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An Economic Analysis of Income Growth by U.S. Oil Firms: The Roles of U.S. Oil Regulation and OPEC

This essay develops a new methodology for using accounting income data to estimate the economic gains and losses experienced by firms from any form of regulation. Rigorously derived from the theory of the firm, a variance components model relates the time-series cross-section variability in firm income growth to firm-specific operating characteristics and industry-wide conditions related to regulatory institutions. The model is used to ascertain how U.S. oil firms were affected by U.S. petroleum price regulation and OPEC pricing policies during the 1970s. Two major economic interpretations are supported by the results: (1) U.S. oil price regulation transferred income from U.S. crude oil producing to U.S. refining interests, without any benefit provided to U.S. consumers; and (2) foreign crude oil production subsidiaries for U.S. firms were not beneficiaries of increased world prices for crude oil.

The 1970s was a decade of large increases in the levels of net incomes earned by U.S. petroleum firms. The year 1973 was a benchmark in that net incomes increased dramatically, and their levels subsequently exceeded those prevailing in the early 1970s (see table 1).[1] This interruption in the time series, of course, coincided with the emergence of the so-called unilateral pricing policies practiced by the Organization of Petroleum Exporting Countries (OPEC).

The relation between OPEC pricing policies and the income flows of U.S. oil firms has been the subject of much unsettled controversy. Concerning U.S. firms with international opera-

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1. If the data were extended backward in time to the mid-1960s, one would observe a declining trend in real net income prior to 1973. So the post-1974 levels would stand out as more inconsistent with a simple extrapolation of the pre-1973 time series. The analysis of these data is omitted since the issues addressed in this paper are not closely intertwined with identifying this declining trend. The important point is the absence of a positive trend before 1973, indicating that there is a role for unanticipated events such as OPEC pricing policy and U.S. oil regulation.

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TABLE 1 Net Income, Excluding Nonrecurring Gains or Losses, for 24 U.S. Oil Firms[a] (Billions of 1972 Dollars)

	Year									
	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Net income	6.4	6.2	9.0	11.4	7.9	8.8	8.7	9.1	13.8	16.3

SOURCE.—*Corporate Annual Reports.*
[a] See table 8, Sec. III, for list of firms.

tions, there have been questions raised: Were these firms in "partnership" with OPEC in increasing and sustaining higher crude oil prices (U.S. Senate 1974; Blair 1978, chap. 12)? Or were they victimized by the increased taxation instituted by the OPEC countries? For firms with operations located in the United States, oil price regulation endeavored to limit their returns earned from increased world market prices for crude oil and refined products.

Yet the identity of the beneficiaries from oil price controls has been the subject of much debate. Some analysts have argued that U.S. regulation transferred revenues deprived from U.S. crude oil producers directly to U.S. consumers of refined products, because price controls insulated U.S. consumers from economic forces in world petroleum markets (Friedman 1975; Helbling and Turley 1975; Hall and Pindyck 1977; Cox and Wright 1978). Others have argued that regulation transferred income from U.S. crude oil producers to U.S. refiners (Phelps and Smith 1977; Smith and Phelps 1980). Yet others have argued that the revenues taken from U.S. crude oil producers were about equally shared by U.S. refiners and U.S. consumers (Arrow and Kalt 1979).

This essay analyzes the income statements of U.S. oil firms to determine which of the variety of hypotheses about U.S. oil regulation and OPEC most accurately describes the timing, magnitude, and interfirm differences in income growth by U.S. oil firms in the 1970s. This endeavor could be deemed interesting for three reasons. First, it uses net income data in a novel way, developing a research methodology consistent with the economic theory of the firm, and is capable of being used in a variety of economic applications. Second, this study supplements other efforts to determine the economic effects of U.S. oil price regulation, efforts that have relied on testing the alternative hypotheses with industry price and quantity data. Economic theory dictates that empirical findings from such data are logically related to a set of consistent effects to be found in the study of income growth for U.S. oil firms. Also, a key hypothesis can only be tested with firm-specific income data. Third, public policy debate over increased taxation of the industry, industrial reorganization through vertical divestiture, and oil price regulation have all been influenced by presumed, though untested, explanations for the income growth of U.S. oil firms. So economic analysis of the income statements possesses an inherent interest.

This study distinguishes among the alternative hypotheses by testing their diverse implications for how firm income growth was associated with firm-specific operating characteristics. Section I chronicles the key economic and regulatory events and derives the empirical implications forthcoming from alternative economic models. Section II develops a system of year-specific, cross-sectional statistical models for firm income growth, rigorously derived from the economic theory of the firm. The models are pooled into a time-series, cross-sectional model by imposing constraints on the coefficient structures of the year-specific models. The alternative hypotheses about petroleum markets have testable and distinct implications about the coefficient structure of the resulting variance components model. These models relate firm income growth to changes in oil prices, subsidies imposed by U.S. regulation, and some of the firm's operating variables, such as crude oil production and refining located in the U.S. and overseas, and the firm's access to price-controlled crude oil under U.S. oil regulation. The hypothesis testing strategy will utilize a decision-making framework that optimally balances the costs of falsely accepting or rejecting selected null hypotheses in favor of well-specified alternative hypotheses.

Section III reports the estimates of the basic model and interprets the results from the hypothesis testing. For the class of decision cost functions considered, the optimal statistical inferences are:

1. U.S. oil price regulation transferred income from U.S. crude oil producing to U.S. refining interests, without any benefit provided to U.S. consumers from alleged separation of U.S. and foreign refined product markets.

2. Income growth from U.S.–owned crude oil interests located overseas has varied in a manner expected if those firms were believed to be competitors on world crude oil markets, not participants in world market manipulation.

Section IV applies the estimated variance components model to the study of two related questions: (1) What was the relative contribution to the income growth of U.S. oil firms of U.S. regulatory forces versus normal income growth, fluctuations in aggregate economic activity, and normal economic effects from increased world prices for crude oil? (2) What was the time pattern of the distribution of gains and losses from U.S. oil regulation for the two key sectors, U.S. crude oil production and U.S. oil refining? The statistical analysis indicates that the income effects from U.S. oil regulation were the dominant forces of income growth for the firms—especially during 1974, 1975, 1979, and

1980—and these effects offset the tendency from other economic forces for declining net incomes earned by U.S. oil firms. The annual, after-tax gains of U.S. refiners from regulation initially peaked in 1976 at $5.0 billion (1972 dollars) and began declining until the second episode of increased world prices for crude oil, when annual refiner after-tax gains reached $6.6 billion by 1980. Annual after-tax income losses for U.S. oil producers generally mirrored the gains of U.S. refiners but were quantitatively smaller. State and federal government severance tax and private royalty interests partly shouldered the income losses suffered by the U.S. crude oil production sector. The essay concludes with a brief discussion of the general role of accounting income data in studying the economic effects of regulation, with an assessment of the comparative advantages of accounting data and more commonly used stock market data.

Before proceeding to the analysis, it is important to clarify how this essay's approach differs from the existing literature on the accounting returns of U.S. oil firms. Past studies have concentrated on identifying when, if ever, the firms have enjoyed "excess returns" measured as the difference between the accounting rates of return earned by the petroleum industry and the entire manufacturing sector (Mitchell 1974; Sundar 1977). These studies did not (nor did they aspire to) test this paper's hypotheses concerning the economic sources for any abnormal returns, nor did the studies explain differences among firms in those returns. One may view these past studies as having measured the data to be explained, with one potentially important qualification.

Concentrating on returns for the firm's entire operations can camouflage the presence of conflicting, though important, economic forces. This problem is especially important whenever there is substantial vertical integration in the industry studied, a most common circumstance in the U.S. petroleum industry.[2] The variance components model explaining firm income growth allows identification of unusual gains or losses from various lines of operation, without reliance on line-of-business financial reporting. Also the measurements are not sensitive to transfer pricing policies and other accounting conventions that complicate the analysis of accounting rates of return.[3]

2. The problem is that oil firms are not sufficiently homogeneous in their operations. In Sec. I, it is shown that economic forces were operating in the 1970s that simultaneously generated gains and losses for oil firms. On net, these forces could even cancel! Section IV recounts how some analysts have been misled by comparing the level of net incomes of U.S. oil firms to the estimated income transfers operating under oil regulation, without consideration given to all the economic forces creating gains and losses to these firms.

3. See Sec. II for a formal comparison of accounting return studies with the multivariate statistical analysis reported here.

TABLE 2 Key International and Regulatory Events Operating in Foreign and U.S. Petroleum Markets

Period	International Events	U.S. Regulation
1974–75	Oil embargo/increased posted prices	Petroleum price controls/allocation and entitlement programs
1979–80	Iranian revolution/Iran-Iraq war	Phased decontrol/windfall profits tax

I. Alternative Hypotheses about OPEC and U.S. Oil Regulation

Let us begin by identifying the basic economic issues that provide the background for analyzing the income statements. A multiple-stage procedure shall be used in deriving the testable implications from the various hypotheses of how U.S. regulation and OPEC influenced the income growth of U.S. oil firms. Each international or regulatory event disturbed the initial equilibrium in world petroleum markets by affecting foreign and U.S. market conditions. The various hypotheses about OPEC and U.S. regulation employ different models of how market equilibrium was restored by movements in U.S. and foreign prices for crude oil and refined products. Theoretical analysis of the firm's "profit function"[4] provides the relation between the postulated price movements and the income earned by the firm's various geographical operations: the hypotheses to be tested by the empirical work. The discussion assumes that all income flows are accurately measured and that there are no other forces influencing the incomes earned by the firms. Section II describes how the analysis accommodates these omissions.

The discussion considers a veritable potpourri of events that have affected international petroleum markets during the 1970s (see table 2). The events are considered in chronological order, allowing direct translation of the discussion into analysis of time-series data. The following four subsections analyze original OPEC actions that quadrupled world crude oil prices during 1973, the U.S. regulatory response (1974–78), the international supply disruptions associated with Iranian political actions, and the recent metamorphosis of U.S. oil policy from regulation to taxation. The Reagan administration's deregulation of the industry is not included in this chronology because the requisite data were not available for analysis.[5]

4. In economic terms, of course, profit refers to unanticipated return to capital, while the income of a firm refers to the anticipated return stream from the firm's investment. Everyday use of the term "profit" lumps together economic profit with income. The economics literature is no exception (Arrow and Hahn 1971). My discussion will follow the convention and continue to use the term "profit function."

5. See Smith (1982) for an analysis of the preliminary data indicating the economic consequences of decontrol.

A. OPEC and the 1973–74 Increases in World Crude Oil Prices

In the following discussion, I treat OPEC as an organization that engaged in the cartel-like activity of manipulating the world price of crude oil for the purpose of obtaining above-competitive returns on its crude oil assets.[6] I first consider the effect on the returns earned by U.S. firms on their OPEC crude oil interests and then consider the returns earned by U.S. crude oil assets and worldwide refinery investment. I will ignore U.S. oil regulation initially. This research strategy allows the identification of economic forces operating on the net incomes of U.S. oil firms independent of any effect from U.S. regulation.

Cooperation hypothesis. Blair (1978, chap. 12) has described the view that U.S. firms cooperated with OPEC in manipulating world crude oil prices for their mutual benefit. In his view, the source of OPEC power was their increasing ownership of their countries' oil reserves. The source of power for U.S. oil firms was their supposed unique ability to refine and to market the large quantities of crude oil produced in the OPEC countries. Blair thought the only issue was the division of the gains enjoyed from this "bilateral monopoly": U.S. firms with OPEC crude oil interests were presumed to enjoy increased returns from their foreign crude oil production as world crude oil prices quadrupled.[7]

According to this view, the posted price system was the mechanism for allocating the gains from market restriction between U.S. oil firms and OPEC governments. Equation (1) illustrates how the system worked. While the systems of the OPEC countries differed, the following discussion will concentrate on the posted price system instituted by Saudi Arabia—the largest producer in OPEC, whose crude oil is generally viewed as the "benchmark" commodity by those engaged in the petroleum industry.[8] A per barrel tax (t_{OPEC}) was related to the

6. A different view about OPEC is that there is no cartel activity. Increased OPEC ownership of their oil reserves replaced owners with "short" time horizons by owners with "long" time horizons. The shorter horizons of U.S. oil firms reflected their fear of expropriation, while OPEC governments, such as the shah of Iran, had less fear of relinquishing control over the oil reserves. According to this view, crude oil prices increased during 1973 because the new owners—with greater emphasis on the future value of crude oil—withheld crude oil in 1973 for extraction in later, high-priced periods.

7. The gains to be divided were substantial. The income transfer between oil importing and oil exporting countries in 1974 has been estimated to be at least $64 billion (Fried and Schultze 1975; Smith and Soesastro 1977). The controversy, of course, pertains to the division of these gains between increased gross domestic product (accruing to host countries) and increased income from direct foreign investment (returns to U.S. oil firms).

8. As OPEC governments extended their ownership interests in production, the posted prices influenced the prices U.S. firms paid for buying back crude oil from the host governments. The precise relation between the firms and the host governments is not public knowledge.

TABLE 3 **OPEC Government Revenues from Crude Oil, 1972–77** (Billions of 1972 Dollars)

	Year					
	1972	1973	1974	1975	1976	1977
Revenue	14.0	21.7	79.0	75.4	80.7	89.2

SOURCE.—Organization of Petroleum Exporting Countries 1978.

posted price (p_{POSTED}) after allowances for operating expenses (c), royalty payments (r), and the "income" tax rate (t). Nowhere did the actual market price for crude oil enter into the computations, a fact that had led analysts of the industry to rename posted prices "tax reference" prices in order to avoid any confusion between posted and actual market prices (Penrose testimony in U.S. Senate [1969], pt. 1, p. 162). The total revenue interest of OPEC governments was the sum of the taxes paid under the posted price system and the royalty payments that were also based upon posted, instead of market, prices.

$$t_{\text{OPEC}} = (p_{\text{POSTED}} - c - r)t, \text{ where } r = .125\ (p_{\text{POSTED}}). \qquad (1)$$

Summary data indicate how successful manipulation of the posted prices was for the OPEC governments in raising revenue. The Saudis increased their posted price for crude oil from \$2.59 per barrel in early 1972, to \$3.01 by early 1973, to \$5.11 per barrel during the Arab-Israeli conflict in October, to \$11.65 by January 1974 (Blair 1978, p. 274). Subsequently, only minor adjustments were made until the outbreak of the Iranian revolution in 1979. Table 3 reports the tax revenues collected by OPEC governments during the 1972–77 period, illustrating that increased posted prices for crude oil yielded increased revenue by approximately \$65 billion on an annual basis (the difference between the 1974 and 1972 years which roughly corresponded to pre- and post-oil crisis years).

Taxation hypothesis. An alternative interpretation of the posted price system holds that only OPEC governments possessed market power. The taxation of crude oil implicit in the posted price system was the mechanism by which OPEC governments levied an export tax on their crude oil. So economic cooperation by the OPEC countries took the form of coordinating their "export tax" policies for the purpose of increasing the world price of crude oil. The U.S. oil firms, under this view, did not possess any market power because nonconcessionary firms—such as excluded U.S., Japanese, European—would be willing to take over existing U.S. operations in the OPEC countries. The U.S. producing interests in OPEC countries suffered standard income losses from increased taxation.

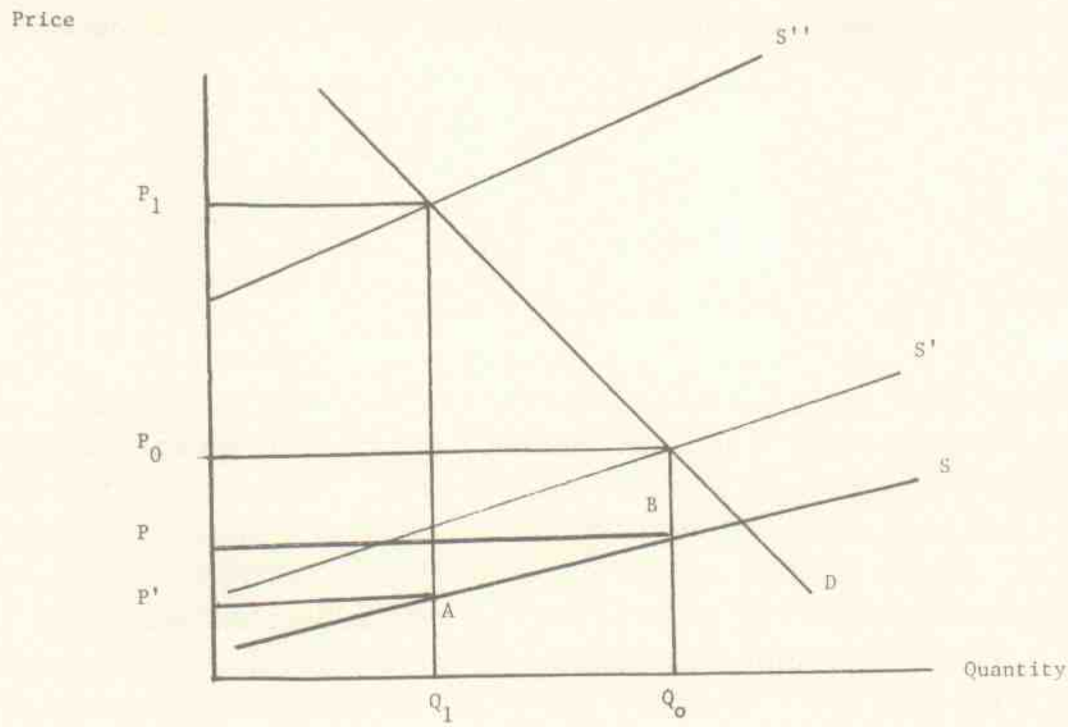

FIG. 1.—Reduced income from U.S. concessions in OPEC countries from increased tax by OPEC governments. D = demand for OPEC crude oil; S = tax-exclusive supply from U.S. oil concessions; S' = pre-oil-embargo OPEC crude oil supply (inclusive of government tax take); S'' = post-oil-embargo OPEC crude oil supply (inclusive of higher government tax take); P_0, Q_0 = pre-oil-embargo market price and OPEC output; P_1, Q_1 = post-oil-embargo market price and OPEC output; P, P' = pre- and post-oil-embargo after-tax price received by U.S. firms; and $P'ABP$ = income loss suffered by U.S. firms from higher OPEC government tax take.

Figure 1 depicts the income loss suffered by U.S. firms. For simplicity, the diagram abstracts from growth in the demand and supply of OPEC crude oil. The tax-exclusive supply curve is assumed to reflect both current marginal costs of production and any user cost associated with the concession companies extracting crude oil today instead of sometime in the future.[9] By increasing the posted price, the OPEC governments increased their revenue take from their oil concessions (see eq. [1]). So OPEC "pricing" policy during late 1973 reduced the supply of crude oil from its properties as concession companies found crude oil production from their OPEC sources to be less profitable at any given world market price. Responding to the increased taxation, private firms would reduce production as reflected by the shift in the supply curve from S' to S''. The figure shows the increase in market price and reduction in OPEC output. An income loss equal to the area

9. Prior to 1973, real prices for crude oil showed a slight declining trend for a long period of time. So the magnitude of the user-cost element of crude oil extraction probably would have been small and therefore is ignored in the discussion. See Pindyck (1977) for an excellent discussion of how the price for a depletable resource can fall in real terms for sustained periods of time.

$p'ABp$ would be generated by the implied reduction in the tax-exclusive price received by U.S. oil firms (from p to p').[10]

While figure 1 succinctly illustrates the taxation hypothesis, it incorrectly presumes that U.S. oil firms could unilaterally select their output rates from their OPEC-controlled properties. With their increased posted prices in 1973, OPEC governments also began dictating production schedules. In theory, a cartel can affect a market by coordinating either pricing (controlled by the taxation contained in the posted price system) or output decisions. The OPEC governments had more than a sufficient number of policy tools available to them for manipulating crude oil prices for their own economic interest. From the viewpoint of U.S. firms, OPEC governments selecting output rates other than Q_1 would intensify the income loss from the taxation instituted by increased posted prices (unless the OPEC governments did not select their "export taxes" with due consideration given to their collective economic power over world oil markets).

Effect on income from other assets. Whichever hypothesis best captures the relationship between U.S. oil firms and OPEC governments, the resulting higher world prices for crude oil affected world petroleum markets. The discussion concentrates on the income earned by non-OPEC crude oil and worldwide refining interests, deriving the implications from elementary supply and factor demand theory.

For non-OPEC crude oil interests, higher crude oil prices obviously increased the returns earned on both previous and prospective investments. As producers expanded production and searched for additional reserves, their activity would bid up the prices of factors of production specific to the industry. It is unimportant in this discussion how the gains from higher crude oil prices were divided between crude oil reserve owners and hired factors in production and development activities.

Analysis of the situation of refiners indicates that yet another segment of the world petroleum industry could have been injured by the OPEC posted price policy. Two conflicting forces were exerted on refining returns by increased world crude oil prices. First, higher crude oil prices, by generating increased prices for refined products, reduced

10. Assuming that the tax-exclusive supply curve is linear, a simple expression for the income loss can be derived. Let $P = a + bQ$ be the inverse supply curve. Then initial income, I_0, is:

$$I_0 = PQ_0 - \int_0^{Q_0} (a + bx)dx = PQ_0 - aQ_0 - \frac{b\,Q_0^2}{2}$$

or, substituting $P = a + bQ_0$, $I_0 = .5\,b\,Q_0^2$. Similarly, post-oil-embargo income (I_1) can be shown by the same computation to be: $I_1 = .5\,b\,Q_1^2$. So, $I_1/I_0 = (1 + Q^*)^2$, where $Q^*=$ proportionate reduction in OPEC output of crude oil.

TABLE 4 Time Line of Key U.S. Oil Regulations

Year First Affecting Earnings	Regulation	Sector Directly Affected
1974	Oil price controls	Production
1974	Crude oil allocation program	Production/refining
1974	Product price ceilings	Refining
1975	Entitlement program	Production/refining
1976	Energy Policy and Conservation Act	Production/refining
1979	Phased decontrol of industry	Production/refining
1980	Windfall profits tax	Production

the demand for refinery capital: fewer capital services were required because consumers were purchasing smaller quantities of refined products. Second, increased crude oil prices could have possibly provided incentives for refinery capital to be substituted for crude oil in the production of refined products: a more capital-intensive technology would have been used to produce any given output slate of products. In theory, the net result depended upon comparing the elasticity of demand for refined products with the elasticity of factor substitution of refinery capital for crude oil. Extraneous information on the industry, however, suggests that on balance higher crude oil prices would have reduced the demand for refinery capital (Phelps and Smith 1977). As refinery capital was immobile in the short run, OPEC pricing policy would have created an (unanticipated) decline in the return to both U.S. and foreign refining capital.

B. U.S. Oil Price Regulation: 1974–78

In the United States, a complex regulatory scheme was devised that sought to regulate in great detail the operation of the entire vertical structure of the domestic industry. Table 4 lists the key regulatory mechanisms whose economic effects are the subject of much debate by economic analysts. Only the distributive benefits from regulation are highlighted here, for those issues can be investigated with the income data of U.S. oil firms. Section II relates the analytical narrative to the econometric analysis.

In my analysis, U.S. crude oil production activity was subjected to a multiple-tier pricing scheme that placed price ceilings on some types of crude oil while exempting others. To avoid a morass of regulatory detail, the discussion consolidates the tiers into two types: controlled oil and exempted oil.[11] Exempted crude oil, of course, enjoyed in-

11. For the unordained but interested reader, see Smith and Phelps (1978) for a detailed description of the evolution of the regulations concerning the pricing of domestic crude oil.

creased returns from the higher world prices for crude oil in 1974. Controlled crude oil, in contrast, would not have enjoyed increased income from higher world prices and actually could have suffered losses. The expansion of production and distribution of exempted crude oil (that initially represented 40% of U.S. production and much of non-OPEC foreign production) would, by itself, bid up the prices of factors used in the production of both exempted and controlled crude oil. Thus, the returns from controlled crude oil operations could have been "squeezed" between a regime of rising costs but stable prices.

The net effect of the increased 1974 world crude oil prices on the income earned from U.S. crude oil investment depended on balancing the gains from higher exempted crude oil prices against possible losses sustained from the production of controlled crude oil.[12] This analysis possesses an empirical implication: firms with larger fractions of their output exempted from controls would have enjoyed larger income gains from their domestic crude oil operations during 1974.

The allocation among refiners of the property rights to price-controlled crude oil played a central role in determining which parties eventually benefited from the revenues deprived from U.S. crude oil operations. During the first full year of regulation, the Crude Oil Allocation Program used historical (December 1973) contracts among U.S. oil producers and refiners for allocating the rights to price-controlled crude oil. In November 1974, a rationing ticket scheme was devised for reallocating the benefits of price-controlled crude oil among refiners. The economic consequences of these property right schemes led to controversy about the beneficiaries of U.S. oil regulation.

Refiner benefit hypothesis and the allocation program. According to this hypothesis the allocation program was effectively a lump sum subsidy to U.S. refining. Each refiner was entitled to a fixed quantity of price-controlled crude oil according to his historical contracts. Hence, price controls "reduced" the price refiners paid for only a portion of their crude oil input. Uncontrolled crude oil remained the marginal source of supply of crude oil for U.S. refiners. So resource decisions by U.S. refiners would be unaffected by the receipt of price-controlled crude oil. Refiners enjoyed a benefit equal to the difference between uncontrolled and controlled crude oil prices for each barrel of controlled crude oil received under the allocation program. This analysis generates an empirical implication: growth of U.S. refining income during 1974 should be higher for the firms with greater access to price-controlled crude oil.[13]

12. To the extent that factor prices increased by more than the various adjustments in ceiling prices, the implied loss would provide incentives to produce less controlled crude oil. Such activity would mitigate, but not eliminate, these losses.

13. The text ignores the possibility that refiners in October and November 1973 anticipated that the allocation program would assign rights to price-controlled crude oil in

Consumer benefit hypothesis and the allocation program. Some analysts (U.S. Senate 1975; FTC 1981) stressed that price ceilings on refined products prevented refiners from retaining the postulated lump sum transfers. According to the product price regulations, refiners had to "average" the cost of controlled and uncontrolled crude oils in computing the maximum allowable prices for refined products. The U.S. refiners receiving price-controlled crude oil were required to reduce their prices for refined products thereby passing on to U.S. consumers the benefits associated with the rights to price-controlled crude oil.

This analysis ignores the structure of product price ceilings. It was possible, and even plausible, that the price ceilings allowed *higher* prices for refined products than would have been sustainable under market forces (Phelps and Smith 1977).[14] If the product price ceilings were not binding, then they could not have prevented U.S. refiners from capturing the lump sum transfers identified by the refiner benefit hypothesis. Testing the empirical implication of the refiner benefit hypothesis discriminates between that hypothesis and the presumption that refiner price ceilings were binding.[15]

The entitlement program. This regulation was instituted in November 1974, partly in response to grumbling among refiners over differences in their access to price-controlled crude oil. The program required that each refiner possess a ticket (entitlement) for each barrel of price-controlled crude oil used in his refinery. Refiners were endowed with entitlements proportional to their total use of crude oil,

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accordance with December 1973 contracts. If the market anticipated these rules, of course, then the prices paid on those contracts could have capitalized the benefits identified in the text. So refiners need not have been the ultimate beneficiaries. This theoretical possibility is not considered in the formal analysis, although the empirical analysis in Sec. III confronts this issue directly.

14. The argument in Phelps and Smith can be summarized as follows. The definition of price ceilings on refined products allowed the level of the price ceiling to depend upon crude oil costs. The formula implicitly maintained at its pre-oil-embargo level the return to be earned on U.S. refining capital. As discussed in Sec. I*A*, the return to U.S. refining capital would have declined with increased world crude oil prices if the U.S. market remained unregulated. So whether the refined product price ceilings were binding depended upon the comparison of two conflicting economic forces: (i) refiner gains from receiving price-controlled crude oil and (ii) the amount by which the return to U.S. refining capital would have declined in an unregulated market. If the latter force was stronger than the former force, then refined product price ceilings would not be binding for a refiner despite his receipt of price-controlled crude oil. The U.S. refiners would benefit from the price-controlled crude oil, as their gains partly offset the losses they would have suffered from higher crude oil prices in an unregulated market. Phelps and Smith relate this analysis to standard factor/product price incidence theory and discuss empirical evidence related to this issue.

15. Even if refiner prices were effectively controlled, consumers would not generally benefit: see Barzel (1974) for a general analysis of resource allocation under price controls. Sorting out the beneficiaries would require consideration of marketing controls, an issue not addressed here.

with the national total of entitlements equaling the national total quantity of price-controlled crude oil. Refiners with access (through their historical contracts) to more price-controlled crude oil than entitlements (endowed by the government) were required to purchase entitlements from refiners whose situation was the reverse. So these interfirm transactions of entitlements neutralized differential gains to U.S. refiners from the allocation program. The price of entitlements was set by the government to be the difference between the average uncontrolled and controlled prices for crude oil.[16] These rules affected resource decisions of U.S. oil firms, unleashing two distinct effects on their income: forced financial transfers among firms, and subsidizing the use of crude oil by U.S. refiners.

The forced sales and purchases of entitlements among U.S. refiners was the most transparent effect of the entitlement program on the income of U.S. oil firms. Buyers of entitlements were exchanging money for a piece of paper allowing them to use their price-controlled crude oil: an expenditure of money that, while maintaining their use of the price-controlled crude oil, represented a new cost to its U.S. refining operation. Sellers of entitlements, on the other hand, received money for relinquishing a piece of paper which had no other use: the proceeds of the sale represented a new source of revenue for the firm's U.S. refining operation. The remaining economic effect from the program originated from the actions taken by U.S. firms to enhance their gains or mitigate their losses from these forced financial transfers.

The subsidization of U.S. refiner demand for crude oil was central to much of the controversy over the ultimate beneficiaries of oil price regulation. Analysts argued that the oil subsidy arose from each refiner receiving additional entitlements for increasing his use of crude oil (see all references in the introductory section above). During the tenure of the program, refiners received from $\frac{1}{7}$ to $\frac{2}{5}$ of an entitlement per barrel of crude oil refined and the price of entitlements had ranged from $8.00 to over $26.00 per barrel. The resulting oil subsidy in any month equaled the fraction of an entitlement issued per barrel of oil use multiplied by the price of entitlements. During the program, the oil subsidy reduced the marginal cost of procuring a barrel of uncontrolled crude oil anywhere from $2.00 to $6.00 per barrel below the uncontrolled market price (see the Department of Energy's *Monthly Energy Review* for February 1981). At given uncontrolled market prices for crude oil and refined products, U.S. refiners would demand greater quantities of crude oil and offer to sell larger quantities of refined products. Ascertaining the incidence of this subsidy on uncontrolled prices for refined

16. The 1975 Energy Policy and Conservation Act instituted more tiers of price ceilings on domestic crude oils. That action necessitated administrative changes in the government's computation of entitlement prices. See Cox and Wright (1978) for details.

products and crude oil was the source of various hypotheses concerning the beneficiaries of the entitlement program.

Consumer benefit hypothesis and the entitlement program. Many analysts assumed that the increased demand for crude oil by U.S. refiners did not affect uncontrolled prices for crude oil. Instead the oil subsidy, by increasing the U.S. supply of refined products, would reduce the prices paid by U.S. consumers (see references in the introductory section above to the consumer benefit hypothesis). Advocates of the extreme form of this hypothesis predicted that the introduction of the entitlement program reduced U.S. prices of refined products by the entire magnitude of the oil subsidy. Full dissipation of the subsidy would have effectively transferred to U.S. consumers the entire subsidy to refining from the allocation program (see Sec. II).

Refiner benefit hypothesis and the entitlement program. The consumer benefit hypothesis neglects important economic forces operating in international petroleum markets. The U.S. refiners entering world crude oil markets would expand their use of crude oil (in response to the oil subsidy) by, partly at least, bidding crude oil away from foreign refiners. The resulting expansion of U.S. refined product supply would be offset by a contraction of foreign refined product supply. The net effect of the entitlement program on world refined product supply (at preprogram prices for crude oil and refined products) depended on the ease with which U.S. and foreign refining activity could have been substituted for each other. If these refining activities were easily substitutable, then the entitlement program would have affected only the geographical location of world refining activity without generating any appreciable increase in world refined product supplies. So refined product prices need not have been reduced by the subsidy to U.S. refiner use of crude oil. According to this view, the entitlement program transformed the refiner-specific subsidy of the allocation program into an increased marginal return to U.S. refiner capital (more heavily utilized because of the expanded U.S. output of refined products).

Proponents of the consumer benefit hypothesis disregarded the importance of substitution possibilities between foreign and U.S. refining. For some, preprogram U.S. international trade in refined products was viewed as "marginal" and irrelevant for understanding U.S. refined product markets.[17] For others, U.S. and foreign refined product markets were believed to be separated because U.S. regulations prohibited the export of refined products by U.S. refiners. Smith and Phelps (1980) show that U.S. imports of refined products did decline after the

17. Economic theory stresses the importance of competition at the margin. This dispute can be settled by testing the empirical implications of the alternative hypotheses.

introduction of the entitlement program (consistent with the substitution hypothesis), but the United States remained an importer of refined products during the oil regulation era for all major refined products (with the exception of gasoline for a few months during 1976). Thus, export controls for refined products could not have been a regulation dominating market forces in the United States.[18] Ultimately any effects of the entitlement program on prices of refined products (and thereby incomes earned by U.S. refiners) must have been related to U.S. monopsony power in world petroleum markets.

The implications of U.S. monopsony power depended critically on the economic structure of the world crude oil market. Economic structure was important in determining whether OPEC would expand its output of crude oil and thereby allow the expansion of the world supply of refined products. The OPEC crude oil output would respond to changes in the demand schedule for OPEC oil if the members of OPEC operated as price takers in world markets. The OPEC output would respond to changes in their marginal revenue schedule, in contrast, if OPEC was behaving noncompetitively. Full analysis of the economic effects of the entitlement program will reveal that this is an important distinction.

Suppose OPEC behaved competitively. The oil subsidy would have increased U.S. demand for crude oil, generating increased OPEC production of crude oil. Despite possible increases in world crude oil prices, refined product prices would nevertheless decline. Increased crude oil prices would have been predicated on increased worldwide use of crude oil (which would have required product price reductions in order to have induced consumers to increase their consumption of refined products). In accordance with the implications of the consumer benefit hypothesis (which would be valid), the marginal return to U.S. refining capital would not have increased by the full amount of the oil subsidy because of the lower refined product prices and higher crude oil prices.

Suppose that OPEC did not behave competitively. Smith (1981) shows that the entitlement program had two conflicting effects on OPEC's marginal revenue schedule. The increased U.S. refiner demand for crude oil would have increased OPEC's marginal revenue schedule. But the program made U.S. refiners' crude oil demands less price elastic. Higher world crude oil prices increased the economic rent from price-controlled crude oil. This in turn increased the magnitude of the oil subsidy. So higher world crude oil prices increased the economic incentive for U.S. refiners to increase their use of crude oil in order to obtain additional individual rights to the larger economic rent

18. Export controls would be economically important for enforcing refined product price controls in any periods when they were binding.

TABLE 5 **Shut-In Capacity in OPEC Countries**

	Date					
	September 1973	November 1973	1974	1975	1976	1977
Amount[a]	.1	2.1	2.9	8.8	8.8	8.1
Percent of total capacity[b]	0	6	9	25	22	21

SOURCE.—*Petroleum Intelligence Weekly* (various issues) for shut-in capacity; OPEC (1978) for actual production.
[a] Millions of barrels per day.
[b] Capacity estimated as shut-in capacity plus actual production.

from price-controlled crude oil. This second effect of the entitlement program exerted downward pressure on OPEC's marginal revenue schedule. That OPEC would have reduced its output in response to the entitlement program is more than a theoretical curiosity. Smith and Phelps (1980) show that the program would on net reduce OPEC's marginal revenue schedule if the preprogram elasticity of demand for OPEC's crude oil was less than 1.7 in absolute value: a likely circumstance.

Table 5 reports data on OPEC shut-in capacity (the amount by which rated crude oil production capacity exceeds actual crude oil production levels) whose time pattern is suggestive of increased output restriction by OPEC in response to the entitlement program. Immediately following successful output restriction, one would have expected a cartel to exhibit unused productive capacity: longer-term output restriction would involve restriction in investment and allowing normal growth to enable increased use of in-place capacity. The data show that unused OPEC capacity materialized immediately after the quadrupling of world crude oil prices in late 1973. During 1975, the first full year of the entitlement program, shut-in capacity increased to three times its preprogram level and had remained at that higher level until the supply adjustments following the Iranian revolution.[19]

If OPEC restricted its output in response to the entitlement program, then that program would have increased prices for both crude oil and refined products. These price effects from regulation would have had different implications for the returns earned by U.S. refining than those

19. The increase in shut-in capacity during 1975 is oftentimes attributed to the 1975 recession. If this explanation were correct, then one should have observed a decline in shut-in capacity as the Western economies recovered in 1976 and 1977. The time pattern of the data in table 5 does not support this explanation. The data are consistent with another hypothesis not related to U.S. oil regulation. The increase in OPEC shut-in capacity simply reflected the difference between immediate and longer-term elasticities of oil demand and non-OPEC oil supply. It is interesting that the implied differences in immediate and 1-year responses to higher prices were so large, while the additional 2-year and beyond adjustments were not of any consequence.

implied by the consumer benefit hypothesis. In theory, the direction of the income effect would depend upon the relative size of the increase of crude oil and refined product prices. Using standard economic relations between international product and factor markets, Smith and Phelps (1980) show that any reduction in income earned by U.S. refiners would have been bound by the preprogram return to foreign refining, which was small.[20] Additionally, increased world prices for crude oil widen the price differential between uncontrolled and controlled crude oils, increasing U.S. refiner gains from the allocation program. As these gains only accrue to U.S. refining (distributed in proportion to U.S. crude oil use because of entitlement transactions), firms with larger fractions of their refining activity located in the United States would have enjoyed greater income growth than firms more heavily involved in foreign refining.

Other policies. Two other policies were instituted during 1975 that would have affected incomes earned by U.S. oil firms: the crude oil tariff and the December extension of price control regulations by the Energy Policy and Conservation Act (EPCA). The analysis of these policies follows the earlier discussion of the economic consequences of U.S. regulation and increased crude oil prices.

The crude oil tariff, of course, increased uncontrolled U.S. crude oil prices paid by U.S. refiners, even if world crude oil prices remained constant. Without regulation, those higher crude oil prices would have reduced incomes of U.S. refiners, for the same reasons that increased world prices for crude oil during 1973–74 would have reduced the return to refining. The return to foreign refining, in contrast, would be increased, because the U.S. oil tariff reduced competition facing foreign refiners from U.S. refiners in both crude oil and refined product markets. At initial prices for crude oil and refined products, U.S. crude oil demand and U.S. refined product supplies were reduced by the U.S. oil tariff.

As the oil tariff was introduced within 3 months after the introduction of the entitlement program, the full analysis of the oil tariff must account for interactions with U.S. oil regulations (and there were many). The oil tariff increased refiner gains from the Crude Oil Allocation Program, because it widened the differential between uncontrolled and controlled prices for U.S. crude oil. In turn, this larger price

20. These conclusions come from examining the economic constraints placed on product price differentials from both direct arbitrage in product markets and indirect arbitrage of product prices from international trade in crude oil. According to industry estimates, the returns to foreign refining were barely positive in 1974 (*Petroleum Intelligence Weekly*, various issues). This method of analysis implies that the entitlement program would increase the return to U.S. refining capital by the full amount of the oil subsidy.

differential increased the oil subsidy operating under the entitlement program. Smith and Phelps (1980) show that, on net, the oil tariff was not large enough to offset fully the oil subsidy to U.S. refining in 1975. The consequences of the entitlement program will still dominate income growth for U.S. oil firms.

The 1975 EPCA extended, with some modifications, the control environment already described. The primary modifications involved restructuring of crude oil pricing regulations and changes in the rules governing the allocation of entitlements among refiners. These modifications affected the magnitude of the transfers and subsidies described above, so there is no need for additional analytical discussion. Time-series data on the oil subsidy and price differentials between uncontrolled and controlled crude oils can capture the effect of the EPCA on incomes earned by U.S. oil firms; the mechanisms of any effects being the same as those dictating the economic effects of the original regulations.

C. International Supply Disruptions: 1979–80

This time period provides additional observations with which to confront the hypotheses about U.S. oil regulation, even though this period differs from the 1974–75 time period in one important aspect. The earlier period reflected the arrival of OPEC market power. The later period witnessed increased world prices for crude oil and refined products because of supply disruptions associated with Iranian political activities.

A brief chronology of events identifies two major actions undertaken by Iranian political forces: the Iranian revolution and the Iran-Iraq war. Before presenting some summary information relating the events to price movements in international crude oil markets, it is useful to understand the importance of both Iran and Iraq in international oil supply.[21] Iran produced about 18% of OPEC's crude oil output during 1977 and 1978, the 2 years preceding the recent "oil crisis" years. Iraq, while a smaller producer, supplied almost 9% of OPEC crude oil output in 1977 and 1978. So events affecting the supply of crude oil from these second and third largest OPEC producers could have plausibly exerted considerable influence on world petroleum markets.

The Iranian revolution, in early 1979, reduced Iranian production from 6 million barrels per day to virtually zero for almost the first half of 1979. As production recovered to about 3 million barrels per day, the taking of the American hostages witnessed another reduction of Iranian output to about 1.5 million barrels per day. International crude oil prices increased, with the price of Saudi Arabian light increasing from \$13.34 per barrel (early 1979) to \$28.00 per barrel by spring 1980. As prices stabilized in mid-1980, the Iran-Iraq war began, driving to zero

21. The data are from the *Monthly Energy Review*.

Iranian and Iraq production that had previously totaled almost 5 million barrels per day. The price of Saudi Arabian crude oil increased to $32.00 per barrel.

These series of supply disruptions unleashed a variety of forces on the incomes earned by U.S. oil firms. For U.S.-owned crude oil production located in Iran and Iraq, the associated income flows were obviously lost. For the U.S.-owned crude oil operations located in other OPEC countries, increased income would be generated according to either the cooperation or taxation hypotheses of the relations between OPEC governments and U.S. oil firms. The cooperation hypothesis would presumably view the episode of increasing world crude oil prices as another opportunity for OPEC governments and U.S. oil firms to exploit their alleged "bilateral monopoly." The taxation hypothesis would also predict increased income flows because the OPEC countries (other than Iran and Iraq) would experience an increased demand for their crude oil. While host governments would increase their export tax, increased tax-exclusive prices would be received by U.S. oil firms to stimulate the profitable expansion of output in the face of increased demand.[22] So the 1979–80 episode of increased world crude oil prices is not able to distinguish between the "cooperation" and "taxation" hypotheses.

The 1979–80 episode, however, still provides an opportunity for testing the key hypotheses concerning U.S. oil price regulation. The disruptions of international oil supply generated increasing differentials between uncontrolled and controlled U.S. crude oil prices. These higher price differentials increased the oil subsidy to U.S. refining: $1.60 per barrel in 1978, $3.05 per barrel in 1979, and $4.40 per barrel in 1980.

As with the introduction of the entitlement program, the refiner and consumer benefit hypotheses of oil regulation have different expectations about the income growth of U.S. and foreign refining. The refiner benefit hypothesis predicts that the income flows from U.S. refining grew relative to those from foreign refining, as the increased oil subsidy enhanced the marginal return to U.S. refining. The consumer benefit hypothesis, on the other hand, predicts no differential income growth, because of its belief that the oil subsidy was dissipated by providing U.S. consumers with lower prices for their refined products than would have prevailed in the absence of the oil subsidy.

D. *The Metamorphosis of U.S. Oil Policy from Regulation to Taxation*

The transition from oil price controls to increased taxation of U.S. crude oil production was the final major development in the 1970s. In

22. An analogous diagram could be drawn to fig. 1, adding a shift in the demand for OPEC crude oil.

spring 1979 the Carter administration began a program of phased decontrol of the U.S. industry: allowing the price ceilings imposed on U.S. crude oil to be lifted at rates computed to eliminate all controls by September 1981. The administration proposed, and finally received from Congress in March 1980, a "windfall profits tax" to be levied on the increased crude oil prices received by U.S. producers.

In principle, the policy of phased decontrol would have influenced the income flows of the U.S. industry by reducing the price differentials between uncontrolled and controlled crude oils and diminishing the oil subsidy given to U.S. refining. The evidence given above, however, showed that phased decontrol was overwhelmed by the international supply disruptions associated with the Iranian revolution and the Iran-Iraq war: the oil subsidy rose to its highest levels during the entire period of oil regulation. So the 1979–80 time period can be studied without explicit consideration given to the consequences of phased decontrol.[23]

The windfall profits tax enacted in 1980 was an ad valorem excise tax levied on the difference between prices received by U.S. crude oil producers and specified ceiling prices in the tax legislation. The regulatory details concerning modifications of price ceilings and the variety of tax rates is not important to the analysis. In general terms, the tax allowed U.S. producers to enjoy only a fraction of the increased revenues generated from increased price ceilings. The consequences of this tax for the income flows of U.S. oil firms is not important from the viewpoint of testing the competing hypotheses about the beneficiaries of oil regulation. All of the controversy arises around the implications of the oil subsidy to U.S. refining.

II. Statistical Research Design

A variance components model explaining income growth by U.S. oil firms can discriminate among the various hypotheses presented in Section I. The model will be derived from the theory of the firm, with consideration given to the many institutional details about U.S. regulation. The analysis reveals that many of the alternative hypotheses about oil regulation can be translated into predictions about the *quantitative* magnitude of key coefficients in the statistical model. After an extensive derivation of the specification, the discussion describes the estimation strategy and the method of hypothesis testing.

A. *Model Specification and Statement of Hypotheses*

The theoretical justification for the equation specification can be found by analyzing the profit function for a hypothetical U.S. oil firm solely

23. Phased decontrol did have an effect in the sense that, in the absence of the policy, the oil subsidy and price differentials between uncontrolled and controlled crude oils would have been even greater during the disruptions of international oil supplies.

TABLE 6 Glossary of Symbols Used in Development of Specification for Variance Components Model

Category and Symbol	Definition
Market prices:	
P_F	Foreign refined products
P_H	U.S. refined products
W_F	Foreign crude oil
W_U	Uncontrolled U.S. crude oil
W_C	Controlled U.S. crude oil
Firm *i*'s quantities:	
Refining subsidiaries:	
Q_{if}	Foreign refined product output
Q_{ih}	U.S. refined product output
Y_{if}	Crude oil use in foreign refining
Y_{ih}	Crude oil use in U.S. refining
Y_{ic}	Quantity of price-controlled crude oil from allocation program
Crude oil subsidiaries:	
Y^*_{if}	Foreign crude oil production
Y^*_{iu}	Uncontrolled U.S. crude oil production
Y^*_{ic}	Controlled U.S. crude oil production
Firm cost functions:	
C_f	Foreign crude oil production
C_h	U.S. crude oil production
Regulatory variables:	
D_A	Dummy variable indicating presence of allocation program
D_E	Dummy variable indicating presence of entitlement program
F	Fraction of entitlement given per barrel of U.S. refining of crude oil
P_E	Price of an entitlement
T	U.S. crude oil tariff
Incidence of various forces on prices of refined products:	
λ_f	World crude oil price on foreign refined products
λ_h	World crude oil price on U.S. refined products
λ_f^E	Oil subsidy on foreign refined products
λ_h^E	Oil subsidy on U.S. refined products
λ_f^T	U.S. oil tariff on foreign refined products
λ_h^T	U.S. oil tariff on U.S. refined products
Tax and royalty rates:	
t_{OPEC}	OPEC crude oil tax described in eq. (1)
t_c	U.S. corporate income tax
r_f	OPEC royalty rates
r_h	U.S. state government severance tax rate and payment to private royalty right owners

engaged in crude oil production and refining in the United States and overseas. The profit function contains standard revenue, cost, and tax terms, plus additional terms that capture the special features of the allocation and entitlement programs. Table 6 provides a glossary of symbols.

Equation (2) presents our hypothetical firm's pretax, net revenue function (NR_i) for the 1970s. All prices, quantities, and regulatory variables are understood to possess a time subscript, which is suppressed for notational convenience and the subscript i is a firm index. The equation assumes that refined product price controls were not binding, an issue considered below. The term involving the allocation program, $D_A\,(W_U - W_C)Y_{ic}$, shows how receiving quantities of price-controlled crude oil reduced the acquisition cost of crude oil by the difference between uncontrolled and controlled crude oil prices. If the firm had no controlled crude oil under the allocation program, then the entire amount of crude oil used in U.S. refining would have been purchased at uncontrolled crude oil prices (as shown by the preceding term). The term involving the entitlement program, $(FY_{ih} - Y_{ic}D_E)P_E$, illustrates the additional source of net revenue created by that program: the net sales of entitlements being the difference between the amount allocated under the rules of the program, FY_{ih}, and the amount required, Y_{ic}.

$$\begin{aligned} NR_i = {} & Ph\,Q_{ih} - W_U Y_{ih} + P_F Q_{if} - W_F Y_{if} + D_A\,(W_U - W_C)Y_{ic} \\ & + D_E(FY_{ih} - Y_i D_E)P_E + (1 - r_h)\,(W_U Y^*_{iu} + W_C Y^*_{ic}) \\ & - C_h(Y^*_{iu}, Y^*_{ic}) + W_F\,(1 - r_f)Y^*_{if} - C_f\,(Y^*_{if}) - t_{\text{OPEC}}\,Y^*_{if}. \end{aligned} \tag{2}$$

The after-tax profit function, equation (3), is derived by subtracting tax liabilities from the pretax, net-revenue function. The firm's tax liabilities are affected by the deductibility of U.S. royalty and severance tax payments and by the taxation situation of foreign income.[24] The testable implications are derived by taking second-order approximations to the change in I and utilizing the various hypotheses about the determination of refined product prices in the United States.[25] The resulting expression for the change in the firm's after-tax income involves a collection of terms measuring the effect of changes in the prices for crude oil and refined products, the allocation and entitlement programs, and normal income growth independent of those economic forces.

$$\begin{aligned} I_i = {} & W_F\,(1 - r_f)Y^*_{if} - C_f(Y^*_{if}) - t_{\text{OPEC}}\,Y^*_{if} + (1 - t_c)[P_{if}Q_{if} - W_F Y_{if} \\ & + P_h\,Q_{ih} - (W_F + T)Y_{ih} + (D_A - D_E)(W_F + T - W_C)Y_{ic} \\ & + P_E F Y_{ih} + (1 - r_h)(W_U Y^*_{iu} + W_C Y^*_{ic}) - C_h(Y^*_{iu}, Y^*_{ic})]. \end{aligned} \tag{3}$$

24. The tax liability was assumed to be proportional to the net revenue function, with the last three terms in eq. (2) being exempted from taxation. This specification amounts to assuming that foreign tax credits were sufficient for removing any U.S. tax liability for income earned from foreign crude oil production and that the income tax rate on foreign refining (primarily European) was less than or equal to the U.S. corporation income tax rate. Under the foreign tax credit law of U.S. income taxation, the U.S. tax rate would have been the effective marginal tax on foreign refining income. Neither assumption distorts the factual matters (Blair 1978, chap. 8).

25. In the derivation, it was assumed that uncontrolled U.S. crude oil prices equaled foreign crude oil prices plus the oil tariff.

A compact expression can be found for the change in the firm's after-tax income. These results provide the background for motivating the specification of the variance components model. The derivation exploits duality results from the theory of the firm and uses approximations to how the firm's resource decisions respond to changes in market prices and the oil subsidy operating under U.S. oil regulation. Facilitating the exposition of the key relations, the discussion begins by analyzing economic forces influencing 1974 income growth. The analysis is then repeated for the economic forces occurring during 1975 and 1976. The discussion initially abstracts from firm income growth associated with technological change in the industry and growth in product demand from increased aggregate income. An Appendix elaborates on the mechanics of the mathematical approximations used in the derivations.

Two special forces influenced the income flows from U.S. refining in 1974: increased market prices for crude oil and refined products, and the institution of the allocation program. The expressions in (4) are the terms approximating the effects of these forces on the firm's after-tax income. Equation (4a) measures the income effects from changes in market prices for crude oil and refined products and reflects how the change in the after-tax income of the firm is a function of the properties of the firm's product supply and factor demand functions (Arrow and Hahn 1971).[26] All of the functions are evaluated at the prices for crude oil and refined products prevailing before the "oil crisis" and U.S. regulation: a fact denoted by the superscript "o." Equation (4b) measures the effect of access to price-controlled crude oil under the allocation program. The terms reflect that the quantity of price-controlled crude oil was fixed to the firm and would not influence the resource decisions of the firm.

$$dI_i\Big|_{\substack{\text{varying}\\ \text{prices}}} = (1 - tc)\Big\{Q^{\text{o}}_{ih}dP_h - Y^{\text{o}}_{ih}dw_f + .5\Big[\frac{\partial Q^{\text{o}}_{ih}}{\partial P_h}(dP_h)^2 + \frac{\partial Q^{\text{o}}_{ih}}{\partial w_f}dP_h dw_f - \frac{\partial Y^{\text{o}}_{ih}}{\partial P_h}dP_h dw_f - \frac{\partial Y^{\text{o}}_{ih}}{\partial w_f}(dw_f)^2\Big]\Big\}; \tag{4a}$$

$$dI_i\Big|_{\text{allocation}} = (1 - tc)\, Y_{ic}\,(w^{\text{o}}_f + dw_f - w_c). \tag{4b}$$

Equation (5) presents the change in net income originating from U.S. refining operations, $dI(hr)_i$, computed from the second-order approximation. The equation utilizes three substitutions: (1) the terms in equation (4a) are simple averages of pre and post price change quantities of crude oil and refined products, because, neglecting normal

26. The relevant product supplies and factor demands are those relating resource decisions to all product and factor prices inclusive of any taxes or subsidies operating under U.S. oil regulation.

growth considered below, those quantities changed only because of the change in prices for crude oil and refined products;[27] (2) the quantity of crude oil approximately yielded the same quantity of refined products, $Q_{ih} \simeq Y_{ih}$; and (3) the change in the price of refined products is proportional to the change in the world price of crude oil.

$$dI(hr)_i = (1 - tc)\,[(\lambda_h - 1)\,\overline{Y}_{ih} dw_f + Y_{ic}\,(w_f^{o} + dw_f - w_c)]\,, \quad (5)$$

where the overbar indicates the simple average of pre and post price change quantity of crude oil refined.

The same strategy of approximation and substitution can be applied to the income terms for the other subsidiaries: see equation (6). The change in net income for firm i during 1974 depended upon its operating characteristics during 1973 and 1974 as given by the right-hand side of the equation. The alternative hypotheses about U.S. oil regulation and OPEC's relations with U.S. oil firms assert different propositions about the signs and magnitudes of the second and third terms. The first term controls for standard economic effects of higher world crude oil prices on the income from U.S. and foreign refining and uncontrolled U.S. crude oil production:

$$\begin{aligned} dIi/1974 = {} & (1 - tc)\,[(\lambda_h - 1)\,\overline{Y}_{ih} + (\lambda_f - 1)\,\overline{Y}_{if} + (1 - r_h)\,\overline{Y}^*_{iu}]\,dw_f \\ & + (1 - tc)(w_f^{o} + dw_f - w_c)Y_{ic} + (dw_f - dt_{\mathrm{OPEC}})\,\overline{Y}^*_{if}. \end{aligned} \quad (6)$$

The key dispute about 1974 oil regulation is whether receiving price-controlled crude oil conferred the benefit depicted in equation (6). View the equation as the deterministic portion of a regression model explaining firm variation in net income growth in 1974. The refiner benefit hypothesis of the allocation program predicts that the coefficient for the firm's quantity of price-controlled crude oil would be about \$1.82 per barrel (1972 dollars).[28] In dissent, advocates of the consumer benefit hypothesis would argue that the derivation of the equation neglected the structure of binding refined product price controls. The price received for U.S. refined product sales was reduced by the cost savings from receiving price-controlled crude oil, implying a zero coefficient for the Y_{ic} variable.

27. For example,

$$dQ_{ih} = \frac{\partial Q_{ih}}{\partial P_h}\,dP_h + \frac{\partial Q_{ih}}{\partial w_h}\,dw_u.$$

28. The average difference between uncontrolled and controlled U.S. crude oil prices was \$4.88 per barrel in 1974. Using the statutory rate for the corporate income tax in 1974 (see Pechman 1977, table A-4), a barrel of price-controlled crude oil should have increased income by about \$2.54, or \$2.19 in 1972 dollars. As the allocation program operated for only 10 months before the introduction of the entitlement program, the \$2.19 was multiplied by 10/12. See text discussion for why the entitlement program destroyed this firm-specific gain from the allocation program, regardless of one's view of the incidence of the oil subsidy.

The dispute about the relation between OPEC and U.S. oil firms involves the last term in equation (6). Under the taxation hypothesis, that last term would measure an income loss. If the cooperation hypothesis were correct, then the above analysis would be incorrect and would presumably miss an income gain for U.S. oil firms from their foreign crude oil production.

Income growth for 1975 reflected the introduction of the entitlement program and the oil tariff. Equation (7) presents the second-order approximation to the change in firm i's net income, allowing for the oil subsidy and the oil tariff to affect the prices received on sales of refined products. The first term controls for standard effects of higher world crude oil prices on incomes generated by U.S. and foreign refining. The second term captures the effect of world crude oil prices on the income from uncontrolled U.S. crude oil production. The third and fourth terms measure the effects of the entitlement program. The fifth term measures the effect of the oil tariff on income from U.S. and foreign refining. The last term captures the changes in income earned from crude oil interests in OPEC countries. The discussion concentrates on the terms involving U.S. policy variables.

$$\begin{aligned} dIi/1975 = {} & (1 - tc)[(\lambda_h - 1)\bar{Y}_{ih} + (\lambda_f - 1)\bar{Y}_{if}]\, dw_f \\ & + (1 - tc)(1 - r_h)\bar{Y}^*_{iu}\, dw_f + (1 - tc)[(\lambda^E_h + 1)\bar{Y}_{ih} \\ & + \lambda^E_f\, \bar{Y}_{if}]dP_E F - (1 - tc)(dw_f + dT - d^P_E)Y_{ic} \\ & + (1 - tc)[(\lambda^T_h - 1)\bar{Y}_{ih} + \lambda^T_f\, \bar{Y}_{if} + (1 - rh)\bar{Y}^*_{ih}]\, dT \\ & + (dw_f - dt_{\mathrm{OPEC}})\bar{Y}^*_{if}. \end{aligned} \tag{7}$$

View equation (7) as the deterministic portion of a cross-sectional model of 1975 firm growth.[29] The various hypotheses about the effect of the entitlement program on U.S. refined product prices possess different expectations about the estimated coefficients for the interaction terms between the oil subsidy ($P_E F$) and U.S. and foreign refining operations ($\bar{Y}_{ih}$, $\bar{Y}_{if}$), the third set of terms in (7).

1. Consider the view that U.S. and foreign refining were so readily substitutable that the oil subsidy did not reduce prices for refined products. Proponents of this view would expect that the coefficient for the foreign refining term equals zero and the coefficient for the U.S. refining term equals one minus the corporate income tax rate (.52),

29. Estimating this cross-section equation with 1975 data would encounter a severe identification problem. There is no interfirm variation in the oil price changes, oil subsidy, and oil tariff given in the equation. Variation in operating characteristics could identify linear combinations of the parameters of interest. For example, the coefficients for the U.S. and foreign refining variables would be $(1 - t_c)\,[(\lambda h - 1)dw_u + (\lambda^E h + 1)P_E F - (1 - \lambda^T_h)T]$ and $(1 - t_c)\,[(\lambda_f - 1)dW_u + \lambda^E_f P_E F + \lambda^T_f T]$, respectively. The text ignores this statistical problem, because later discussion indicates how the parameters can be identified by pooling the system of cross-sectional equations (such as eqq. [6] and [7] in the text).

because the oil subsidy only increased the marginal return to U.S. refining.

2. Consider the view that U.S. refined product markets were economically separated from foreign refined product markets. Proponents of this view would expect the coefficient on the U.S. refining term to be less than .52 (the hypothesis that the entire oil subsidy was passed on to U.S. consumers as lower refined product prices would expect a zero coefficient). Expectations about the magnitude of the coefficient for the foreign refining term are less clear: it must be less than zero.

3. Consider the view that U.S. and foreign refined product markets were not separated, but U.S. monopsony power reduced prices for refined products. Proponents of that view would expect the coefficient for the foreign refining term to be negative and the coefficient for the U.S. refining term to be larger by .52.

4. Consider the view that the entitlement program increased output restriction by OPEC. The higher prices for refined products would be reflected in the term capturing the consequences of higher world prices for crude oil. The oil subsidy would not be exerting any independent effect on refined product prices. Instead, the oil subsidy would increase the marginal return to U.S. refining, an effect captured by a .52 coefficient for the U.S. refining term. As foreign refiners would only be influenced by higher crude oil prices, the coefficient would be zero for the term involving the interaction between the oil subsidy and foreign refining.

Unlike a subsidy financed from the public treasury, the oil subsidy generated by the entitlement program was financed from the benefits provided by the allocation program: the fourth term in (7) captures this effect. In principle, the government computed the price of entitlements to equal the difference between uncontrolled and controlled U.S. crude oil prices. If accurately computed, the total value of entitlements issued to the industry would have equaled the value of the rights to price-controlled crude oil. This internal financing of the oil subsidy meant that the firm-specific benefits under the allocation program were destroyed.

So each firm contributed to the financing of the subsidy in proportion to its quantity of price-controlled crude oil. Of course, U.S. refiners "recaptured" the benefits to price-controlled crude oil only to the extent that the oil subsidy increased the marginal return to U.S. refining instead of reducing U.S. prices for refined products. The gains from that increased marginal return would be distributed in proportion to the firm's scale of U.S. refining as already indicated by the third term in (7).

The oil tariff in 1975 was the final force influencing the refining incomes of U.S. oil firms (see the fifth term in eq. [7]). The expression measures the three distinct income effects. First, U.S. refining would suffer a differential loss because it must pay the tariff while foreign refining was exempted from the tariff. Second, the oil tariff may have affected refined product prices by reducing U.S. product supply. The same issues concerning the incidence of the oil subsidy arise in the incidence of the oil tariff, because both policies involve a differential shift in U.S. product supply. A similar pattern of coefficients for the interactions among the refining variables and the oil subsidy and oil tariff should be observed.[30] Finally, income from uncontrolled U.S. crude oil production would be enhanced because of its protection against the competition from foreign crude oil.

Examining the expression for the change in net income during 1976 will reveal the equation structure that remained for the duration U.S. oil regulation (see eq. [8]). The first term is the now familiar measure of how changes in world crude oil prices affect the income flows from U.S. and foreign refining. The second term measures the effect of uncontrolled U.S. oil prices on income earned from uncontrolled U.S. oil production. The third term measures the incidence of the oil subsidy to U.S. refining on the incomes earned from U.S. and foreign refining. The fourth term measures the standard effect of changes in the oil tariff on the income earned from U.S. and foreign refining. The fifth term measures the income flows created by OPEC crude oil concessions. The last term measures the effects of adjustments in price ceilings for controlled U.S. crude oil production following the implementation of the EPCA. An individual firm's access to price-controlled crude oil disappears, because differential access to price-controlled oil generated an offsetting differential liability for purchases of entitlements.

$$
\begin{aligned}
dIi/1976 = {} & \\
& (1 - tc)[(\lambda_h - 1)\bar{Y}_{ih} + (\lambda_f - 1)\bar{Y}_{if}]dw_f \\
& + (1 - tc)(1 - r_h)\bar{Y}^*_{iu}(dw_f + dT) + (1 - tc)[(\lambda^E_h + 1)\bar{Y}_{ih} \\
& + \lambda^E_f \bar{Y}_{if}]dP_E F + (1 - tc)[(\lambda^T_h - 1)\bar{Y}_{ih} + \lambda^T_f \bar{Y}_{if}]dT \\
& + (dw_f - dt_{\text{OPEC}})\bar{Y}^*_{if} + (1 - tc)(1 - r_h)\bar{Y}^*_{ic}\, dw_c.
\end{aligned}
\tag{8}
$$

Additional considerations. The discussion thus far has abstracted from economic forces that could have influenced the income of U.S. oil firms. How can the model be specified to capture how firm income grows in response to changes in product demand due to changes in aggregate economic activity and technological change in the industry?

30. The oil subsidy and oil tariff may affect refining incomes differentially because the former policy increases world oil prices while the latter policy decreases world crude oil prices. The first term in eq. (7) holds constant these effects, so the refining terms discussed in the text can be viewed as the partial effects of the policies. As discussed in n. 29, an isolated 1975 cross-section regression would be unable to identify all the parameters discussed in the text. See the discussion in subsection *B* on identifying all the parameters.

In principle, any influence of changes in aggregate economic activity on the incomes earned by U.S. oil firms must be transmitted through changes in factor or product prices. The specifications presented in (6)–(8) already include the income effects from changes in crude oil prices. So only the potential effect of aggregate economic activity on refined product prices must be considered. The inclusion of an interaction term between worldwide refining activity and the change in aggregate income can be justified by the following procedure. The change in refined product prices can be written to depend upon the change in aggregate income, in addition to other variables already considered by the analysis. Substituting that expression in the portion of the Taylor Series expansion involving the change in the price of refined products yields the stated addendum to the earlier specifications.

Two issues arise concerning the role of firm income growth associated with industry technological progress in the models explaining the change in net income earned by U.S. oil firms. First, the background derivations of (6)–(8) used actual changes in output and crude oil inputs to refining in the approximations to the second-order income effects from changes in the crude oil prices, the oil subsidy, and the oil tariff. If inputs and outputs would have changed even if prices and subsidies had remained constant, then does the approximation introduce an error into the computation? The Appendix shows that the method remains valid.

The second issue concerns how to model the magnitude of firm income growth that would have occurred even if crude oil prices, oil subsidies, tariffs, and aggregate income had all remained constant. The simplest specification is chosen: firm income growth associated with technological progress is proportional to a simple moving average of the previous and current year's total refining activity. So dividing both sides of equations (6)–(8) by the moving average of total refining transforms the dependent variable to be the change in net income per barrel of world refining activity. The operating characteristics are now expressed as ratios to the moving average of world refining. The addition of a constant term in the new expression measures firm income growth associated with technological change.

Economic theory suggests that two conflicting forces will be captured by that term. Holding the prices of refined products constant, industry technological progress will increase the amount of output attainable from given levels of inputs. This force suggests that technological change will increase the firm's income, for a given level of input expenditure will yield greater revenues. Another economic force, however, operates in the opposite direction. The expansion of firm and industry output would reduce prices of refined products, for given levels of crude oil prices, and product demand conditions. From standard economic analysis of technological change, the balance of these two forces depends upon the elasticity of product demand (Hicks 1968). The income-reducing effects from lower real prices for refined products will dominate the income-increasing cost savings if the demand for refined products is price inelastic (a reasonable assumption). So the constant term in the statistical model should be negative.

Measurement problems. Linking the theoretical specification to observable variables encounters three problems: accounting data must be used for estimating the flow of income earned by U.S. oil firms, firm-specific information on key operating variables is not publicly available, and details of the financial relations between U.S. oil firms and OPEC governments are not in the public domain. The problems are surmountable.

Using accounting income to indicate the income flows of a corporation is subject to a variety of well-known difficulties. Amortization and depreciation practices need not reflect economic depreciation. Line-of-business income accounts can be distorted by arbitrary rules concerning joint cost allocation and transfer pricing policies that are more attuned to the incentives operating under tax systems facing the firm than to the economically relevant pricing of intrafirm transactions. These problems need not portend problems for the empirical analysis pursued below.

Line-of-business reporting problems are circumvented by analyzing the consolidated income account of the firm. The following example illustrates this point. Suppose that the firm's optimal transfer pricing policy generates accounting reports whereby a portion of the income earned from U.S. refining actually accrues as reported income for the firm's foreign crude oil production subsidiary. For analysis based on line-of-business reports, this practice would mislead the analyst. He would potentially underestimate the amount of income generated by U.S. refining and possibly misunderstand the economic source of any increased accounting income associated with foreign crude oil production. Such problems in inference would be avoided by viewing the firm as the unit of analysis. The statistical analysis would estimate income growth associated with the firm's operating characteristics. So in the above example, the statistical model's estimate of income growth associated with U.S. refining is not predicated on its being correctly reported as accruing to U.S. refining. The statistical procedure only requires that the income flow shows up *somewhere* in the firm's subsidiaries.

The economics profession's skepticism of accounting income estimates has other dimensions, primarily related to (1) concerns about the use of historical instead of opportunity costs in the computation of "net profit" and (2) the use of arbitrary depreciation rules. This essay is no place to do justice to the many subtleties encountered in that debate:

instead the econometric implications of potential measurement error are considered. Equation (9) presents a simple linear specification of the relation between accounting income, Y_A, and economic income, Y_E. The intercept (a) measures the magnitude of systematic bias in the reported levels of income. If the slope coefficient (b) differs from unity, then the degree of measurement error depends upon the level of economic income. If the size of the measurement error is an increasing function of economic income, then the slope will be less than one. Finally, the error term in the relation (e^t) represents random measurement error.

$$Y_A^t = a + bY_E^t + e^t, \qquad t \text{ is a time index.} \tag{9}$$

Three econometric implications can be drawn from this simple model of the process describing the measurement error from using accounting income as measuring economic income. First, the first differencing of the dependent variable (as required by the theoretical specification) will eliminate a, the absolute systematic error in the measurement of income. Second, if the degree of measurement error is an increasing function of the level of economic income ($b < 1$), then the coefficient in the estimated statistical model will be biased toward zero, in effect increasing the likelihood of accepting hypotheses of no relation between firm income growth and the variables identified by the economic theory. Finally, the random measurement errors in (9) will be part of the stochastic structure of the estimated statistical model. If the first difference of these measurement errors is uncorrelated with the explanatory variables in the model, then no additional problems of estimation bias are introduced. In effect, the random movement errors in equation (9) will increase the magnitude of the noise in the process to be studied, thereby reducing the statistical power of the tests to be conducted. In what follows, these potential biases and loss of statistical power are accepted without further comment: they represent the "price" I must pay for using accounting income data.

Potential measurement problems of two key firm operating variables can pose greater obstacles to the analysis. Firm-specific information on refiner access to price-controlled crude oil and production of controlled crude oil is not generally publically available. A firm's access to price-controlled crude oil can be approximated by the quantity of price-controlled crude oil reported under the entitlement program. Undoubtedly, these reported quantities are subject to error, because each firm had an incentive to underreport (thereby reducing its entitlement obligations). To the extent that the standard "errors-in-variables" model captures the essence of the reporting error, the resulting coefficient on the access to price-controlled crude oil variable will be biased toward zero (in favor of the consumer benefit hypothesis of the allocation program).

No similar method was available for approximating a firm's production of price-controlled crude oil. So total U.S. crude oil production could not be decomposed into the uncontrolled and controlled categories required by the theoretical specifications derived above. In an attempt to distinguish among the firm's proportion of U.S. crude oil output subject to price controls, the following line of reasoning was adopted. Vertically integrated firms supply appreciable fractions of their U.S. refining subsidiaries' oil input from their U.S. production subsidiaries. So a firm's net entitlement position probably indicated whether its production subsidiary produced relatively more or less price-controlled crude oil than the national average. So U.S. crude oil output was interacted with a dummy variable indicating whether the firm was a net seller or buyer of entitlements. The exact form of the production variables and the intrepretation of the coefficients will be presented in the discussion surrounding equation (10) below.

The final measurement problem involves the inability to develop a time-series variable summarizing the effective tax rate levied on U.S. crude oil production interests by OPEC governments. Since 1974, governments have been renegotiating equity participation and buy-back provisions. So the terms containing changes in t_{OPEC} in (6)–(8) could not be explicitly included in the analysis. Instead, the analysis only includes a term for foreign crude oil production multipled by the increase in foreign crude oil prices. Its coefficient will determine whether periods of increasing prices generated income gains or losses for U.S. oil firms.

B. Estimation Strategy

As discussed above, estimating separate cross-sectional regressions for each year cannot identify the incidence of world crude oil prices from the incidence of the oil subsidy or the oil tariff. Complicating matters further, the oil subsidy was introduced during the 1974–75 recession. Any observed declines in net income may reflect either the price reductions postulated by the consumer benefit hypothesis of the entitlement program or standard net income reductions experienced during recessions. Pooling the time-series cross-section data will enable one to identify all the relevant parameters and, as a by-product, exploit information in the disturbance term enabling more efficient estimates than would be obtained by not pooling the data. After describing the specification of the time-series cross-section model, the discussion concludes with relating the key estimated coefficients to the variety of hypotheses about U.S. oil regulation and OPEC.

Reexamining equations (6)–(8) reveals a commonality in their coefficient structure. The terms involving the oil subsidy interacted with U.S. refining, for example, always involve one plus the fraction of the subsidy changing U.S. refined product prices $(1 + \lambda_h^E)$ multiplied by one minus the corporation income tax rate $(1 - t_c)$: see the third terms in equations (7) and (8). Restricting the coefficient structures of the separate cross sections to satisfy these relations enables the writing of a basic time-series cross-section regression; see Appendix for a detailed description of the pooling procedure.

Equation (10) presents the specification of the fundamental model.[31]

$$
\begin{aligned}
YM_{it} = {} & \\
& B_0 + B_1\, dW_{F(t)} + B_2\, SR_{it}\, dW_{F(t)} + B_3\, dFP_{E(t)} + B_4\, SR_{it}\, dFP_{E(t)} \\
& + B_5\, dT_{(t)} + B_6\, SR_{it}\, dT_t + B_7\, D_{74}\, R_{it} + B_8\, D_{75}\, R_{it} + B_9\, dP_{AD(it)} S^H_{Q(it)} \\
& + B_{10}\, D_S S^H_{Q(it)}(dW_{F(t)} + dT_t - dP_{AD(t)}) + B_{11}\, dGNP_t + B_{12}\, S^F_{Q(it)} dW_{F(t)} \\
& + B_{13}\, S^F_{Q(it)} dW_{F(t)}\, D_{79\text{-}80} + B_{14}\, \text{contract}_{it} + B_{15}\, \text{Ashland}_{79} \\
& + B_{16}\, \text{Ashland}_{80} + U_{it},
\end{aligned}
\tag{10}
$$

where[32]

YM_{it} is the change in real net income for firm i in year t divided by the moving average of its world refining,
SR_{it} is the ratio of the moving average of U.S. refining to the moving average of world refining for firm i in year t,
R_{it} is the ratio of 1974 access to price-controlled crude oil to the moving average of world refining for firm i in year t,
$dP_{AD(t)}$ is the change in the average U.S. domestic price for crude oil in year t,
$S^H_{Q(it)}$ is the ratio of the moving average of U.S. crude oil production to the moving average of world refining for firm i in year t,
$S^F_{Q(it)}$ is the ratio of the moving average of foreign crude oil production to the moving average of world refining for firm i in year t,
$dGNP_t$ is the change in real U.S. GNP in year t,
contract_{it} is the estimated quantity of foreign crude oil obtained under preferential terms from OPEC governments for firm i in year t,
Ashland_{79} and Ashland_{80} are dummy variables for the firm Ashland in 1979 and 1980, respectively,
D_{74} and D_{75} are dummy variables indicating 1974 and 1975, respectively,
$D_{79\text{-}80}$ is a dummy variable indicating either 1979 or 1980, and
U_{it} is the random disturbance term for the regression model.

31. The reader should recall the extensions to eqq. (6)–(8) for measuring the effects of changes in aggregate income and normal income growth of firms associated with technological innovation. This transforms the model by deflating all variables by the two-year moving average of world refining activity. Since the deflated U.S. and foreign refining variables sum to one, the portion of the model in the text pertaining to the change in net income from refining activities includes changes in the world oil price, the oil subsidy, and the oil tariff as separate explanatory variables and the interaction of those variables with the share of world refining located in the United States.

32. The remaining variables have been defined in table 6. The d preceding a variable indicates the first difference.

The economic interpretation of the parameters are:

B_0 measures net income growth per barrel total refining associated with industry-specific technological innovation,
B_1 measures the effect of increased foreign crude oil prices on the per barrel return from foreign refining and any refining inventory profits,
B_2 measures the differential effect of increased foreign crude oil prices on per barrel U.S. refining income in comparison to foreign refining,
B_3 measures the effect of the oil subsidy from the entitlement program on the per barrel income earned from foreign refining,
B_4 measures the differential effect of the oil subsidy on the income earned per barrel of U.S. refining activity,
B_5 measures the effect of the U.S. crude oil tariff on the per barrel income earned from foreign refining,
B_6 measures the differential effect of the U.S. oil tariff on the income earned per barrel U.S. refining,
B_7 measures the income gain per barrel of price-controlled crude oil, from under the allocation program (1974),
B_8 measures the income effect, per barrel of price controlled crude oil, from property rights under the allocation program during the first year of the entitlement program (1975),
B_9 measures the effect of changes in the average price received for U.S. crude oil production (national weighted average of uncontrolled and controlled prices) on the income earned per barrel of U.S. crude oil production,
B_{10} measures the differential growth from U.S. crude oil production for those firms likely to have larger than average proportion of their output uncontrolled,[33]
B_{11} measures the effect of changes in aggregate U.S. income, presumably reflecting the consequences of changes in demand for refined products, on income earned per barrel of total refining,
B_{12} measures how increased world prices for crude oil affected the income earned per barrel of foreign crude oil production,
B_{13} measures how the effect from increased world crude oil prices on income earned from foreign crude oil production differed during 1978–80, for reasons presented in Section I*C*,
B_{14} measures any differential income gains from the ARAMCO companies receiving contract crude oil from Saudi Arabia,
B_{15} measures the abnormal income gain earned by Ashland Oil Company from its voluntary divestiture of its U.S. crude oil production properties in 1979, expressed in terms of per barrel of total refining, and
B_{16} measures the negative income growth for Ashland in 1980, because the dependent variable is in first differenced form.

33. See discussion on the problem of measuring a firm's production of price-controlled crude oil, Sec. II*A*.

Equation (11) presents the variance components model for the error term in the fundamental model. The decomposition of the error term reflects the pooling of time series with cross-section data. Three basic components are present: firm specific (e_i), time specific (v_t), and remaining random effects varying across firms and over time (w_{it}). All three effects are assumed to be independently distributed. The firm-specific effects may be viewed as capturing permanent differences in the normal income growth of firms (recall that the constant term captures the average normal income growth for the group of firms). The time-specific effects may be viewed as representing unusual gains and losses operating in each year: such as inventory profits not related to the scale of world refining activity during 1974, 1979, and 1980.

$$U_{it} = e_i + v_t + w_{it}$$

$$E(e_i) = E(v_t) = E(w_{it}) = 0$$

$$\begin{array}{llll} E(e_i,e_{i'}) = \sigma_e^2 & \text{if } i = i' & E(v_t,v_{t'}) = \sigma_v^2 & \text{if } t = t' \\ \qquad 0 & \text{if } i \neq i' & \qquad 0 & \text{if } t \neq t' \end{array} \tag{11}$$

$$\begin{array}{ll} E(w_{it},w_{i't'}) = \sigma_w^2 & \text{if } i = i', t = t \\ \qquad 0 & \text{otherwise.} \end{array}$$

See Fuller and Batesse (1974) for a discussion of the estimation procedure for identifying this model's parameters.

Equation (12) presents the relations among the estimated coefficients and the basic underlying parameters of interest for testing the various hypotheses about the income effect of U.S. oil regulation. Table 7 indicates the expected magnitudes for the relevant combinations of coefficients under the alternative hypotheses. The competing hypotheses about the allocation program involve the magnitude of coefficient B_7:

$$\begin{aligned} B_3 &= (1 - t_c)\lambda_f^E; \\ B_4 &= (1 - t_c)(1 + \lambda_h^E - \lambda_f^E); \\ B_7 &= (1 - t_c)(W_F - W_C). \end{aligned} \tag{12}$$

The hypotheses about the entitlement program are captured by two coefficients, B_3 and B_4. In essence two questions are addressed. First, did the oil subsidy increase the return to U.S. refining or reduce U.S. refined product prices? As indicated by equation (12), comparing the sum of B_3 and B_4 with .52 (one minus the corporation income tax rate) provides the answer. Second, was the United States separated from world refined product markets by the entitlement program? If the United States was completely separated, then the oil subsidy would have had no effect on either foreign prices or the income from foreign refining ($B_3 = 0$). If the United States was not separated from world product markets, then the oil subsidy would have equally influenced

TABLE 7 Summary of Key Hypotheses about U.S. Oil Regulation and Their Implications for the Coefficient Structure of the Time Series, Cross-Section Model of Net Income Growth by U.S. Oil Firms

Regulation and Hypothesis	Coefficient Structure
Allocation program:	
Consumers receive benefits of price-controlled oil	$B_7 = 0$
Refiners receive benefits of price-controlled oil	$B_7 = 1.82$
Entitlement program:	
U.S. product prices reduced by full amount of oil subsidy	$B_3 + B_4 = 0$
with	
U.S. separated from world product markets	$B_3 = 0$
U.S. product prices reduced by ½ of oil subsidy	$B_3 + B_4 = .26$
with	
U.S. separated from world product markets	$B_3 = 0$
U.S. product prices reduced by full amount of oil subsidy	$B_3 + B_4 = 0$
with	
U.S. not separated from world product markets	$B_3 = -.52$
U.S. product prices reduced by ½ of oil subsidy	$B_3 + B_4 = .26$
with	
U.S. not separated from world product markets	$B_3 = -.26$
U.S. product prices not reduced at all by oil subsidy	$B_3 + B_4 = .52$
with	
U.S. not separated from world product markets	$B_3 = 0$

U.S. and foreign refined product prices. The reduction in foreign prices would have come at the expense of the income from foreign refining. The reduction in U.S. product prices would have come at the expense of U.S. refining income not increasing by the full amount of the after-tax oil subsidy.

C. Hypothesis Testing

A common approach would arbitrarily designate one hypothesis as the "null hypothesis" and then "test" its implications about the coefficient structure. The alternative hypothesis would be accepted only if the null hypothesis could be rejected, say, at the 5% level of significance. A one-tailed test would be appropriate, because the alternative hypothesis implies that the coefficient should lie on one side of the value predicted by the null hypothesis.

This classical approach to hypothesis testing will not be followed, because it neglects the power of the tests to discriminate among the competing hypotheses. The power of a test is important for avoiding the conclusions' being driven by the arbitrary decision about which hypotheses are designated the "null" and the "alternative." Otherwise, different analysts could conclude, from the same data, that different hypotheses best explain observed phenomena.

The general approach can be illustrated by considering the test of the refiner/consumer benefit hypotheses about the allocation program.

These hypotheses have different predictions about the coefficient (B_7) for the access to price-controlled crude oil variable in explaining income growth during 1974. The consumer benefit hypothesis predicts that B_7 equals zero. The refiner benefit hypothesis predicts that B_7 equals \$1.82. The regression analysis provides an estimate, $\hat{B}_7$, with a standard deviation of σ_7. The generic problem for hypothesis testing is selecting a critical value, B_7^*, for defining a critical region so that the following inferences may be drawn:

If $\hat{B}_7 < B_7^*$, then accept the consumer benefit hypothesis.
If $\hat{B}_7 > B_7^*$, then accept the refiner benefit hypothesis.

The closer this critical value B_7^* is set to the value predicted by the consumer (refiner) benefit hypothesis, B_7^c (B_7^r), the more likely it is that this test procedure will accept the consumer (refiner) benefit hypothesis of the allocation program.

Two considerations influence the selection of the critical value B_7^*: the prior probability that the hypotheses are true and the cost of mistakenly rejecting the particular hypotheses. Equation (13) formalizes these notions by computing the expected loss (EL) from the selection of any critical value B_7^* for defining the critical region.

$$EL = P(C \mid B_7^*)L_c\pi + P(R \mid B_7^*)L_r\,(1 - \pi), \tag{13}$$

where $P(C \mid B_7^*)$ and $P(R \mid B_7^*)$ are, respectively, the probabilities of falsely rejecting the consumer and refiner benefit hypotheses given the selection of the critical value B_7^*; L_c and L_r are, respectively, the losses from falsely rejecting the consumer and refiner benefit hypotheses; and π is the prior probability that the consumer benefit hypothesis is correct. Assuming that $\hat{B}_7$ is normally distributed, the probabilities of falsely rejecting the various hypotheses are:

$$P(C \mid B_7^*) = \int_{(B_7^* - B_7^C)/\sigma7}^{\infty} (2\pi\sigma_7^2)^{-.5}\, e^{-t^2/2}\, dt$$

and

$$P(R \mid B_7^*) = \int_{-\infty}^{(B_7^* - B_7^R)/\sigma7} (2\pi\sigma_7^2)^{-.5}\, e^{-t^2/2}\, dt.$$

These expressions reflect that the probability of falsely rejecting the consumer (refiner) benefit hypothesis is the area under the density function, given the assumption that the consumer (refiner) benefit hypothesis is true, for the values of the estimated coefficient exceeding (less than) the critical value B_7^*.

Equation (14) gives the expression for the optimal critical value,

$\hat{B}_7^*$.[34] The optimal value lies exactly between the competing hypotheses, unless the relative costs of mistaken inference and/or the prior probabilities are unequal. The optimal value moves toward the value predicted by the consumer (refiner) benefit hypothesis, the higher the prior probability assigned to the consumer (refiner) benefit hypothesis or the greater the cost of mistakenly rejecting the consumer (refiner) benefit hypothesis. The magnitude of the adjustment in the critical value is larger, the greater the variance of the sample estimate for the coefficient relative to the difference between the values predicted by the competing hypotheses. The optimal inference rule is sensible economics.

$$\hat{B}_7^* = .5(B_7^r + B_7^c) - \sigma_7^2 \frac{\log b_r}{(B_7^r - B_7^c)}, \; b_r = \frac{(1 - \pi)\, L_r}{\pi L_c}. \tag{14}$$

The analysis will select two specifications for the expected loss function from the infinite variety of priors and relative costs of decision error. The reader can specify his own loss function and reinterpret the results. First, the "fair-play" loss function assigns equal prior probability to the competing hypotheses and equal costs of decision error. This loss function would represent the situation of someone who does not possess any individual prior beliefs on the issues, has access to the dissenting opinions of equally qualified experts, and gains no differential utility from accepting either hypothesis. Equation (14) states that the optimal critical value for hypothesis testing is the midpoint between the competing hypotheses. Second, the "biased" loss function is defined by the relative bias (through uneven priors or decision error costs) that must exist for deriving an optimal critical region that would reverse the inferences based upon the fair-play loss function.

34. Substituting for $P(C \mid B_7^*)$ and $P(R \mid B_7^*)$ into eq. (13), the first-order equilibrium condition is:

$$\frac{\partial EL}{\partial B_7^*} = -(2\pi\sigma_7^2)^{-.5} e^{-.5} \left(\frac{B_7^* - C_7^C}{\sigma_7}\right)^2 Lc\pi + (2\pi\sigma_7^2)^{-.5} e^{-.5} \left(\frac{B_7^* - B_7^r}{\sigma_7^2}\right)^2 (1 - \pi) L_Y = 0.$$

Moving the second term to the other side and taking logs, the resulting expression can be solved for $\hat{B}_7^*$. This yields eq. (14) in the text. This optimal critical region minimizes expected loss, because

$$\frac{\partial^2 EL}{\partial (B_7^*)^2} = -e^{-.5} \left(\frac{B_7^* - B_7^C}{\sigma_7}\right)^2 \frac{[-(B_7^* - B_7^C)]}{\sigma_7^2} + b_Y e^{-.5} \left(\frac{B_7^* - B_7^Y}{\sigma_7}\right)^2 \left[\frac{-(B_7^* - B_7)}{\sigma_7^2}\right].$$

Substituting from the first-order equilibrium condition,

$$\frac{\partial^2 EL}{\partial (B_7^*)^2} \simeq (B_7^r - B_7^c) > 0.$$

TABLE 8 **Summary Statistics for Change in Net Real Income per Barrel of World Refining for 24 Oil Firms, 1972–80** (1972 Dollars per Barrel)

	Year								
	1972	1973	1974	1975	1976	1977	1978	1979	1980
Mean	.017	.438	.536	−.397	.235	.022	.046	.809	.410
Standard deviation	.261	.247	.616	.256	.263	.234	.496	.545	.660
Standard error of mean	.053	.050	.126	.052	.054	.048	.101	.111	.135

NOTE.—Firms in sample: Amerada Hess, American Petrofina, Ashland, Atlantic Richfield, Cities Services, Clark Oil Refining, Continental Oil, Diamond Shamrock, Exxon, Getty Oil, Gulf, Kerr-McGee, Marathon, Mobil, Murphy, Phillips, Shell, Standard of California, Standard of Indiana, Standard of Ohio, Sun Oil, Tenneco, Texaco, Union Oil.

III. Statistical Estimates and Hypothesis Testing

The time-series cross-section model was estimated for 24 firms during 1972–80. Table 8 reports the year-specific summary statistics for the dependent variable and the list of firms. These firms have been designated as the major refining/marketing firms in the United States by the *National Petroleum News* (1978). These firms account for about 95% of all U.S. crude oil refining activity and reported almost 85% of price-controlled crude oil during the first few months of the entitlement program. All of the firms also had U.S. crude oil producing interests. Their collective production of crude oil in 1974, for example, equaled 71% of all U.S. production.

The data in table 8 indicate that there is room for the economic forces emphasized in the analyses presented in Sections I and II. The substantial year-to-year variation in average firm net income growth per barrel of world refining activity suggests that there is a role for industry-wide changes in world crude oil prices, the oil subsidy, the oil tariff, and aggregate economic activity. Yet the variability in the net income growth among firms—indicated by the standard deviation of the dependent variable for the key years 1974, 1975, 1979, and 1980—also promises a role for the firm-specific operating variables. The discussion presents the basic estimated model and then discusses the implications of the variables controlling for economic forces unrelated to the testing of the key hypotheses about U.S. oil regulations and OPEC. The discussion concludes with the hypothesis testing.

A. Estimated Model

Table 9 presents the estimated model.[35] About two-thirds of the total variability of the firms' net income growth during 1972–80 is explained

35. The following data sources were used: (1) Corporate annual reports and 10-K reports submitted to the Securities and Exchange Commission provided information on

TABLE 9 **Time Series, Cross-Section Model of Change in Real Net Income per Barrel of Worldwide Refining Activity, 1972–80** (1972 Dollars per Barrel)[a]

Variable	Estimated Coefficient	*t*-Statistic
Intercept (B_0)	−.792	−2.96
Change in real Saudi oil price:		
Additive effect (B_1)	.183	2.59
Multiplied by share of U.S. refining (B_2)	−.124	−1.92
Change in real oil subsidy:		
Additive effect (B_3)	.058	.241
Multiplied by share of U.S. refining (B_4)	.478	1.95
Change in real oil tariff:		
Additive effect (B_5)	.199	.783
Multiplied by share of U.S. refining (B_6)	−.408	−1.52
Ratio of price-controlled oil to world refining:		
1974 (B_7)	1.591	4.19
1975 (B_8)	−.327	−.49
Change in real U.S. GNP (billion dollars) (B_{11})	.015	3.65
Change in real average U.S. oil price, multiplied by U.S. oil output, divided by world refining:		
Additive effect (B_9)	.321	6.99
Multiplied by entitlement seller dummy, multiplied by change in difference between tariff-inclusive real foreign oil price and average U.S. real oil price (B_{10})	.087	1.51
Change in real Saudi oil price, multiplied by ratio of foreign oil production, divided by world refining:		
Additive effect (B_{12})	−.085	−1.65
Interacted with 1979–80 dummy variable (B_{13})	.060	.85
Ratio of estimated foreign contract crude oil to world refining during 1979 and 1980 (B_{14})	.139	.54
Ashland dummy variable:		
1979 (B_{15})	.59	1.70
1980 (B_{16})	−1.40	−3.90

NOTE.—Summary statistics: R^2 = .668, σ_e = .061, σ_v = .126, σ_w = .335, degrees of freedom for *t*-statistics = 199.

[a] The coefficient in eq. (9) is stated in parentheses.

firm-specific operating variables and net income. (2) The firm's access to price-controlled crude oil was taken from reports submitted to the regulatory agency during the entitlement program and reprinted as "deemed old oil receipts" in the *Federal Register*. The first 2 months' data were used, pertaining to November and December 1974 as reported in the January 13 and February 9, 1975, issues (pp. 2566–73 and 7132–34, respectively). The 2-months' data were then multiplied by 6 to obtain the annual barrels of price-controlled crude oil received by U.S. refiners. (3) *Economic Report of the President*, 1980, provided data on real GNP and the GNP price deflator used in deflating all variables expressed in dollars. (4) U.S. Department of Energy, *Monthly Energy Review*, yielded annual data on oil subsidy, average U.S. crude oil prices (post-1973), and Saudi crude oil prices (post-1973). (5) Pre-1974 U.S. crude oil prices were obtained from *Survey of Current Business, Bureau of Labor Statistics*. (6) Blair (1978) was the source of pre-1974 prices of Saudi crude oil.

by the industry wide explanatory variables (oil prices, oil subsidy, oil tariff, and GNP) and their interactions with firm-specific operating variables. The firm-specific component of the random term accounts for only 1% of the total variability in the dependent variable. The firm-specific operating variables are capturing the interfirm variability in net income growth. The time-specific component of the random term accounts for only about 4% of the total variability in the dependent variable. The time-series variation in the industry-wide variables—foreign crude oil prices, the oil subsidy, the oil tariff, and GNP—are explaining the considerable year-to-year variation in net income growth by U.S. oil firms. The final component of the random term, random variation in firm effects varying over time, comprises the remaining 28% of the total variation in the dependent variable.

The model identifies statistically significant normal income growth and sensitivity of net incomes earned by U.S. oil firms to changes in U.S. aggregate real income. The constant term indicates that the real net incomes of U.S. oil firms would decline by about $0.80 per barrel of world refining activity in the absence of changes in U.S. aggregate real income, real crude oil prices, or U.S. oil regulation. As expected, technological innovation appears, on net, to reduce the income earned by these firms. Using the coefficient for the GNP variable, an increased U.S. real aggregate income of almost $52 billion (about 3.5% growth in 1980 real U.S. GNP) would offset this declining trend and leave unchanged the per barrel level of real net income earned by U.S. oil firms.

The variables involving U.S. crude oil production activity performed in predictable ways. A $1.00 increase in the average U.S. crude oil price received by producers generated a $0.33 increase in real net income for each barrel of U.S. crude oil production. Firms likely to have larger proportions of their U.S. crude oil output exempted from price controls (entitlement selling firms) also enjoyed larger income gains: the magnitude of the gain was specified to depend upon changes in the difference between uncontrolled and average U.S. prices of crude oil.

Increased foreign crude oil prices increased the net income growth of U.S. oil firms. For every dollar increase in the real price of Saudi crude oil, U.S. oil firms enjoyed an increased income flow of about $0.18 per barrel. The role of inventory profits in this estimated effect cannot be isolated, but must certainly be important. The increased income was lower for firms with larger fractions of their refining located in the United States. This differential effect cannot be attributed to U.S. oil regulation, for the effects of regulation pertain to other terms in the regression.[36]

36. Additional empirical analysis, not reported here, showed that the coefficient for the interaction term between the change in uncontrolled crude oil prices and the U.S. refining share was the same for preregulation, 1972–73, as it was postregulation, 1974–80.

The remaining control variables in the model performed much as expected. Ashland showed abnormal income growth durings its year of divesting itself from its U.S. crude oil activities and abnormal losses the following year. The estimated quantities of crude oil received under special contract from Saudi Arabia in 1979–80 had a statistically insignificant, positive effect. Whether this shows a small gain or a poor measure of the volumes is not an important issue for this analysis.[37]

B. *Hypothesis Testing*

The model clearly supports the refiner benefit hypotheses of both the allocation and entitlement programs. Substantial biases must be introduced into the optimal inference rule—through uneven priors or decision error costs—in order to use the estimated parameters as support of any of the alternative hypotheses. Incredibly large biases must exist for sustaining belief in the hypotheses that only consumers benefitted from either the allocation or entitlement programs. After discussing these inferences in detail, the tests of the cooperation and taxation hypotheses of the relations between OPEC governments and U.S. oil firms is interpreted.

Net income growth for U.S. oil firms in 1974 was strongly and positively related to their estimated access to price-controlled crude oil. The estimated coefficient rejects the hypothesis that binding price controls prevented U.S. refiners from capturing the benefits of price-controlled crude oil under the allocation program (t = 4.18 for the null hypothesis of no gain from price-controlled crude oil). In fact, the estimated coefficient is consistent with the magnitude predicted by the refiner benefit hypothesis (t = .605 for the null hypothesis that the refiner benefit hypothesis is correct).

The support for the refiner benefit hypothesis is even more striking when considering the optimal inference rule. The estimated coefficient (1.59) greatly exceeds the critical value (.91) generated by the fair-play loss function. Astronomical bias must exist to reverse the optimal inference in favor of the refiner benefit hypothesis.[38] The strength of this result reflects that the estimated variance of the coefficient is quite small relative to the difference in the values predicted by the competing hypotheses about pre-entitlement-program oil regulation.

The estimated coefficients involving the oil subsidy from the entitlement program address two separate issues. First, which of the three

37. The quantities of oil from Saudi Arabia were estimated by extrapolating 1975–79 foreign oil production for the ARAMCO members (Exxon, Mobil, Standard of California, Texaco) and subtracting that quantity from reported total foreign oil production and contract oil during 1979 and 1980.

38. The relative bias in favor of the consumer benefit hypothesis, b_c, can be computed by solving eq. (14) for the b_c, yielding 1.59 as the critical value for the definition of the inference region: $1.59 = .91 - .1443316/1.82 \log b_r$. Rearranging and exponentiating, b_r = .00019, or b_c = 5,263/1, because the bias in favor of the consumer benefit hypothesis equals the reciprocal of the bias in favor of the refiner benefit hypothesis.

hypotheses—consumer benefit, refiner benefit, or equal sharing—accurately explains the effect of the oil subsidy on the income earned from U.S. refining? Second, were U.S. and world product markets separated? The first question is answered by comparing the refiner benefit hypothesis with each of its competitors.

Consider the comparison between the extreme hypotheses. By summing the estimates of B_3 and B_4, about 54% of the oil subsidy increased the after-tax income growth associated with U.S. refining. This compares quite closely with the refiner benefit hypothesis' prediction of 52% (t = .10 for the null hypothesis that the refiner benefit hypothesis is correct). The consumer benefit hypothesis ($B_3 + B_4 = 0$) can be rejected by a standard statistical test (t = 3.41 for the null hypothesis that the consumer benefit hypothesis is correct). The optimal inference rule illustrates the power of the empirical support for the refiner benefit hypothesis in comparison to the consumer benefit hypothesis. Substantial bias must exist for the estimated parameters to be viewed as supporting the hypothesis that the oil subsidy was fully passed on to U.S. consumers as lower refined product prices.[39]

The refiner benefit hypothesis also compares favorably with the equal-sharing hypothesis about the beneficiaries of the entitlement program. Standard statistical tests would not show much difference, the t-statistics are .10 and .93 for the respective null hypotheses that the refiner benefit and the equal-sharing hypotheses are correct. The optimal inference rule suggests accepting the refiner benefit hypothesis. The estimated gain to U.S. refining (.54) exceeds the value dictated by the fair-play loss function (.39). Only biases exceeding 4.6/1 in favor of the equal-sharing hypothesis would justify using the estimated parameters as supporting that hypothesis over the refiner benefit hypothesis of the entitlement program. This smaller power in favor of the refiner benefit hypothesis simply reflects that we are asking the data to distinguish between hypotheses that $B_3 + B_4$ is either .52 or .26 instead of the larger differences of opinion proposed by the refiner and consumer benefit hypotheses.

The estimated coefficients for the oil subsidy terms also reject the hypothesis that U.S. and world product markets were separated by the entitlement program. All of the effect of the oil subsidy was absorbed in the coefficient measuring the differential effect on U.S. refining, but the magnitude suggested no reductions in the U.S. prices for refined products. The coefficient for the oil subsidy term indicates no effect of the oil subsidy on foreign refined product prices because the return to foreign refining was independent of the oil subsidy.

Comparing the coefficients for the terms involving the oil subsidy

39. Evaluating the optimal inference rule for the bias required to reverse the inference yields the result that one's bias in favor of the consumer benefit hypothesis must exceed 328/1.

with the terms involving the oil tariff provides an independent check on the estimated variance components model. In theory, the coefficients of the tariff and oil subsidy variables should be the same, except for sign, because they capture effects of relative shifts in U.S. product supply on refined product prices (see discussion in Sec. II). The estimated coefficients do indeed support this restriction. The t-statistic is .35 for the null hypothesis that coefficients for the terms involving the oil subsidy and the oil tariff interacted with the U.S. refining share sum to zero. The t-statistic is about 1.2 for the null hypothesis that the coefficients for the oil subsidy and oil tariff variables sum to zero: the null hypothesis could be rejected only at the 20% level of significance.

Turning to the hypotheses concerning OPEC governments and U.S. oil firms, the estimated model favors the taxation over the cooperation hypothesis. For 1972–78, net income growth for U.S. oil firms was inversely related to the presence of foreign crude oil production. Every dollar per barrel increase in Saudi crude oil prices reduced the net income growth of U.S. oil firms by about \$0.09 per barrel of foreign crude oil production. As expected, the inverse relation between income growth and foreign crude oil production weakened in the 1979–80 time period: net income growth was virtually independent of foreign crude oil production as the estimated coefficient ($B_{12} + B_{13} = -.025$) was insignificantly different from zero ($t = -.66$ for the null hypothesis of no relation).

IV. Conclusion

Studying income growth of U.S. oil firms has developed evidence hitherto absent from the existing debate over the beneficiaries of U.S. oil regulation. The estimated income effects corroborate and extend conclusions advanced by other studies using different types of data. In the process, a methodology has been developed indicating how firm income data can be an important adjunct to the study of the quantitative effects of regulation more generally. This essay concludes by reporting the estimated transfers under U.S. oil regulation and indicating some of the pitfalls that have arisen in using income data for testing hypotheses about U.S. oil regulation. Some final thoughts are then offered on the situations when accounting income data can be usefully studied in juxtaposition to the analysis of other types of data: product and factor prices, output and employment, and stock market returns for the industry subjected to regulation.

A. U.S. Oil Regulation: Estimated Distribution of Gains and Losses among the Sectors of the Industry

The variance components model strongly supports two basic propositions about U.S. oil regulation advanced by Phelps and Smith (1977) and Smith and Phelps (1980). First, pre-entitlement-program regulations conferred a lump sum benefit to U.S. refiners. Prior to the study of income growth by U.S. oil firms, this theoretical proposition has been debated by examination of incomplete data on whether a significant portion of U.S. refiners were operating under binding refined product price ceilings. The income growth of U.S. oil firms directly corroborates their key empirical implication. Second, post-entitlement-program regulation did not have refiners dissipating these income gains. Instead, the benefits from the allocation program were transformed into an increased marginal return to U.S. refining capital. So the entitlement program did not reduce aggregate U.S. refiner benefits from price control regulation. The program did achieve the apparently important political task of redistributing among U.S. refiners the gains from price-controlled crude oil through the forced sales and purchases of entitlements. In the first full year of the program, these interfirm transactions totaled over $1.5 billion (Phelps and Smith 1977). So the estimated model of income growth for U.S. oil firms has supported the refiner benefit hypothesis of U.S. oil regulation.

Many analysts have attempted to use the evidence on the level of industry income for rejecting the refiner benefit hypothesis; see Greenhill and Company (1977) as an excellent example of the method of analysis. By comparing the implied after-tax U.S. refiner gains against the net income earned by the entire industry (or reported incomes for the U.S. refining sector), the computations show that the alleged refiner gains equaled about 60% of the income of the industry and exceeded the stated income of the U.S. refining sector.[40] Viewing these results as absurd, analysts have rejected the refiner benefit hypothesis.

The statistical model of income growth by U.S. oil firms can reconcile the level of industry net income with the estimated refiner gains and, in the process, highlight the importance of adopting a multivariate statistical approach in testing hypotheses about regulation with net income data. Table 10 reports a decomposition of actual year-to-year variations in the average change among firms in their real net income per barrel of world refining activity. The decomposition uses five categories; the change in per barrel net income due to (*a*) normal

40. The following arithmetic illustrates the analysis. Smith and Phelps (1980) estimate the after-tax refiner gain from price controls at $5.1 billion (1972 dollars) during 1975. As the 24 oil firms studied account for 94% of U.S. oil refining, these firms should have received benefits equal to $4.8 billion in 1975 (ignoring entitlement payments to independent refiners). But table 1 shows that these 24 firms earned $7.8 billion in 1975 on *all* of their worldwide operations, implying that almost 62% of their income was from the income transfer from price controls. Examining income for the U.S. refining sector, Exxon reported U.S. refining income of $261 million (1972 dollars) in 1975. Exxon's market share in U.S. refining was about 8%. Scaling up Exxon's earnings implies that U.S. refining operations earned almost $3.3 billion in 1975. Estimated refiner gains from price controls exceeded U.S. refining income by $1.8 billion.

TABLE 10 Decomposition of Year-to-Year Variation in Average Change in Firm Net Income per Barrel World Refining (1972 Dollars per Barrel)

Factor	Year								
	1972	1973	1974	1975	1976	1977	1978	1979	1980
Normal growth and GNP	.181	.266	−.899	−1.008	.227	.300	.207	−.086	−.827
Foreign oil prices	.034	.042	.550	−.008	.010	−.013	−.036	.198	.412
Foreign oil production	−.014	−.016	−.168	.002	−.002	.003	.009	−.002	−.017
U.S. oil production	−.014	.022	.383	.030	−.017	−.011	−.021	.274	.560
Regulations affecting refining	0	0	.687	.587	.019	−.120	−.249	.373	.276
Total "explained"	.187	.314	.553	−.395	.237	.159	−.090	.757	.404
Observed	.017	.438	.536	−.397	.235	.022	.046	.809	.410
Year-specific error	−.170	.124	−.017	−.001	−.001	−.129	.136	.052	.006

income growth and changes in U.S. real GNP, (*b*) changes in foreign oil prices whose gains are unrelated to crude oil production activity, (*c*) changes in foreign oil prices related to foreign crude oil production, (*d*) changes in average U.S. crude oil prices related to U.S. production activity, and (*e*) regulation affecting refining (access to price-controlled crude oil in 1974 and 1975, the oil subsidy, and the 1975 oil tariff). This decomposition was estimated by multiplying each coefficient in the model by the year-specific mean for the corresponding explanatory variable.

The decomposition indicates that regulations affecting refining activity played an important role in the net income growth during the 1970s. The normal declining trend in a real net incomes and standard income losses during declines in real U.S. GNP in 1974, 1975, and 1980 would have created substantial losses in net income during those years. The refiner gains from regulation, gains from higher foreign crude oil prices unrelated to production activity and U.S. crude oil production were all important offsetting factors. In 1975, the effects of refiner gains from regulation were solely responsible for insulating real net incomes from even greater losses from the 1975 recession and the normal trend for declining real net incomes for U.S. oil firms. The deterministic portion of the model also captures the year-to-year movement in the dependent variable; especially 1974, 1975, 1979, and 1980 when U.S. regulations were initially introduced and later when their economic effects were intensified by international supply disruptions. The year-specific error terms for 1972, 1977, and 1978 represent unaccounted economic forces. While important in those years, those unaccounted for forces are unimportant for understanding the overall variability among firms in net income growth during the 1970s. Recall that the variance in the year-specific error terms explained only 4% of total variance in the dependent variable.

Table 11 reports the estimated gains and losses from U.S. oil regulation by sector of the U.S. petroleum industry.[41] The computations assumed that uncontrolled crude oil prices were unaffected by regulation, even though Smith and Phelps (1980) present evidence to the contrary. U.S. refiner gains from regulation first peaked in 1976, after the repeal of the oil tariff, and began declining during the next two years as the oil subsidy began declining.[42] The 1979–80 episode of

41. The losses to U.S. crude oil producers were computed by estimating the gain from increasing average U.S. crude oil prices to the level of uncontrolled U.S. crude oil prices in the indicated year. The gains of U.S. refiners was computed by taking the estimated coefficients for the effect of price-controlled crude oil, and oil subsidy, and the oil tariff and multiplying by the industry-wide values for the relevant quantities.

42. At first appearance, the estimated refiner gains in 1975 are considerably less than the $5.1 billion asserted by Smith and Phelps (1980). The estimates can be reconciled by noting that table 11 includes a $2.3 billion loss from the 1975 oil tariff: an income effect not included in their estimate.

TABLE 11 Estimated Effect of U.S. Oil Regulation on Net Income of U.S. Petroleum Industry, by Sector and by Year (Billions of 1972 Dollars)

Year	U.S. Oil Production		U.S. Oil Refining[a]	
1974	−2.5	(.36)	3.9	(.98)
1975	−2.9	(.42)	3.1	(2.0)
1976	−2.6	(.37)	5.0	(1.47)
1977	−3.1	(.45)	4.6	(1.35)
1978	−3.0	(.43)	3.1	(.91)
1979	−4.9	(.71)	5.4	(1.57)
1980	−4.5	(.65)	6.6	(1.92)

NOTE.—Standard errors in parentheses.
[a] Reflects allocation program, entitlement program, and 1975 oil tariff.

increasing crude oil prices witnessed a leap in refiner benefits, as accelerating uncontrolled crude oil prices increased the revenues deprived from U.S. crude oil producers. The gains of the U.S. refining sector exceeded the losses of the U.S. crude oil production sector, because of the different taxation liabilities of crude oil and refining activities. State government severance taxes and royalty payments to nonindustry owners of mineral rights (which may have represented more than 20% of the market value of U.S. crude oil) shouldered some of the losses from price controls. In effect, oil price regulation legalized a transfer pricing scheme whereby the increased value of U.S. crude oil was captured in refining operations, a segment of the industry not subject to the same financial liabilities to industry "outsiders."

B. General Methodology

The methodology developed in this paper appears to be an useful adjunct to the tools commonly used in studying the quantitative effects of regulation. Certainly direct study of how regulation affects equilibrium prices and resource allocation provides insight into the distributive effects of regulation. One simply utilizes the theoretical relation between price changes and producer surplus given by the theory of the firm. Yet that same theory can specify the econometric analysis of income growth by the regulated firms. While the use of accounting information encounters potential measurement problems, the empirical analysis of price data would itself confront its own well known measurement problems. The virtue of examining income data in conjunction with industry price data would be that the respective measurement errors are separate.

Analyzing stock returns data, of course, is an alternative research strategy for verifying and/or complementing the findings from the study of industry price and quantity data. Yet stock returns provide their own difficulties. In cases where the quantitative magnitude of the effects are of interest, stock data can confound the analysis with considering anticipated duration of the regulation and the likelihood that other, nonrelated, events will occur sometime in the future. In the study of U.S. oil regulation, for example, U.S. regulation was a response to the rise of OPEC market power. So studying the stock market returns must confront the identification problem of sorting out the effects of U.S. regulation from expectations about the duration of OPEC. To make matters even more challenging, the 1970s saw consideration, but general inaction, on other legislative proposals that would have affected the value of U.S. oil firms. The most important issues addressed by Congress were divestiture legislation and "reforms" in the industry's tax status in relation to depletion allowances and foreign tax credit. So in some instances, at least, the insensitivity of income statements to anticipations about future prospects can itself be a disguised virtue.

I am not advocating that stock return studies should be replaced by accounting income studies based on the analysis presented in this essay. My position is far more modest. I am advancing the proposition that studying the relation between regulation and income growth of firms appears to be an area which warrants additional research attention.

Appendix

I. Further Exposition of Second-Order Approximation to Firm Income Growth

The details of the approximation procedure can be illustrated by developing the specification for a hypothetical firm solely engaged in U.S. refining during 1973–74. The computation fully derives equation (5) found in the text and provides the background for deriving the remaining equations. Additionally, the discussion below illustrates how the approximation procedure, as asserted in the text, correctly captures (to a second order) the consequences for income growth of fluctuations in aggregate economic activity and industry-specific technological innovation.

Equation (A1) presents the after-tax income function for the hypothetical firm. The subsequent analysis utilizes the product supply and factor demand curves for the firm, given respectively in equations (A2) and (A3) as depending upon the prices for refined products and crude oil and the state of technology (indexed by τ). The specification imposes the hypothesis that the resource decisions of U.S. refiners were not affected by receipt of price-controlled crude oil under the allocation program. The notation below follows that given in the text.

$$I_i = (1 - t_c)(P_H Q_{ih} - W_F Y_{ih} + D_A(W_F - W_C)Y_{ic}) \tag{A1}$$

$$Q_{ih} = Q_{ih}(P_H, W_F, \tau) \tag{A2}$$

$$Y_{ih} = Y_{ih}(P_H, W_F, \tau). \tag{A3}$$

Income growth during 1973–74 was generated by four basic forces: changes in prices of refined products and crude oil, the institution of the allocation program, and technological innovation. The approximation procedure applies standard Taylor Series approximations. The first-order terms are given in (A4a)–(A4d). Note that the adjustments in the quantities of crude oil used and refined products produced contributed nothing to the first-order changes in firm income: an implication of the well-known "envelope theorem."

$$\partial Ii/\partial P_h = (1 - t_c)Q^0_{ih} \tag{A4a}$$

$$\partial Ii/\partial W_F = -(1 - t_c)Y^0_{ih} + D^0_A Y_{ic}(1 - t_c) = -(1 - t_c)Y^0_{ih}, \quad \text{because } D^0_A = 0. \tag{A4b}$$

$$\partial Ii/\partial\tau = (1 - t_c)\left(P_H\frac{\partial Q_{ih}}{\partial\tau} - W_F\frac{\partial Y_{ih}}{\partial\tau}\right) > 0, \tag{A4c}$$

because innovation, at constant prices for crude oil and refined products, increases the amount of revenue earned for given levels of inputs.

$$\frac{\partial Ii}{\partial D_A} = (1 - t_c)(W^0_F - W^0_C)Y_{ic} = 0, \tag{A4d}$$

because before the oil embargo the differential between controlled and uncontrolled prices for crude oil did not exist. The matrix of second-order income effects, given in terms of the relevant quadratic form, is shown in equation (A5). The matrix is symmetric, because $\partial Q_{ih}/\partial W_f = -\partial Y_{ih}/\partial P_H$ (by virtue of symmetry results from the theory of the firm) and the assumption that the effects of technological innovation are proportional to firm size (see text).

$$[dP_H\; dw_f d_\tau\; dD_A] \times [dP_H\; dw_f d_\tau\; dP_A]$$

$$\begin{bmatrix} (1 - tc)\dfrac{\partial Q^0_{ih}}{\partial P_h} & (1 - tc)\dfrac{\partial Q^0_{ih}}{\partial w_f} & (1 - tc)\dfrac{\partial Q^0_{ih}}{\partial_\tau} & 0 \\ -(1 - tc)\dfrac{\partial Y^0_{ih}}{\partial P_h} & -(1 - tc)\dfrac{\partial Y^0_{ih}}{\partial w_f} & -(1 - tc)\dfrac{\partial Y^0_{ih}}{\partial_\tau} & (1 - tc)Y_{ic} \\ (1 - tc)\dfrac{\partial Q^0_{ih}}{\partial_\tau} & -(1 - tc)\dfrac{\partial Y^0_{ih}}{\partial_\tau} & 0 & 0 \\ 0 & (1 - tc)Y_{ic} & 0 & 0 \end{bmatrix} \begin{bmatrix} dP_H \\ dw_f \\ d_\tau \\ dD_A \end{bmatrix}. \tag{A5}$$

The "own" second-order effect for technological innovation is zero (the element in the third row and third column of the above matrix) because of the assumption that firm growth from this source is proportional to firm size.

The formula for the firm's income growth can now be computed by summing the first-order terms plus $\frac{1}{2}$ the quadratic form given in (A5). The details of the algebraic manipulations are omitted. Using the first-order differential for growth in refined product output and crude oil use obtained from differentiating (A2) and (A3), substitution yields the expression given in (A6).

$$dI_i = (1 - t_c)(dP_H\bar{Q}_{ih} - dW_F\bar{Y}_{ih} + (W^0_F + dW_F - W_C)\,Y_{ic} + K\bar{Y}_{ih}), \tag{A6}$$

where K measures firm income growth at constant prices from technological innovation. The expression can be simplified further by using the following relation explaining the change in refined product prices as a function of technological change (a), the change in world price for crude oil, and the change in aggregate real income ($dGNP$).

$$dP_H = a + \lambda_h dW_F + \gamma\, dGNP, \tag{A7}$$

where $a < 0$ because innovation reduces real product price. Substituting for dP_H in (A6) yields the following expression for firm income growth:

$$dI_i = \overline{Y}_{ih}(1 - t_c)\,[(\lambda_h - 1)dW_F + Y_{ic}(W_F^0 + dW_F - W_C) + \gamma dGNP. + (K + a)]. \tag{A8}$$

As discussed in the text, $(K + a)$ will on net be negative, because the income increasing effect from innovation (K) is likely to be counterbalanced by the reductions in product prices (a) because the demand for refined products is price inelastic.

Expanding the analysis to allow the firm to have other subsidiaries—foreign crude oil and refining, U.S. crude oil production—is a straightforward generalization of the preceding discussion. The moving average of the quantities interacted with the price and income variables used in the text originates from substituting a comparable expression for (A7) for the change in foreign refined product prices. The resulting expression for the change in the firm's net income can then be divided by the moving average of the firm's total worldwide refining use of crude oil, generating the equation estimated in the text. Expanding the analysis for the other years simply requires adding additional terms in the product price equations for capturing the effects of the oil subsidy and the oil tariff.

II. Pooling the Year-specific Models into the Variance Component Model

The pooling procedure can be illustrated by considering the terms for a hypothetical firm solely engaged in U.S. and foreign refining (neglecting crude oil production subsidiaries reduces the terms in the example) for 1974–76: see equations (A9)–(A11). For 1974, the terms involving the oil subsidy under the entitlement program and the crude oil tariff have been suppressed because their levels were unchanged at their preprogram values of zero. The GNP and growth terms are applied to the sum of foreign and U.S. refining activity, because the model was not specified to entertain differences in how those economic forces differentially affected the income earned from foreign and U.S. refining. For 1975, the terms for the crude oil tariff and the oil subsidy are added to the specification, as well as the term representing the one-time payments from the entitlement program destroying the firm-specific benefits from the allocation program. Finally, the error structure represents the variance component model discussed in the text. The term e_i' is the same for each firm across equations, but differs among firms. The v_t' term is the same for each firm in each equation but varies across equations. The term w_{it}' varies across firms for each equation as well as across equations.

$$\begin{aligned}\text{1974:}\quad dI_i = {} & \overline{Y}_{ih}(1 - t_c)\,[(\lambda_h - 1)dW_F + Y_{ic}(W_F^0 + dW_F - W_C)] \\ & + \overline{Y}_{if}(1 - t_c)\,[(\lambda_f - 1)dW_F] + (\overline{Y}_{ih} + \overline{Y}_{if})(1 - t_c)\,[\gamma dGNP \\ & + (K + a)] + e_i' + v_t' + w_{it}';\end{aligned} \tag{A9}$$

$$\begin{aligned}\text{1975:}\quad dI_i = {} & \overline{Y}_{ih}(1 - t_c)\,[(\lambda_h - 1)dW_F - Y_{ic}(W_F - W_C) + (\lambda_h^E + 1)dP_EF \\ & + (\lambda_h^T - 1)dT] + \overline{Y}_{if}(1 - t_c)\,[(\lambda_f - 1)dW_F + \lambda_f^E dP_EF \\ & + \lambda_f^T\, dT] + (\overline{Y}_{ih} + \overline{Y}_{if})(1 - t_c)\,[\gamma dGNP + (K + a)] \\ & + e_i' + v_t' + w_{it}';\end{aligned} \tag{A10}$$

$$\text{1976:} \quad dI_i = \overline{Y}_{ih}(1 - t_c)\,[(\lambda_h - 1)dW_F + (\lambda_h^E + 1)dP_EF + (\lambda_h^T - 1)dT] + \overline{Y}_{if}(1 - t_c)\,[(\lambda_f - 1)dW_F + \lambda_f^E\, dP_EF + \lambda_f^T\, dt] + (\overline{Y}_{ih} + \overline{Y}_{if})(1 - t_c)\,[\gamma dGNP + (K + a)] + e_i' + v_t' + w_{it}'. \tag{A11}$$

Equation (A12) presents the pooled model obtained by noting that each variable in equations (A9)–(A11) has the same coefficient. The only exceptions to that observation are the terms related to the firm's access to price-controlled crude oil under the allocation program. Those terms have year-specific coefficients, a situation that motivates the interaction terms with the year dummy variables. Two further manipulations will produce the equation specification estimated in Section III. First, both sides of the equation can be divided by $\overline{Y}_{ih} + \overline{Y}_{if}$. This transformation yields the dependent variable as firm income growth per barrel of world refining (the moving average), the independent variables in the first two terms expressed as ratios of firm operating variables to world refining activity, the last term as a constant and a linear term in the change in GNP, and the new error structure representing a variance component model in firm income growth per barrel of world refining activity, so the error terms in equations (A9)–(A11) were implicitly assumed to be independently distributed with variances proportional to the scale of world refining activity. Second, as the sum of the ratios of U.S. and foreign refining to world refining is unity, the estimation equation can not include any explicit terms involving both ratios. The specification in the text was obtained by substituting out the ratio of foreign to world refining. That procedure implied that the industry-wide variables affecting refining income growth (oil prices, oil subsidy, oil tariff) are entered separately (identifying the coefficients pertaining to foreign refining) and interacted with the share of world refining located in the United States (identifying how U.S. coefficients differ from foreign refining coefficients).

$$\text{Pooled:} \quad dI_i = \overline{Y}_{ih}(1 - t_c)\,[(\lambda_h - 1)dW_F + (\lambda_h^E + 1)dP_EF + (\lambda_h^T - 1)dT] + \overline{Y}_{if}(1 - t_c)\,[(\lambda_f - 1)dW_F + \lambda_f^E dP_EF + \lambda_f^T dT] + (\overline{Y}_{ih} + \overline{Y}_{if})(1 - t_c)\,[\gamma dGNP + (K + a)] + e_i' + v_t' + w_{it}'. \tag{A12}$$

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