the output of the entire system are similar to rates of change in the output of the interstate system.

There are reasons to believe that these rates of change will be similar. A handful of states account for the bulk of U.S. natural gas production and importation. While some of these states are large gas consumers, most of the gas is shipped to other states. Interstate trade in gas is thus extensive. The percentage change in the output of distribution companies that receive gas from the interstate system should thus be similar to the percentage change in the output of the interstate system.

Despite these assurances, there are two sources of legitimate concern with the price-distance index as a measure of interstate system output. Other gas transporters may experience different changes in the quality of transportation services over time. Secondly, growth in deliveries in Texas and other producing states served primarily by intrastate pipeline companies may differ from the growth rate in deliveries to interstate markets. We are not aware of research that would indicate that the net effect of these problems would be to bias the price-distance output index.

The price-distance approach to output indexing places restrictions on the kind of rate indexes we can construct without new data. Specifically, a national output index corresponds to national input price and quantity indexes. Our industry is therefore the aggregation of major interstate gas pipeline companies. No individual company has an appreciable effect on the performance of this aggregate. Hence the index can in principle be used to adjust the rate ceilings of individual companies.

B. INPUT PRICE AND QUANTITY INDEXES

The percentage change in our input price index is a weighted average of the percentage changes in the prices of various inputs. The weight for each input is a simple average of its share in total cost this period and last. To construct our input price index we therefore need two kinds of information. One is the total cost of service and its breakdown between input categories. The other is the percentage changes in the corresponding input prices.

Our input quantity index is simply the ratio of total cost to the input price index. The percentage change in inputs is then the difference between the percentage changes in total cost and the input price index. This treatment ensures that total cost is the product of the input price and quantity indexes.

GENERAL DATA AVAILABILITY

Generally speaking, data on the input utilization costs of interstate gas transporters is of high quality. The main source is once again the Statistics. Good data on most of the prices paid by interstate gas pipeline companies are less readily available. This is a common problem in indexing work. We are forced to rely partly on proxy variables such as common measures of inflation. Price proxies are satisfactory to the extent that the percentage change in their values over time are similar to the percentage changes in the prices paid by gas transporters.

OPERATION AND MAINTENANCE COSTS

The major categories of operation and maintenance expenses for interstate gas pipeline companies include: purchased gas for resale; other gas supply expenses (FERC Account 813); employees; transmission and compression of gas by others (FERC Account 858); and gas used in utility operations. A list of operation and maintenance expense categories employed in the present study and the price variables assigned to them is presented in Table 1.

There are several features of the breakdown that merit note. Other operation and maintenance expenses include one of the most important expenditure categories — other gas supply expenses. These consist primarily of take-or-pay expenses. The inclusion of take-or-pay expenses in a rate index is controversial. Absent regulation, they could be viewed as a part of a normal cost-minimizing supply strategy. During the 1980's, however, these expenses rose dramatically after FERC Orders 380 and 436/500 altered the purchase obligations of interstate gas company customers.

Note also that revenues from certain sales not subject to rate regulation are treated as "negative" inputs. This treatment is consistent with the usual practice of subtracting these revenues from the cost of service before determining rate ceilings.

The item "other revenues not subject to rate regulation" has been excluded from the computation of the input price and quantity indexes pending clarification of its nature. Several other input categories are also excluded from the input indexes. One class of exclusions is those necessary to confine the rate adjustment index to non-gas costs. Any cost that is allocated solely to sales customers can be excluded on these grounds. In the present exercise we have excluded only purchased gas costs on this basis.

Services purchased by individual interstate companies from other transporters are excluded from the input price index but not the input quantity index. This treatment is tantamount to assuming that prices of excluded items change at the same rate as the index for the included prices.

CAPITAL COSTS

A typical gas pipeline company holds an array of production assets in pursuit of its business. Line pipe, compressors, structures, meters, gas wells, and stored gas are some of the more important categories. The cost of holding these assets is the dominant cost of operating a gas transportation system.

Our approach to productivity indexing requires that costs decompose into a price and a quantity. Two kinds of capital cost data are needed to implement this approach. One is the current annual cost of holding capital. The second is the rate of change in the capital "price". By price, we mean a dollar-denominated value that, multiplied by the size of the asset stock, yields the current cost of holding that stock.

The specification of these items is a nettlesome issue in the construction of rate adjustment indexes. In this section we try to shed some light on the problem. Methodologies are considered for

Table 1

TREATMENT OF OPERATION AND MAINTENANCE COSTS IN THE INPUT PRICE INDEX

Input Category	Price Series
Gas used in utility operations	Average price of gas purchased by major interstate pipeline companies[1]
Employee costs	Employment cost index for private industry employees[2]
Total salaries and wages	
Employee pensions and benefits	
Transmission and compression of gas by others	Not explicitly included in index
Other operation and maintenance expenses	Fixed-weight price index for gross national product[2]
Revenues from sales of natural gas by products	Refiner and gas plant average sales price of propane (consumer grade) for resale[3]

[1] Statistics of Interstate Natural Gas Pipelines, various issues.

[2] Business Statistics 1981-88.

[3] 1978-88: Petroleum Marketing Monthly, various issues.

calculating the cost of holding capital equipment. Details of the capital cost treatment in the present study are also discussed.

THE NATURE OF CAPITAL COSTS

For many goods and services consumed by pipeline companies the treatment of cost is straightforward. The products are consumed as used and are paid for in their year of use. The cost of their use is then approximated by current expenditure, which is the product of their price and the amount purchased. Treatment of capital cost is more complicated. Some capital assets are durable goods that generate services over many years. Such goods continue to hold resale value even when used. It is then improper to assign expenditures on them to the year of their purchase as a cost. Some non-durable goods maintain their market value if stored. When such goods are purchased and stored for later use, it is improper to assign expenditures on them to their year of purchase as a cost.

What, then, is the current cost of capital? Absent taxation, a company incurs three kinds of cost as an owner of production assets. One is the opportunity cost. The company could sell the asset and invest the proceeds in other profitable activities. The size of the opportunity cost depends on the rate of return on alternative investments and on current asset prices. A second cost of capital is depreciation. An asset declines in value as its remaining useful life declines. The size of the loss also depends on current asset prices.

The third cost of capital is capital loss. Since prices of capital assets change over time, firms holding assets incur capital gains and losses. A capital loss adds to the cost of capital while a capital gain reduces it.

Taxation complicates the analysis of capital costs in several ways. The company may incur property taxes on its production assets. By holding assets, the company may also generate income subject to income taxes. The net effect on the income tax burden is usually smaller than the gross since depreciation is tax-deductible and new investment in some assets produces tax credits.

COST OF STORED GAS

Underground storage is an important part of the interstate gas transport system. Twenty-two of the companies considered in this study owned underground storage facilities in 1988. Many of the others were specialized project pipelines owned by companies with storage facilities.

For purposes of rate indexing, the equipment used to operate gas storage facilities is treated like other kinds of capital equipment. There remains the issue of how the stored gas itself should be treated. However they are measured, the stored gas costs of gas pipeline companies are volatile. Two factors are primarily responsible for this. The price of natural gas in the United States has been extremely variable since 1970. Year-end stocks of gas are quite sensitive to winter weather conditions.

Inclusion of stored gas costs can for these reasons hamper the measurement of the long-run trends in gas pipeline industry productivity. Since our objective in this study is to measure long-run trends, we have elected to exclude stored-gas costs from this analysis.

TREATMENT OF CAPITAL EQUIPMENT COSTS BY THE FERC

The main source of data on capital costs is the Statistics. The character of this data is heavily influenced by its use in FERC regulation. We have seen that interstate gas transport rates are established by a cost of service method. This method requires a measure of capital costs. Three kinds of costs are allowed for capital equipment: depreciation, depletion, and amortization of the rate base; a return on the rate base; and taxes. The rate base is defined as the value of the company's plant that is "used and useful" in gas service, less the accumulated provision for depreciation, depletion, amortization, and accumulated deferred income taxes, plus working capital.

Allowed capital costs thus depend greatly on the method used to value production assets. The FERC values assets using the original cost method. Individual assets are valued by their price at time of purchase. Additions to plant are thus assigned a current market value. However, the reported values of total plant, depreciation, and retirements are "book" values that reflect asset prices at the times that the various assets were purchased. Thus rates for gas transport services are not adjusted for capital gains and losses. Since asset prices have risen substantially over the years, book values for gross plant, depreciation, and retirements tend to be significantly below the current market values of these items.

ALTERNATIVE TREATMENTS OF CAPITAL EQUIPMENT COST

In this study, we consider three alternative treatments of capital costs. The first, which we will call the cost of service method, is a conscious attempt to approximate the workings of cost of service regulation. The second treatment, which we will call the RCAF method, is similar to the treatment of capital costs in the RCAF Index. The third approach, which will be called the Christensen-Jorgenson method, is a rigorous way of estimating the full economic cost of capital. In this section we describe each method only briefly. Further details are found in Appendix B.

Cost of Service Method. The cost of service treatment of capital costs involves three cost categories: taxes, depreciation, and return on investment in gas utility plant. Each category is assigned its own price index. The cost of depreciation is measured using the reported values of depreciation and depletion and amortization. The price assigned to this cost category is a simple average of the past thirty values of an index of gas transmission industry asset prices. The return on gas utility plant is measured as the product of an interest rate and the book value of net gas utility plant in the previous year. The price assigned to this category is the product of an interest rate and the asset price index.

Taxes are measured by tax outlays — including provisions for deferred income taxes and investment tax credit adjustments — as reported in the Statement of Income and Retained Earnings. The price assigned to this cost category is the fixed-weight price index for gross-national product.

RCAF Method. The second alternative examined in this study is similar to the approach to capital cost measurement employed in the RCAF index. Here three categories of capital cost are considered:

Depreciation
Taxes
Net Interest

This breakdown differs from that under the cost of service method by the exclusion of a rate of return on owned capital.

The treatment of depreciation and taxes is the same as in the cost of service method. Net interest is measured as Net Interest Charges as reported in the Statement on Income and Retained Earnings. An interest rate is assigned to this asset category as a price.

Christensen-Jorgenson Method. Methods have been developed for calculating the full economic cost of capital and the rate of change in the "price" of capital from book value data. In this study we employ a method that was first detailed in Christensen and Jorgenson (1969), a study of aggregate U.S. capital costs. The method is based on two basic results of the economics literature. One is the perpetual inventory approach to asset valuation popularized by Goldsmith (1951). The other is the neoclassical theory of capital accumulation discussed in Jorgenson (1963).

The Christensen-Jorgenson method was first used to analyze utility costs in the Caves, Christensen, and Swanson (1980) study of productivity in the U.S. railroad industry. Gollop and Karlson (1980) used the method to measure the capital costs of U.S. electric companies. A similar method is employed by Sing (1987) in a study of the costs of U.S gas and electric companies.

We may think of the Christensen-Jorgenson method as creating an index of the price a company would pay in a given period to rent the assets that it actually owns. The approach for capital equipment involves three steps. First, a capital equipment quantity index is created using an index of gas transmission sector costs, an estimate of the average physical depreciation rate, and data on the value of net plant in a benchmark year and of additions to gas plant in later years. The second step is to calculate a service price index for capital equipment using the same cost index and data on tax rates, depreciation rates, and the rate of return on alternative investment. Multiplying these indexes together, we estimate the economic cost of capital.

D. EVALUATING THE ENCOUNTERED PROBLEMS

To recap the results of parts B and C, two kinds of problems were encountered in constructing input price and productivity indexes for interstate gas transporters. One problem, the treatment of capital costs, is common in rate indexing. The arguments for alternative approaches are parallel to the arguments for different valuations of capital in rate regulation. We devised input and quantity indexes based on: the economic theory of capital costs; the RCAF treatment of capital costs; and the cost treatment used by the FERC.

The second major problem confronted in the indexing work was the treatment of output. The published EIA data do not permit the construction of a conventional output index. The FERC OEP proposal uses interstate throughput as an output measure. This measure is incentive to distance shipped. We devised a price-distance measure of output as an alternative to the OEP approach. Though based on data for the entire gas transport system, it is more sensitive to changes in distance shipped.

Our development of an alternative output index should not be interpreted as an outright rejection of the interstate throughput index. We suspect that the interstate throughput index provides a poor measure of output changes during the 1980's. The price-distance output index can shed light on the extent of this distortion. However, the distortion may be less in future years when the pace of industry restructuring slows.

Speaking more generally, indexes must be credible to induce companies and their customers to abandon traditional regulation. Credible indexes require quality data. Absent new data collection initiatives, rate adjustment indexes must also be based on available data. In every regulated industry published data are not fully satisfactory for rate indexing.

The interstate gas pipeline industry is not an exception to this rule. Like other industries which have considered rate indexing, it must therefore face two questions. First, what are the best indexes available from published data? Secondly, do the best feasible indexes provide a satisfactory basis for rate indexing?

We feel that the indexes explained in this section are the best that can be derived from published data. The decision as to their adequacy must be left to others. To facilitate such an evaluation, we provide some empirical results using these indexes in the following section.

Section 7
EMPIRICAL RESULTS

In Section 6 we addressed the practical matter of constructing rate adjustment indexes for interstate gas transporters. Both railroad- and telecommunications-style indexes are based on indexes of productivity growth. The indexing of gas transportation industry productivity is complicated by unusual problems with output data and by the common problem of specifying capital costs. Alternative approaches were devised to deal with each of these problems.

In this section we report some results of our indexing work. Results are discussed in turn for the alternative input and output indexes, and for productivity and rate adjustment indexes that make use of them. A large number of productivity and rate adjustment indexes can be calculated from the alternative output and input indexes. We report here full results for only a few of the possible combinations.

A. SCOPE OF THE RESEARCH

Indexes were estimated using aggregate data for major interstate pipeline companies in the 1977-88 period. 1977 is sufficiently far back in time to permit some smoothing out of short-term swings like those resulting from the rise and fall of oil prices. At the same time, 1977 is recent enough to be deemed relevant to the world of the 1990's.

Before 1984, the EIA and predecessor agencies published data on all Class A and B interstate pipeline companies. Since 1984, only data on the "major" companies have been published. These are companies whose combined gas sales and unbundled transportation and storage deliveries exceeded 50 billion cubic feet in each of the last three years. The group of major companies has changed over time. Companies enter and leave the group via growth and/or a change in their regulatory status.

To ensure the consistency of intertemporal comparisons under these circumstances, we have focussed in this study a group of thirty-nine companies for which data was available throughout the 1977-88 period. These companies are listed in Table 2. It can be seen that the companies accounted for a large share of major interstate pipeline company assets in 1983. This year was roughly the midpoint of our sample period.

Table 2

COMPANIES INCLUDED IN THE SAMPLE

Company	Book Value of Total Gas Utility Plant in Service, 1983 (Dollars)	Share of Total for all Class A & B Pipelines (Percent)
Algonquin Gas Transmission	213,262,059	0.5
ANR Pipeline	2,310,786,724	5.1
ARKLA	1,117,978,289	2.4
CNG Transmission	1,099,344,377	2.4
Colorado Interstate	671,837,744	1.5
Columbia Gas Transmission	2,031,328,438	4.4
Columbia Gulf Transmission	1,014,877,850	2.2
East Tennessee Natural Gas	78,223,902	0.2
El Paso Natural Gas	3,049,427,788	6.7
Enron	2,699,604,747	5.9
Florida Gas Transmission	474,539,642	1.0
Great Lakes Gas Transmission	519,318,403	1.1
High Island Offshore System	352,217,403	0.8
K N Energy	363,040,513	0.8
Michigan Gas Storage	53,231,285	0.1
Midwestern Gas Transmission	159,583,448	0.3
Mississippi River Transmission	355,353,985	0.8
National Fuel Gas Supply	218,418,377	0.5
Natural Gas Pipeline	2,114,260,346	4.6
Northern Border Pipeline	1,294,664,867	2.8
Northwest Pipeline	1,185,314,868	2.6
Overthrust Pipeline	62,807,680	0.1
Pacific Gas Transmission	383,436,606	0.8
Panhandle Eastern Pipeline	1,443,119,095	3.2
Sea Robin Pipeline	239,449,890	0.5
Southern Natural Gas	1,120,149,119	2.5
Stingray Pipeline	237,294,180	0.5
Tennessee Gas Pipeline	3,116,834,868	6.8
Texas Eastern Transmission	2,288,010,997	5.0
Texas Gas Transmission	844,091,753	1.8
Trailblazer Pipeline	269,688,064	0.6
Transco Gas Supply	10,344	0.0
Transcontinental Gas Pipe Line	2,753,338,727	6.0
Transwestern Pipeline	655,506,229	1.4
Trunkline Gas	956,145,247	2.1
United Gas Pipe Line	1,079,119,382	2.4
U-T Offshore System	62,842,507	0.1
Williams Natural Gas	580,838,760	1.3
Wyoming Interstate	177,128,788	0.4
Subtotal: all companies in sample	37,646,427,291	82.4
Total: All Class A and B Pipelines	45,712,323,384	100.0

Source: Statistics of Interstate Natural Gas Pipeline Companies

B. OUTPUT AND INPUT INDEXES

Figure 5 depicts output indexes for the 1977-88 period that correspond to the interstate throughput and price-distance approaches to output indexing. As a point of comparison, we also present an index based on U.S. gas consumption. Average percentage changes in all three indexes are presented in Table 3. The time periods considered in calculating averages were our full sample period (1977-88) and two shorter periods (1980-88 and 1982-88). The first of the shorter periods was chosen as one likely to produce a negative output trend. The second sub-period was chosen as one likely to produce no trend.

An inspection of Figure 5 reveals that there are broad similarities in the trajectories of the three output indexes over time. In all three indexes output trended upward in the first years after 1977, reaching sample period peaks in the early 1980's. There followed a downward trend in output to sample-period lows in 1986. Output trended upward in 1987 and 1988.

These results square with our knowledge of events during this period. U.S. gas flows were buoyed 1979-81 by rapid increases in the prices of competing oil products. Thereafter, gas flows fell due to a set of circumstances that included a recession, higher gas prices, and falling oil prices. Consumption rebounded 1987-88 thanks to more competitive gas prices and a strong economy.

As for the differences between the indexes we find that the consumption and price distance indexes had quite similar trajectories during the sample period. The indexes diverged most noticeably in 1980, when the price-distance index rose sharply and consumption was unchanged. This may reflect the effect on average distance shipped of the substitution to gas from residual fuel oil that occurred in 1980. These substitutions were concentrated in markets that are far from the main sources of gas supply.

Another interesting result is that the interstate throughput index diverges substantially from the alternative indexes. It trended upward during the 1977-88 period whereas the other indexes displayed no trend. The difference in growth rates was especially pronounced in 1987 and 1988. These are precisely the years during our sample period when Orders 436 and 500 stimulated multiple-company shipments.

Average annual rates of change in the inputs of major interstate gas transportation companies are presented in Table 4 for the same time intervals as in Table 3. Results are reported for the cost of service, RCAF, and Christensen-Jorgenson indexes.

Figure 5
A COMPARISON OF THREE INDEXES OF NATURAL GAS PIPELINE INDUSTRY OUTPUT

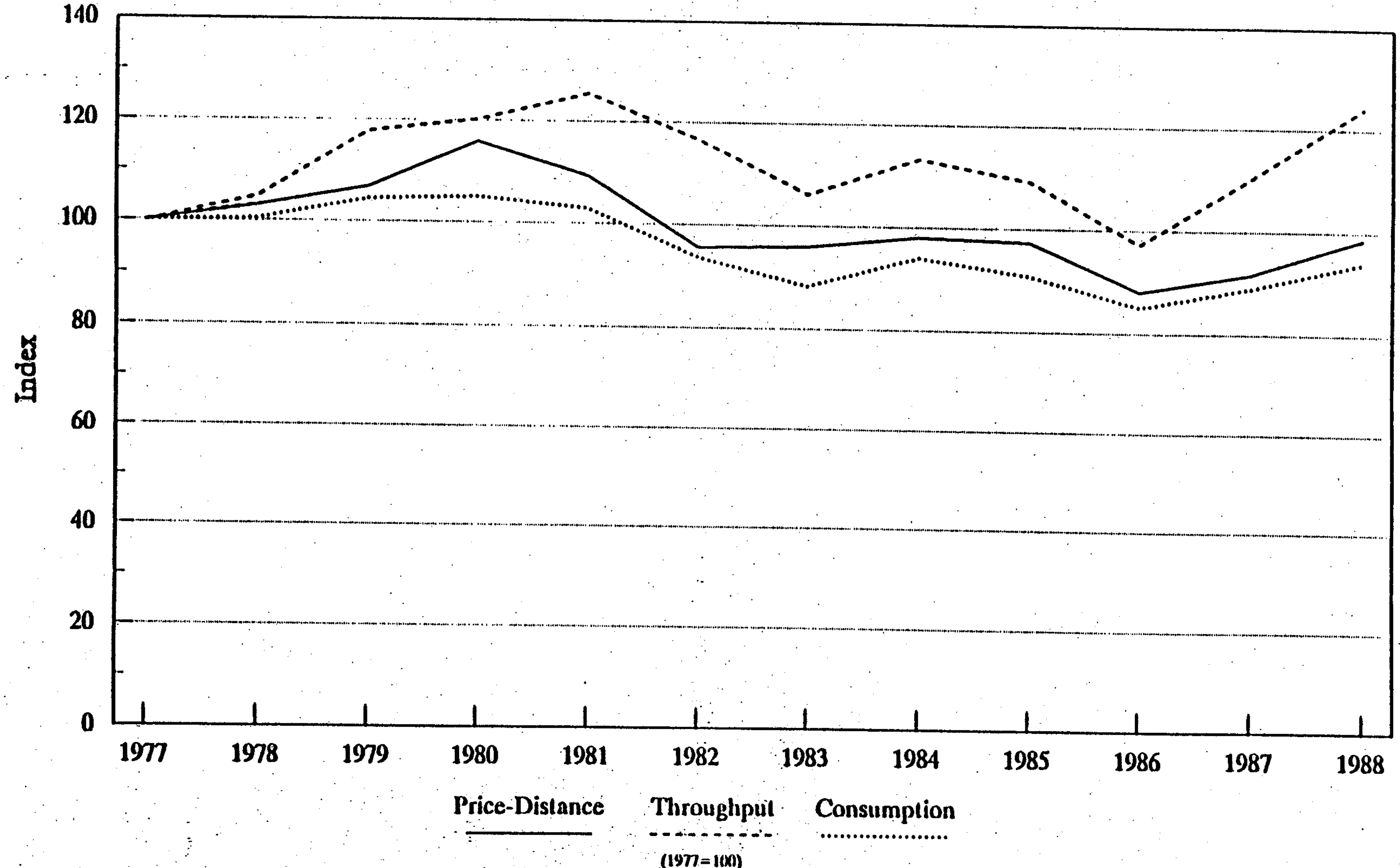


Table 3

AVERAGE ANNUAL PERCENTAGE CHANGE IN KEY VARIABLES USING ALTERNATIVE MEASURES OF OUTPUTS (1)

Index	Time Interval 1977–88 (%)	1980–88 (%)	1982–88 (%)
Output I: Interstate Throughput (2)	2.0	0.4	1.0
Output II: Price–Distance	–0.1	–2.0	0.5
Output III: Consumption (3)	–0.5	–1.4	0.0
Input Quantity (1)	0.4	–0.9	–1.8
Input Price	5.6	3.8	1.5
Productivity I: Interstate Throughput	1.6	1.2	2.8
Productivity II: Price–Distance	–0.5	–1.2	2.3
Productivity III: Consumption	–0.9	–0.5	1.8
Rate Adjustment (Unsmoothed) I: Interstate Throughput	4.1	2.5	–1.4
Rate Adjustment (Unsmoothed) II: Price–Distance	6.2	4.9	–0.8
Rate Adjustment (Unsmoothed) III: Consumption	6.6	4.3	–0.3

(1) All runs employ RCAF treatment of capital costs.

(2) Sum of total natural gas sales and deliveries of gas transported or compressed for others.
Source : FERC Form 2, "Annual Report of Major Natural Gas Companies".

(3) Total deliveries by gas transporters to residential, commercial, industrial, and electric utility customers except for lease and plant operators.
Source : Form EIA–176, "Annual Report of Natural & Supplemental Gas Supply and Disposition".

Table 4

AVERAGE ANNUAL PERCENTAGE CHANGES IN KEY VARIABLES USING ALTERNATIVE MEASURES OF CAPITAL (1)

Index	Time Interval 1977–88 (%)	1980–88 (%)	1982–88 (%)
Input I: Cost of Service	-1.5	-3.4	-4.8
Input II: RCAF	0.4	-0.9	-1.8
Input III: Christensen–Jorgenson	2.2	0.8	0.7
Output (1)	-0.1	-2.0	0.5
Productivity I: Cost of Service	1.3	1.4	5.3
Productivity II: RCAF	-0.5	-1.2	2.3
Productivity III: Christensen–Jorgenson	-2.4	-2.9	-0.1
Rate Adjustment (unsmoothed) I: Cost of Service	5.6	3.9	-2.1
Rate Adjustment (unsmoothed) II: RCAF	6.2	4.9	-0.8
Rate Adjustment (unsmoothed) III: Christensen–Jorgenson	7.9	7.5	-2.9

(1) All runs employ the Price–Distance output index.

Comparing results across capital cost treatments, we find significant differences. The Christensen-Jorgenson treatment found significant growth in input utilization over the 1977-88 period. The cost of service treatment found a significant decline. The input index based on the RCAF treatment found little change in input utilization. It follows that the capital cost treatment has a very significant impact on the measured growth in input utilization.

C. PRODUCTIVITY INDEXES

Productivity results are also presented in Tables 3 and 4. The results in Table 3 employ alternative output measures and the RCAF treatment of capital costs. Hence, differences are due entirely to the different output indexes. Comparing results across indexes, we see that the average productivity growth during the 1977-88 period for the price-distance and consumption indexes fell within the narrow range of -0.5% to -0.9%. That is, a downward trend in productivity occurred. In contrast, use of the interstate throughput approach to output measurement yielded a 1.6% positive average annual growth rate.

The results in Table 4 employ alternative capital cost treatments in measuring input and input price growth. Hence, differences are due entirely to the different capital cost treatments. Comparing results across indexes, we find large differences in average productivity growth during the 1977-88 period. A significant negative growth rate of 1.3% resulted from the cost of service approach. At the other extreme, a -2.4% average annual growth rate resulted using the Christensen-Jorgenson Approach.

All estimates are within the range of those commonly found in studies of productivity growth. The difference between the estimates is more striking. Since capital costs dominate the total non-gas costs of pipeline companies, substantially different treatments of these costs should be expected to yield substantially different productivity growth estimates.

D. RATE ADJUSTMENT INDEXES

Figures 6 and 7 and Tables 3 and 4 report unsmoothed, railroad-style rate adjustment indexes for the 1977-88 period. An unsmoothed index bases rate adjustments on current changes in industry

Figure 6

A COMPARISON OF UNSMOOTHED RATE ADJUSTMENT INDEXES USING THREE ALTERNATIVE OUTPUT MEASURES

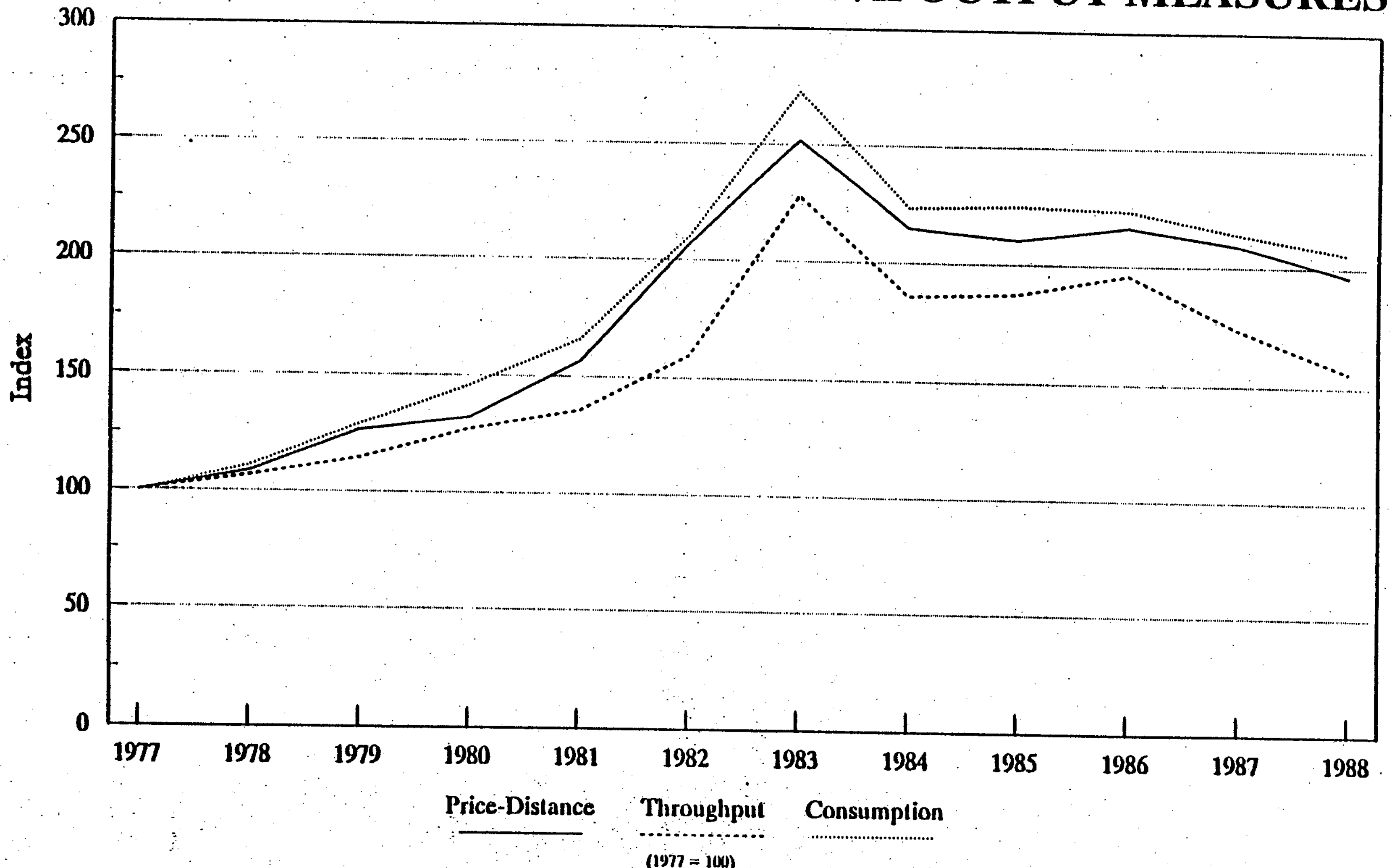
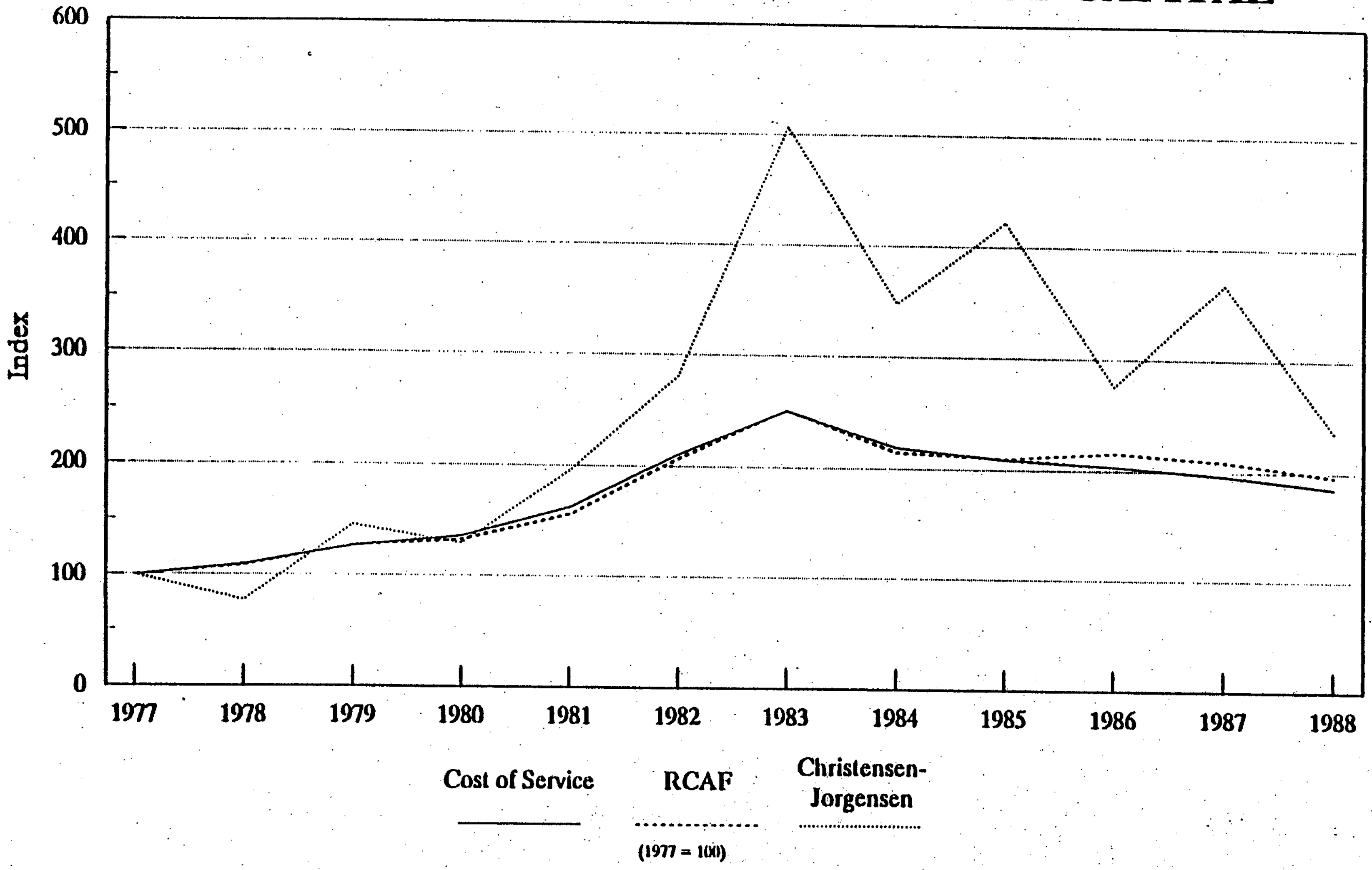


Figure 7
A COMPARISON OF UNSMOOTHED RATE ADJUSTMENT INDEXES USING THREE TREATMENTS OF CAPITAL



input prices and productivity. Although the lack of timely data makes them unfeasible, they reveal more clearly than a smoothed index the impact of alternative input and output specifications on rates.

The results in Figure 6 and Table 3 are for the alternative output measures. All runs employ the RCAF treatment of capital costs. Hence, differences are due entirely to the different output indexes. The three indexes display broadly similar trajectories. Rates would have trended upward from 1977 to 1983 and trended downward thereafter. The growth in rates permitted using the interstate throughput approach would have been significantly less favorable to the industry than the growth afforded by the alternative approaches. This reflects the higher growth in measured output, which would restrain rate increases by boosting measured productivity.

The results in Figure 7 and Table 4 are for alternative capital measures. All runs employ the price-distance output index. Differences are therefore due entirely to the capital cost treatments. Once again, the trajectories are broadly similar, with indexes trending upward 1977-1983 and downward thereafter. The most striking result is the departure of the Christensen-Jorgenson index from the other indexes. This reflects the large negative average annual growth in productivity recorded by the Christensen-Jorgenson index during the sample period. Lower productivity growth means higher rate increases.

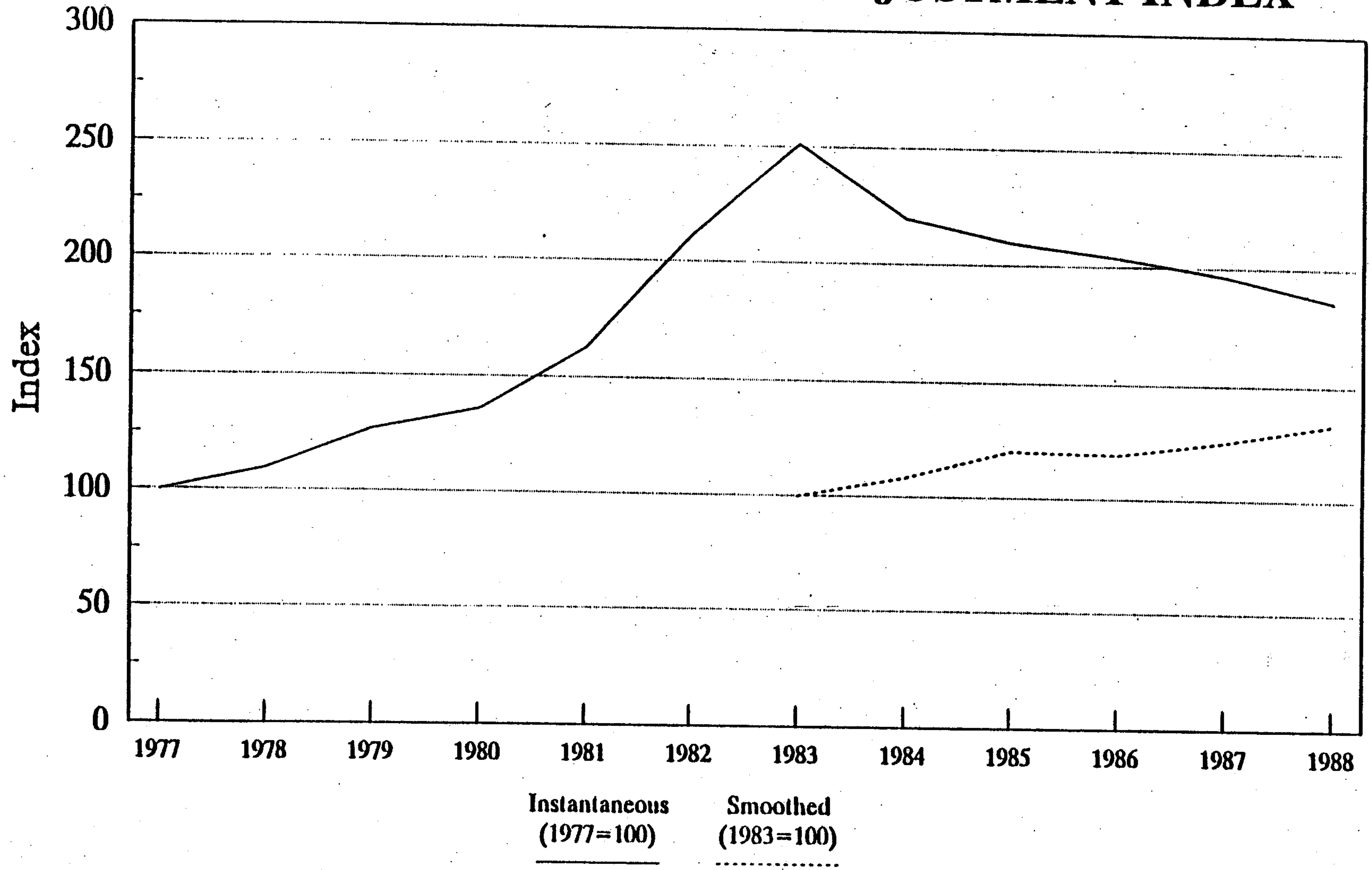
We next calculated a smoothed rate adjustment index similar to the indexes used in the U.S. railroad industry. This is illustrated in Figure 8. Changes in the index reflect current trends in input prices and a five-year moving average of productivity changes that is lagged two years. The index is based on the price-distance output treatment and the cost of service capital treatment. We see that the smooth index trends upward while the unsmoothed index declines during the years that they coincide. This reflects the fact that the productivity offset is based on past industry performance.

As a final exercise, we considered what sort of telecommunications-style index could be constructed from our indexing work. Our research did not produce productivity results for individual companies, as are required for indexes of this type. As a further complication, we do not feel that our research to date permits us to identify a long run productivity trend for the industry.

To illustrate the construction of such an index, let us nonetheless use as our productivity trend for a typical firm the 1.3% average annual productivity growth rate for the 1977-88 period that makes use of the cost of service capital treatment. The long-run annual productivity growth rate for the U.S. economy is about 0.8%. The long-run differential in the productivity growth rate would then be 0.5%. To this we will add a 1/2% consumer productivity dividend. An appropriate percentage offset

Figure 8

CONSTRUCTION OF A SMOOTHED RATE ADJUSTMENT INDEX FROM AN UNSMOOTHED RATE ADJUSTMENT INDEX



might then be 1%. In that event, the rate adjustment index for an interstate gas transporter would be permitted to rise 1.0 percentage points less rapidly than the annual rate of inflation. A common forecast of the U.S. inflation rate in the 1991-92 revenue year is 3.5%. If this holds, the percentage increase in 1991-92 rates allowed by a typical telecommunications-style index would be 2.5%.

E. EVALUATION OF RESULTS

Recapping the section, we presented indexing results for an aggregation of interstate gas transportation companies in the 1977-88 period. Three approaches to output measurement and three treatments of capital costs were considered. Results using all measures were broadly consistent with our knowledge of the industry during this period. However, significant differences were produced using different index approaches. A key question is whether these differences are a cause for concern.

Considering first the output treatment, it is evident that the instantaneous rate adjustment indexes based on the price-distance and consumption indexes had quite similar trajectories. While the interstate throughput index behaves differently, the differences reflect known flaws. In effect, large differences are not observed among the more credible indexes.

As for the capital cost treatment, the rate adjustment indexes based on the RCAF and cost of service treatments are fairly similar. While the results for the Christensen-Jorgenson treatment differ greatly from these, this treatment also differs from the others in being very much at variance with FERC's treatment of capital costs. We would be surprised if advocates of this approach made more headway before FERC than they did in the ICC proceeding.

A second area where remarks are in order is the adequacy of the output index that we have devised. We believe that there is a good chance that this index will be deemed an acceptable basis for a national, railroad-style rate adjustment index. Problems are more likely to arise if approval of rate indexing requires measurement of productivity trends for individual companies. Quality output indexes for individual companies cannot be produced from published data.

Since this may pose a problem, it may be constructive to note the kind of additional data needed to measure the output of individual companies. An index of comparable quality can be constructed from information about how much gas the individual company received and delivered in each state that it served. The index can be enhanced by distinguishing between sales and transportation services, and between firm and interruptible services.

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Appendix A:

THEORY OF RATE INDEXING FOR GAS TRANSPORTATION SERVICES

1. DERIVATION OF THE RATE ADJUSTMENT INDEX

We begin by defining a gas transportation system in the business of transporting natural gas between various geographic locations. The array of services performed by the system may include any combination of natural gas gathering, processing, transmission, and distribution.

Suppose, now, that there are N locations in the system at which gas can be received or delivered. In a typical transaction, a customer requests delivery of an amount, y_{ji}, at delivery point j, while pledging to deliver an amount, x_{ij}, at receipt point i. If the transporter does not buy gas from or sell gas to the party, the volume of service between points i and j, s_{ij}, is equal to the amounts received and delivered:

$$x_{ij} = y_{ji} = s_{ij} \qquad (i,j = 1,2,...N)$$

Let

$$\underline{s} = (s_{11}, s_{12}, ... s_{NN})$$

be the (NxN) - element vector of all outputs in a given period.

Several inputs are required to transport gas. These include line pipes, compressors, labor, and fuel. Let

$$\underline{z} = (z_1, z_2, ... z_M)$$

denote the quantities of each of the M inputs that may be employed in the production process.

In transporting gas, the firm incurs costs and receives revenues. If W_m is the price of input m, the total cost, c, of the transportation system in a given period may be written:

$$
\begin{aligned}
c &= z_1 \cdot W_1 + z_2 \cdot W_2 + \cdots + z_M \cdot W_M \\
&= \Sigma_{m=1} z_m \cdot W_m .
\end{aligned}
\tag{A.1}
$$

If R_{ij} is the rate charged for receiving gas at location i and delivering it at location j, then the revenue of the gas transportation system in a given period may be written

$$
\begin{aligned}
r &= s_{11} \cdot R_{11} + s_{12} \cdot R_{12} + \cdots + s_{1N} \cdot R_{1N} + \\
&+ s_{21} \cdot R_{21} + s_{22} \cdot R_{22} + \cdots + s_{2N} \cdot R_{2N} + \\
&+ s_{N1} \cdot R_{N1} + s_{N2} \cdot R_{N2} + \cdots + s_{NN} \cdot R_{NN} \\
&= \Sigma_{ij} s_{ij} \cdot R_{ij} .
\end{aligned}
\tag{A.2}
$$

We add up first all of the revenues from shipments of gas from each field to a certain delivery point. We then add up the subtotals to all delivery points to obtain total revenue.

Under cost of service regulation it is approximately true that the revenue commensurate with maximum rates in a given period should equal the cost of service. This restriction can be written mathematically as a profit constraint equation:

$$
\Sigma_{ij} s_{ij} \cdot R_{ij} = \Sigma_m z_m \cdot W_m . \tag{A.3}
$$

Suppose, now, that we take the log of each side of (A.3), then totally differentiate with respect to time. We obtain

$$\Sigma_y \left(\frac{R_y \cdot s_y}{r}\right) \cdot \tilde{R}_y + \Sigma_y \left(\frac{R_y \cdot s_y}{r}\right) \cdot \tilde{s}_y$$

$$= \Sigma_m \left(\frac{W_m \cdot z_m}{c}\right) \cdot \tilde{W}_m + \Sigma_m \left(\frac{W_m \cdot z_m}{c}\right) \cdot \tilde{z}_m. \tag{A.4}$$

Here for any variable V,

$$d\tilde{V} = \frac{dlnV}{dt}.$$

The rate of change in revenues equals the rate of change in cost. The rate of change in revenues is the sum of the average rate of change in rates and outputs. The revenue shares of the N·N services are the weights. The rate of change in cost is the sum of the average rate of change in input prices and inputs. Here the cost shares of the M inputs are the weights. If we now solve (A.4) for the rate of change in rates we obtain the rate adjustment equation:

$$\Sigma_y \left(\frac{R_y \cdot s_y}{r}\right) \cdot \tilde{R}_y = \Sigma_m \left(\frac{W_m \cdot z_m}{c}\right) \cdot \tilde{W}_m - \left[\Sigma_y \left(\frac{R_y \cdot s_y}{r}\right) \cdot \tilde{s}_y - \Sigma_m \left(\frac{W_m \cdot z_m}{c}\right) \cdot \tilde{z}_m.\right] \tag{A.5}$$

Equation (A.5) is the main result of the exercise. The equation tells us that the average rate of change in rates equals the average rate of change in input prices minus the difference between the average rates of change in outputs and the average rate of change in inputs. The latter difference is more simply described as the rate of change in productivity. Hence the average rate of change in rates equals the average rate of change in input prices minus the average rate of change in productivity.

The average rates of change in input prices, inputs, and outputs are examples of Divisia indexes. The instantaneous rates of change in Divisia indexes are not useful in the practical world of regulation where rates are revised only quarterly or annually. However, there are discrete approximations to Divisia indexes available. The most widely used of these approximations is the Tornqvist index. To illustrate, the Tornqvist index for input prices in the present case is:

$$WNDX_t = \Sigma_m \,(1/2) \cdot \left[\left(\frac{W_{mt} \cdot z_{mt}}{c_t} \right) + \left(\frac{W_{m(t-1)} \cdot z_{m(t-1)}}{c_{t-1}} \right) \right] \cdot \ln(W_{mt}/W_{m(t-1)}) . \tag{A.6}$$

Here the instantaneous rate of change in each input price is replaced by the logarithmic rate of change in the price between this period and last. The cost share of the input at an instant in time is replaced by the (even-weighted) average cost share this period and last.

2. THE OUTPUT MEASUREMENT PROBLEM

One problem in measuring the output of the interstate natural gas industry is that we lack the appropriate output and rate data. Specifically, our information on shipments and revenues is not broken down into the relevant ij pairings. We don't know very precisely, for instance, how much gas is transported from Louisiana to Illinois. We seek, then, an alternative output index that at a given point in time comes as close as possible to producing the value

$$\Delta s = \Sigma_{ij} \left(\frac{R_{ij} \cdot s_{ij}}{r} \right) \cdot \left(\frac{d\ln s_{ij}}{dT} \right).$$

The additional information that we require is on the relationship between the price of gas at the wellhead and at the burner-tip. The activity of arbitragers ensures that between any two locations m and n between which trade occurs, prices conform to the arbitrage equation.

$$P_j = P_i + R_{ij} \tag{A.7}$$

Here

P_i = market value per unit of gas at receipt point i (i = 1,2,...N)
P_j = market value per unit of gas at delivery point j (j = 1,2,...N)

Suppose now that the rate charged for commissioning the receipt of gas at location i and its delivery at location j is R_{ij}. Then

$$
\begin{aligned}
\Sigma_i P_i x_i + \Sigma_k W_k \cdot z_k
&= \Sigma_i P_i \cdot x_i + \Sigma_{ij} R_{ij} \cdot s_{ij} \\
&= \Sigma_i P_i \cdot x_i + \Sigma_{ij} (P_j - P_i) \cdot s_{ij} \\
&= \Sigma_i P_i \cdot x_i + \Sigma_{ij} P_j \cdot s_{ij} - \Sigma_{ij} P_i \cdot s_{ij} \\
&= \Sigma_i P_i \cdot x_i + \Sigma_j P_j \cdot y_j - \Sigma_i P_i \cdot x_i \\
&= \Sigma_j P_j \cdot y_j
\end{aligned}
\tag{A.8}
$$

The value of gas at the <u>burner tip</u> equals the value of gas at the <u>wellhead</u> plus the expenditures on transportation services.

If we now differentiate total deliveries at each point j with respect to time, we obtain

$$
\begin{aligned}
\dot{y}_j &= \frac{d\ln(\Sigma_i s_{ij})}{dT} \\
&= \Sigma_i \left(\frac{\partial \ln y_j}{\partial \ln s_{ij}} \right) \cdot \dot{s}_{ij} \\
&= \Sigma_i \left(\frac{s_{ij}}{y_j} \right) \cdot \dot{s}_{ij}
\end{aligned}
$$

and

$$
\left(\frac{P_j \cdot y_j}{a} \right) \cdot \dot{y}_j = \Sigma_i \left(\frac{P_j \cdot s_{ij}}{a} \right) \cdot \dot{s}_{ij}
$$

where

$$
a = \Sigma_j P_j \cdot y_j .
$$

Summing over every delivery point j it follows that there is an <u>index of deliveries</u>

$$\Sigma_j \left(\frac{P_j \cdot y_j}{a}\right) \cdot \hat{y}_j = \Sigma_{ij} \left(\frac{P_j \cdot s_{ij}}{a}\right) \cdot \hat{s}_{ij}. \tag{A.9}$$

Analogous operations can be made on total receipts at each receipt point i. Totally differentiating with respect to time we obtain an <u>index of receipts</u>.

$$\Sigma_i \left(\frac{P_i \cdot x_i}{b}\right) \cdot \hat{x}_i = \Sigma_{ij} \left(\frac{P_i \cdot s_{ij}}{b}\right) \cdot \hat{s}_{ij} \tag{A.10}$$

where

$$b = \Sigma_i P_i \cdot x_i .$$

From equations (A.8) and (A.9) we now obtain the main result:

$$\begin{aligned}
\Delta s &= \Sigma_{ij} \left(\frac{R_{ij} \cdot s_{ij}}{r}\right) \cdot s_{ij} = \Sigma_{ij} \left[\frac{(P_j - P_i) \cdot s_{ij}}{c}\right] \cdot \hat{s}_{ij} \\
&= \left(\frac{1}{c}\right) \cdot (\Sigma_{ij} P_j \cdot s_{ij} \cdot \hat{s}_{ij} - \Sigma_{ij} P_i \cdot s_{ij} \cdot \hat{s}_{ij}) \\
&= \left(\frac{a}{c}\right) \cdot \Sigma_{ij} \left(\frac{P_j \cdot s_{ij}}{a}\right) \cdot \hat{s}_{ij} - \left(\frac{b}{c}\right) \Sigma_{ij} \left(\frac{P_i \cdot s_{ij}}{b}\right) \cdot \hat{s}_{ij} \\
&= \Sigma_j \left(\frac{P_j \cdot y_j}{c}\right) \cdot \hat{y}_j - \Sigma_i \left(\frac{P_i \cdot x_i}{c}\right) \cdot \hat{x}_i .
\end{aligned} \tag{A.11}$$

The average rate of change in the output of the system equals the difference in the average rates of change in deliveries and receipts. Here the market values of gas at each receipt and delivery point divided by the cost of transportation service are the weights. It is possible, then, to compute an output index for a gas transport system without knowing the rates and volumes involved in each of the N*N transport service offerings. We require only knowledge of how much gas was delivered and received at each point and its unit price.

Appendix B
DETAILS ON THE CHRISTENSEN-JORGENSON TREATMENT OF CAPITAL COST

1. BASIC METHOD

To help explain the Christensen-Jorgenson method for measuring capital costs we make some simplifying assumptions. A company is in the business of transporting and storing gas. It has only one kind of capital equipment. There are no income or property taxes.

There is a geometric pattern of decay in capital equipment whereby the productive value of an asset — and therefore its market value (absent inflation)— is reduced by a constant fraction, δ, between years. The size of the capital stock can also be adjusted each period through purchases and sales of the asset. The size of the capital stock in a given year, t, then conforms to the following perpetual inventory equation:

$$K_t = I_t + (1 - \delta) \cdot K_{t-1}. \tag{B.1}$$

where

K_t = size of the asset stock at the beginning of the year
I_t = size of new investment

Here $\delta \cdot K_{t-1}$ is the amount of decay in the asset.

The level of production in each year depends on the amount of capital accumulated at the end of the prior year. Thus new capital investments cannot produce earnings for one period. This rule applies equally to investments in alternative profitable activities. A company may increase funds available for alternative investments by selling the subject assets or by reducing net new investment in these assets. However, funds pooled in this manner and reinvested do not earn money until the following year. The opportunity cost of holding an asset at the end of one year thus depends on the rate of return on alternative investments in the following year.

Under these assumptions, the neoclassical theory of investment tells us that the cost of holding an asset stock of size, K_{t-1}, evaluated in the dollars of period, t, is given by:

$$CK_t = r_t \cdot PA_{t-1} \cdot K_{t-1} + \delta \cdot PA_t \cdot K_{t-1} - (PA_t - PA_{t-1}) \cdot K_{t-1} . \tag{B.2}$$

Here in each period, t,

CK_t	=	total cost of holding K_{t-1} evaluated in dollars of period t
PA_t	=	unit price of the asset
r_t	=	rate of return on competing investments
δ_t	=	rate of decay in the asset

The cost of holding K_{t-1} can be disaggregated into three components:

opportunity cost of capital	$r_t \cdot PA_{t-1} \cdot K_{t-1}$
cost of depreciation	$\delta \cdot PA_t \cdot K_{t-1}$
capital loss	$(PA_t - PA_{t-1}) \cdot K_{t-1}$

To construct the productivity index, we express the cost of holding K_{t-1} as the product of K_{t-1} and a price, which we will denote PSK_t.

$$CK_t = PSK_t \cdot K_{t-1} \tag{B.3}$$

From (B.2) and (B.3) it follows that

$$PSK_t = r_t \cdot PA_{t-1} + \delta \cdot PA_t - (PA_t - PA_{t-1}) . \tag{B.4}$$

PSK_t is called the <u>service</u> (or <u>rental</u>) <u>price</u> of capital equipment since under certain assumptions it is the price that the firm would pay to a competitive, expected profit-maximizing company to rent the capital services it utilizes.

Suppose, now, that we have an <u>asset price index</u>, $PANDX_t$, that differs from the true asset price by a constant factor of proportionality, a:

$$PANDX_t = a \cdot PA_t . \tag{B.5}$$

We can use $PANDX_t$ to construct a service price index for capital equipment:

$$PSKNDX_t = r_t \cdot PANDX_{t-1} + \delta \cdot PANDX_t - (PANDX_t - PANDX_{t-1}) . \tag{B.6}$$

This has the same rate of change as the true service price since:

$$\begin{aligned} &\ln(PSKNDX_t/PSKNDX_{t-1}) \\ &\quad = \ln\{[r_t \cdot a \cdot PA_{t-1} + \delta \cdot a \cdot PA_t - (a \cdot PA_t - a \cdot PA_{t-1})]/ \\ &\quad\quad [r_{t-1} \cdot a \cdot PA_{t-2} + \delta \cdot a \cdot PA_{t-1} - (a \cdot PA_{t-1} - a \cdot PA_{t-2})]\} \\ &\quad = \ln(PSK_t/PSK_{t-1}). \end{aligned}$$

To complete estimation of the economic cost of capital equipment, we need an asset quantity index, $KNDX_{t-1}$, that, when multiplied by the service price index, yields CK_t.

$$CK_t^{estimated} = PSKNDX_t \cdot KNDX_{t-1} . \tag{B.7}$$

In a benchmark year, s, we calculate a benchmark value for the quantity index using the following formula:

$$KNDX_s = VA_s/[\Sigma_{i=1,\ldots 30} (1/30) \cdot PANDX_{s-30+i}]. \tag{B.8}$$

Here VA_s is the published (book) value of net utility plant in year s. In effect, the book value in the benchmark year is divided by an even-weighted average of the price index numbers in the most recent thirty years.

Multiplying this index number by $PSKNDX_{s+1}$, we obtain an estimate of the economic cost of capital in period s+1 that is clearly sensible:

$$\begin{aligned} &CK_{s+1}^{estimated} \\ &= PSKNDX_{s+1} \cdot KNDX_s \\ &= r_{s+1} \cdot VA_s \cdot \{PANDX_s/\{[\Sigma_{i=1,\ldots 30} (1/30) \cdot PANDX_{s-30+i}]\} \\ &\quad + \delta \cdot VA_s \cdot \{PANDX_{s+1}/[\Sigma_{i=1,\ldots 30} (1/30) \cdot PANDX_{s-30+i}]\} \\ &\quad - VA_s \cdot \{PANDX_{s+1}/[\Sigma_{i=1,\ldots 30} (1/30) \cdot PANDX_{s-30+i}]\} \end{aligned}$$

$$+ VA_s \cdot \{PANDX_s/[\Sigma_{i=1,\ldots 30} (1/30) \cdot PANDX_{s-30+i}]\} .$$

Given a benchmark estimate, an asset price index, and data on the value of plant additions, a quantity index can be calculated for each succeeding year as well using the following formula developed from the perpetual inventory equation:

$$KNDX_t = [(1 - \delta) \cdot KNDX_{t-1}] + \text{Value of plant additions}_t/PANDX_t . \qquad (B.9)$$

INCORPORATION OF TAX EFFECTS

Equations incorporating tax effects are more complex. We consider the effects of corporate income taxes, investment tax credits, and property taxes. The service price equation for capital equipment is now:

$$PS_t = \{[(1 - u z - v + 0.5 \cdot D \cdot v \cdot u \cdot z)/(1 - u)] \cdot [r_t \cdot PA_{t-1} + \delta \cdot PA_t - (PA_t - PA_{t-1})]\} + w \cdot PA_t \qquad (B.10)$$

where

u = income tax rate

v = income tax credit rate

w = property tax rate

z = present value of tax depreciation on $1 of investment.

The variable, D, is a dummy that equals one in the years 1982-86 and zero in other years. In the 1982-86 period, depreciation was allowed only on the value of the investment less 50% of the investment tax credit.

The cost of holding K_t corresponding to this equation is:

$$PS_t \cdot K_{t-1} = \{[(1 - u \cdot z - v + .5 \cdot D \cdot u \cdot z)/(1 - u)] \cdot [r_t \cdot PA_{t-1} \cdot K_{t-1} + \delta \cdot PA_t \cdot K_{t-1} - (PA_t - PA_{t-1}) \cdot K_{t-1}]\} + w \cdot PA_t \cdot K_{t-1} . \qquad (B.11)$$

2. IMPLEMENTATION DETAILS

In this part we discuss details of the implementation of the methods described above.

TIME FRAME

The time-frame for the productivity analysis was previously noted to be 1977-1988. The benchmark year for estimating the size of the gas utility plant stock of major pipeline companies was 1976. Calculation of a benchmark in an earlier year is possible but costly due to the many changes in the identity of the "major" pipeline group before 1976.

DATA

VALUE OF PLANT IN SERVICE

Data on the value of gas plant additions and net gas utility plant are taken from Statistics of Interstate Natural Gas Pipelines. Summary data on the value of gas plant is employed to avoid separately calculating the value of specific kinds of gas plant such as transmission mains. A detailed breakdown of asset values by type of asset is published for gross plant. Salient figures for major interstate pipeline companies in 1988 are reported in Table B.1. Unfortunately, only summary data is published on the value of net plant, which is required for the benchmark calculation.

Gas plant additions data has an intermediate level of disaggregation. It is published for such general categories as transmission plant, distribution plant, and underground storage plant. However, these categories comprise assets of markedly differing types.

Some examples from Table B.1 may help to explain the problem. The gross value of the production and gathering plant of all major pipeline companies in 1988 was $5.0 billion. Of this, $2.3 billion was for field lines, $0.7 billion was for producing gas wells, and $0.5 billion was for compressor station equipment. The breakdown of underground storage plant was similarly diverse.

ASSET PRICE INDEX

The price index employed for gas transmission industry equipment was an even-weighted average of the six regional Handy-Whitman Indexes of Gas Utility Construction Cost Trends - Total Transmission Plant. Each regional index is a weighted average of indexes for structures and improvements, transmission mains, compressor station equipment, and measuring and regulating station equipment.

Table B.1

GROSS BOOK VALUE OF GAS UTILITY PLANT: ALL MAJOR PIPELINE COMPANIES, 1988 (1)

	Gross Book Value (Dollars)	Share of Total Gas Utility Plant in Service	Share of Plant Subcategory
Transmission Plant	32,051,472	72.8%	100.0%
Mains	23,494,689		73.3%
Compressor Station Equipment	5,503,832		17.2%
Structures and Improvements	1,180,744		3.7%
Measuring and Regulating Equipment	733,434		2.3%
Other Transmission Equipment	1,138,773		3.6%
Natural Gas Production Plant	5,411,451	12.3%	100.0%
Field Lines and Pipelines	2,374,170		43.9%
Well Construction	546,341		10.1%
Compressor Station Equipment	522,472		9.7%
Measuring and Regulating Equipment	447,209		8.3%
Purification Equipment	372,776		6.9%
Extraction and Refining Equipment	259,407		4.8%
Structures and Improvements	212,540		3.9%
Other Gas Production Plant	676,536		12.5%
Natural Gas Storage and Processing Plant	2,684,352	6.1%	100.0%
Wells	854,217		31.8%
Compressor Station Equipment	604,455		22.5%
Lines	468,114		17.4%
Structures and Improvements	123,814		4.6%
Measuring and Regulating Equipment	72,242		2.7%
Other Storage and Processing Plant	561,510		20.9%
Distribution Plant	2,218,244	5.0%	100.0%
General Plant	1,537,823	3.5%	100.0%
Transportation Equipment	423,990		27.6%
Structures and Improvements	375,793		24.4%
Office Furniture & Equipment	344,268		22.4%
Other General Plant	393,772		25.6%
Total Gas Utility Plant in Service	44,018,826	100.0%	
Subtotal: Itemized Pipe Lines (2)	26,336,973	59.8%	
Itemized Compressor Station Equipment (2)	6,630,759	15.1%	
Itemized Structures & Improvements (2)	1,892,891	4.3%	
Itemized Measuring and Regulating Equipment (2)	1,252,885	2.8%	
All of the Above	36,113,508	82.0%	

(1) Value is gross of accumulated provisions for depreciation, depletion, and amortization
(2) Excludes value of assets held in distribution sector

This index covers a substantial share of the value of pipeline industry assets. In 1988, specified structures and improvements, pipeline main, compressor station equipment, and measuring and regulating station equipment accounted for 82% of the gross book value of the total gas utility plant in service for interstate gas companies. The share of all equipment of these types was even larger since distribution-plant assets, which accounted for 5% of the total, were not itemized.

PARAMETERS OF THE SERVICE PRICE EQUATIONS

The service price equations require a number of parameter values in addition to the asset price and the value of plant. We discuss each of these in turn.

RATE OF RETURN AND TAX RATES

The rate of return on alternative investments was measured by the rate of return on AAA bonds reported by Moody's Investors Service. This time series is published in the Survey of Current Business. The posited federal income tax and investment tax credit rates were drawn from Pechman (1987) and are reproduced in Table B.2.

For a property tax rate, we employed the ratio of expenses on "Taxes Other Than Income Taxes" to our estimate of the current value of net gas utility plant.

RATE OF PHYSICAL DETERIORATION

The rate of physical depreciation of capital equipment was computed with the 150% declining balance formula. This means that:

$$\delta = 1.5/\text{average service life of assets.}$$

As in other depreciation formulas, decay is sensitive to the duration of useful service (the service life) that is posited for the asset. Since capital equipment is treated as an aggregate in this study, we need an estimate of the average life of the diverse assets in the aggregate.

To compute this estimate, we first consulted with depreciation specialists at the Federal Energy Regulatory Commission. They suggested average service lives for four kinds of capital equipment: line pipe; compressor station equipment, structures and improvements; and measuring and regulating equipment.

Table B.2

FEDERAL INCOME TAX AND INVESTMENT TAX CREDIT RATES

Income Tax Rates

1975-1978	.48
1979-1986	.46
1987	.40
1988	.34

Investment Tax Credit Rates

1975-1986	.10
1987-1988	.00

We calculated a weighted average service life from these numbers where the weights were the shares of these items in the 1988 gross value of itemized gas utility plant in service for all major pipeline companies. The value of itemized plant differs from the value of total plant by the value of gas distribution plant. The lack of itemized data for gas distribution plant was noted above.

This procedure requires us to posit an estimate of the average service life for other kinds of plant owned by interstate pipeline companies. The main items in the "other" category are gas wells, gas well equipment, transportation equipment, office furniture, and gas purification and processing equipment. We posited an average service life of 15 years for these items.

The average service life for all itemized assets was computed to be 46.7 years. This implies an average annual rate of decay of 3.21%. The average productive capacity of new investment in the interstate pipeline industry is thus assumed to decline by 28% after ten years, 48% after twenty years, 62% after thirty years, and 73% after 40 years.

PRESENT VALUE OF TAX DEPRECIATION

Our formula for the service price of capital equipment includes a parameter, z, defined as present value of tax depreciation on $1 of investment. This value depends on the manner in which companies treat depreciation for tax purposes. Of particular importance are the depreciation method and the assumed asset life for purposes of taxation. The latter item is commonly called the tax life.

Different companies use different treatments of depreciation for tax purposes. This complicates the specification of a typical approach for the interstate pipeline industry. Our task is simplified by the fact that most companies are likely to choose the most favorable approach allowed by law. Further, the range of depreciation options is limited by law. Tax authorities set guidelines for tax lives and the treatment of depreciation. These guidelines change over time. Our specifications for depreciation method and tax life are based on a survey of changes in corporate tax policy at the federal level.

During different years of the 1977-88 period three different treatments of tax lives and depreciation for tax purposes prevailed at the federal level. From 1977 to 1980, both 200% declining balance and sum of years digits depreciation were allowed, a policy that had been in force since institution of the Internal Revenue Code of 1954. Sum of years digits yielded the highest present value. As for service lives, corporations were allowed to posit lives that were within 20% of the averages in the 1962 IRS pamphlet, Depreciation Guidelines and Rules. Jorgenson and Sullivan (1981) report a range of tax lives for gas utility structures with a midpoint of 24 years.

From 1981 to 1986, an Accelerated Cost Recovery System was in place as sanctioned by the Economic Recovery Tax Act of 1981. The standard depreciation method was a hybrid consisting of 150% declining-balance treatment for early recovery years and straight-line treatment for later years. Most structures were allowed a tax life of nineteen years.

Under the Tax Reform Act of 1986, a modified accelerated cost recovery system was put in place. Structures were required to be depreciated using the straight-line method. Most non-residential structures were assigned a tax life of 31.5 years.

Depreciation treatments posited in the present study for the calculation of z reflect these trends. Our tax lives for the three periods are 24 years, 19 years, and 31.5 years. As for depreciation method, we assume a sum-of-years digits treatment 1975-80; 150% declining balance treatment 1981-86; and straight-line treatment 1987-88. The formulas for computing z under these treatments are available from the authors.