Effects of a Severance Tax on Oil Produced in California

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PREFACE

This report, prepared under Rand's Energy Policy Program, is the final product of the Heavy Oil Project funded by the State of California. It grew out of a recognition that the state policy most likely to affect the production of heavy oil in California was some form of production tax or subsidy. The dominance of heavy oil in California distinguishes California from every other major oil production area in the United States. On the basis of revenue, heavy oil is the most important mineral in the state, and it is growing in importance. As a result, any change in policy affecting it deserves careful attention.

Just as the authors were arriving at the conclusion that a production tax was the most powerful instrument of heavy oil policy available to California policymakers, California policymakers interested in new revenues were growing interested in a particular type of production tax: a *severance* tax on *all* oil in the state. Hence, the authors used the information they had developed on heavy oil policy as a starting point for examining the effects of a new severance tax on all California oil production. They were especially sensitive to differences in oil produced within the state and the implications of these differences for tax effects.

The report does not address itself to a specific severance tax proposal. Neither does it rank proposals nor even take a position on the desirability of a severance tax in general, relative to some other action as a source of new revenue. The report instead offers the results of formal analyses that should help policymakers understand the likely effects of a variety of severance tax proposals. It is meant to support the general debate on the acceptability and design of a severance tax, not any particular point of view within that debate.

The report is thus addressed to the legislator, the staff member, and the informed layman with a special interest in severance taxation of oil in California. Although some understanding of economics is assumed in a few parts of the text, most technical discussions are reserved for the appendixes. The models and methods presented there may also interest analysts concerned with other types of mineral taxation issues.

SUMMARY

This report examines the effects of a new severance tax on tax revenues collected from California oil properties, the share of the tax borne by California oil producers, refiners, and consumers, and the pattern of oil production in the state. Our analysis centered around three basic questions:

- How much net revenue would a severance tax raise for state and local governments in California?
- Who would pay the tax?
- How would the tax affect the production of oil within California?

The net revenue yield would be high on most properties in the state. "Net yield" is the amount of new revenue that a severance tax would bring to state and local governments after its negative effects on current taxes and royalties were subtracted. Only in the Long Beach Tidelands would net yield be low; if revenue for severance taxes were to rise by a dollar, revenue currently collected from state royalties in this area would fall by almost 90 cents. This occurs because severance taxes are deductible from the income base used to calculate royalties in this area. Net yield from other state lands would probably be 50 percent or higher; lower levels are associated with greater tax-induced production cutbacks. Most production in the state occurs on private lands where net yield would be even higher—80 to nearly 100 percent. Again, lower levels in this range reflect higher tax-induced production cutbacks.

Two relevant policy conclusions flow from these results. First, California policymakers may wish to consider exempting the Long Beach Tidelands from the tax; there would be little net gain from a severance tax there. Second, although severance taxes lower oil property values, and hence local property tax receipts, the state could easily compensate local governments for losses of property tax receipts induced by the severance tax. *At most, property taxes would fall by only about six cents for every dollar of new severance tax revenue collected.*

A new severance tax on California oil production would be paid principally by governments outside California and refiners and producers operating within California. Most small producers could easily be exempted without reducing revenues much. The tax would affect final consumers very little. A new severance tax would be imposed

statutorily on producers, but it could be shifted elsewhere in two ways. First, a new severance tax would reduce California producers' federal and state tax obligations outside California and thereby effectively force governments outside California to pay a portion of the tax. Setting the Long Beach Tidelands aside, and assuming that a new tax had no effect on production, refiners and producers in California would pay 30-55 percent of the severance tax revenue collected by California. The remainder would be shifted to out-of-state governments. These firms' "share" of the tax will remain in this range even after the federal windfall profit tax phases out.

Second, producers could potentially pass part of the tax on to refiners, who in turn could pass a portion on to consumers. Taxes imposed on producers of *light* crude oil would be passed forward to refiners only if those taxes were to raise the *world* price of oil. We expect California taxes to have only a negligible effect on world price. Producers of *heavy* crude oil should be able to pass a portion of the tax on to refiners with less difficulty. Prices for heavy crude oil depend not only on world prices for the lighter crudes typically exchanged in world trade, but also on the availability of refining capacity to transform heavy crude into a good substitute for oils traded in the world market. A shortage of such refining capacity depresses heavy crude oil prices in California. By discouraging production, a severance tax would reduce the effects of this shortage; it would cut the supply relative to the demand for heavy crude oil and thereby drive up its price. The price rise would effectively pass a portion of the tax on to refiners; their stockholders would absorb the resulting loss because product prices are essentially set in markets beyond the influence of events in California and hence the refiners could not pass the tax on to final consumers.

These results imply that a uniform severance tax would tend to have what is generally accepted as a desirable differentiated effect on oil producers. Because heavy oil producers would share the tax with refiners, they would bear a smaller portion of the tax than light oil producers. This pattern of taxation is generally considered desirable if higher production costs cause heavy oil producers to reduce production and investment more than light oil producers in response to a uniform severance tax.

A variety of exemption arrangements are available to avoid taxing certain types of operators and production activities without significant revenue losses. Proposals to tax an operator's production only after it exceeds a certain quantity, such as 100,000 barrels a year or 100 barrels a day, would focus the tax on the state's largest producers. State policymakers should, of course, recognize that taxing only large producers creates a strong incentive for producers to split up their companies, at least for tax purposes. Tax provisions could be written to make this difficult. Current proposals would not do particularly well in achieving another goal set for them: shifting part of the tax burden away from the high-cost production, like stripper oil production, often associated with smaller producers. Specific allowances, or reduced tax rates, for such production would be necessary to shift the effect of the tax away from this production and onto other, often more profitable, types of production.

Tax effects on production would be small in the short term; they might grow slowly over time. In the short term, only tax-induced changes in production from existing wells would be likely to be important. The only significant response would be a tendency to shut in wells earlier than otherwise. This would result because the profitability of wells tends to fall over their lifetimes; a new tax would accelerate the date at which their profitability fell to zero. For the range of production and tax characteristics probable in California fields, we find that state-wide production lost through tax-induced shut-ins would cut total production by *less than 1 percent.*

Over the longer term, accelerated shut-in would continue to cut production and would be joined by tax-induced reductions and delays in new investment. The data and models required to yield good predictions about how a severance tax would affect new investment in California are not readily available. We can make two observations, however. First, new investment accounts for only 5 to 8 percent of total production in the state each year. Hence, even very large tax effects on new investment would have small effects on total production until post-tax investment accounted for a significant fraction of total production. That would take time. Second, tax-induced cuts in investment would be about the same whether real oil prices were rising or not, but they would *appear* less troubling if oil prices were rising rapidly. Rising oil prices tend to encourage rising production over time. Under these circumstances, production levels would return to their pre-tax levels after a certain period, creating the appearance that the tax had simply delayed production. And it would have. But because production would typically be delayed beyond any planning horizon likely to appear reasonable to the policymaker—perhaps decades into the future—it is probably more appropriate to characterize this tax effect as a production cut than as a delay.

In sum, California policymakers will probably see a severance tax on oil as an effective source of revenue. For most properties, it would have a high net yield. It would export a substantial portion of its tax burden outside the state, suggesting that its benefits would exceed its costs from the state's point of view. Within California, it would tend to fall on refiners and oil producers and not on the final consumers of petroleum products. And it would probably have relatively small effects on production. These observations, of course, in no way suggest that a severance tax is the best new source of revenue or even that California needs a new source of revenue. But viewed by itself, the oil severance tax has many desirable features from California's point of view.

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I. INTRODUCTION

California is the fourth largest oil producing state in America and the only major producing state that does not impose a severance tax on oil production. That is the starting premise of a series of bills that have been introduced into the California Assembly and Senate during 1981 and 1982.[1] Although these bills emphasize the revenue raising ability of a severance tax, such a tax can have a wide variety of effects. A severance tax can be used to redirect production into the future; in some states, a severance tax is called a conservation tax. Conversely, current production discouraged by a tax can raise dependence on foreign sources of oil; the production effects need not be viewed positively. A severance tax can also be used to reflect the costs of effluents and "boom-town" effects associated with mineral production, and is often justified in this way. In California, however, policy interest has focused almost exclusively on the new revenue that a severance tax could bring to the state and on the fact that the tax burden of such a tax is not so troubling as that of other potential revenue sources.[2] This report examines in detail the likely effects of a new severance tax on net revenues collected from oil-producing properties within California, on the tax burdens of different kinds of Californians, and on the level of oil production from properties in the state.

Because the interests of state policymakers focus on revenue and tax burden effects, we concentrate our analysis there too. But, potentially, our analysis has broader applications. Principal effects other than those on revenues and tax burden all stem from the tax's effect on production. For example, *any* tax-induced cut in production will increase California's dependency on Alaska, Indonesia, and perhaps other outside sources of crude oil. Although we emphasize the importance of production cuts for revenue and tax burden issues, precisely the same information on production effects can be used to assist policymakers more concerned about the tax's effect on "foreign" de-

[1]For example, see the bills introduced by Lockyer (A.B.19, 16 March 1981), Bates (A.B.1597, 18 May 1981), Farr (A.B.3415, 11 March 1982), Alquist (S.B.2077, 21 April 1982), Roos (A.B.3756, 3 May 1982).

[2]For example, legislative analyses accompanying some of the bills introduced recently argue that the federal government will bear a substantial portion of the tax, at least as long as the federal windfall profit tax remains in place, and that oil producers will bear the rest. Final consumers will be unaffected. See, for example, California Assembly, Revenue and Taxation Committee, 1981, 1982.

pendence than about its effects on, say, revenue. Similarly, to the extent that a tax lowers the profitability of oil production in Kern County, it reduces the pressure to expand production in an area with severe air pollution for which oil production is primarily responsible. Again, our information about tax effects on the profitability of production should assist policymakers more concerned about specific environmental issues than about, say, tax burden. In sum, just as a severance tax has important effects apart from those on revenues and tax burden, our results and methodology have important applications that carry beyond the scope of this report.

The report proceeds in two parts. Part 1 provides some basic background information on severance taxation in general and on oil production in California. It also explains our methodological approach to the tax analysis. Part 2 presents the results of our formal analysis. It is framed around five basic policy questions about a new severance tax:

1. How much *net* revenue will it raise for state and local governments in California?
2. How much of its *net* tax burden will fall within California, and how much can be exported?
3. Who pays the portion of the tax that falls within California?
4. How will the tax affect the production of oil within California?
5. How do alternative exemption arrangements affect oil production and revenue collection under a severance tax?

Technical information on the tools used to answer these questions appears in the appendixes, below. The conclusion brings together the results of the study most likely to concern policymakers.

Part 1

BACKGROUND

FOREWORD TO PART 1

Our estimates of the effects of a new severance tax can most easily be understood if we first outline the chief considerations that guided our approach and provide some basic background on oil production in California and severance taxation of oil in general. Part 1 provides this introductory material.

Section II examines the goals typically associated with severance taxation, emphasizing those associated with revenue enhancement. Variations in tax design that have been used in the past suggest that the tax level, the levels of exemptions, and the tailoring of both to specific types of production and producers are likely to interest policymakers charged with designing and maintaining a tax. Section II then reviews the key features of oil production in California and the variety of options available to apply severance taxes to oil production. It emphasizes what is "different" about California production: the concentration of heavy oil in the state; the odd match between the availability of heavy crude and the demand for products made from light fractions; and the effects of environmental regulations, trade restrictions, and other public policies on California production patterns. Such information provides a background for the range of property types considered in the formal analysis, and should prove useful in estimating the disaggregated effects of design variations in a new severance tax.

Section III explains the three principal guidelines underlying our analysis. It addresses tax effects within California rather than comparing tax levels across states. It focuses on individual properties as the relevant unit of observation, presenting numerical results wherever possible. Such analysis provides a broad base of information with which to examine different types of severance taxes and the effects of any given tax on different Californians.

Part 1 provides basic background material relevant to most of the analyses reported in Part 2. More specific background material is provided as necessary in discussions of the results of each analysis.

II. SEVERANCE TAXATION AND CALIFORNIA OIL PRODUCTION

Here we address the purpose and design of severance taxes and their uses in other oil-producing states than California. We follow this discussion with an overview of California oil production in 1981, and then draw some inferences for the design of a severance tax on California oil.

SEVERANCE TAXATION

Recent budgetary pressures have led many state policymakers and others to look at a substantial oil severance tax as a new and necessary revenue source. Generally speaking, a severance tax is a tax imposed on the production of a natural resource. It is levied on the privilege of extracting a nonrenewable resource such as oil, gas, or coal from the earth. Usually, a severance tax is imposed on the value of the resource at the time the resource is removed, or "severed," from the ground. In this sense, any tax on resource *production* is a severance tax, whereas a property tax on the estimated value of the resource remaining in the ground is not.

There are many types of state severance taxes. The major producing states and their versions of one or more severance taxes are listed in Table 2.1. The table illustrates an important point: Even among those taxes already in place, a tremendous variety of severance tax designs is available.

A severance tax is one of a family of production taxes going by many different names and having many different intents. Some states have a tax specifically to help finance public schools. Many permit local governments to levy production taxes for schools and other purposes. Because estimating the quantity of a resource ultimately recoverable and extractable, and evaluating its present taxable worth, are problematic assessments, some states and localities impose a severance tax in lieu of property taxes, although some have both.

Property taxation of oil reserves has been a particular problem for California governments. California's Proposition 13, adopted in 1978, significantly exacerbated the problem of taxing subground resources. The State Board of Equalization Rule 468 interpreting Proposition 13 for oil and gas properties is currently being challenged in the courts by both oil companies and local assessors. A bill by Assemblyman Bill

Table 2.1

State Oil Production Taxes

State	Type or Name of Tax	Basis	Rate
Alaska	Oil and gas production tax	Gross value, with adjustment for royalties and some production costs	15%
		Except property coming into production after 6/30/81 and for first five years	12.5%
California	Severance tax on operation of oil and gas wells--to cover costs of Division of Oil and Gas in supervising and protecting deposits of oil and gas	Fixed fee per barrel, set annually based on operating budget of Division and prior year's production	
		1981 Assessment:	$0.0163839
Florida	Gross production tax	Gross value	8%
		Except for tertiary production and wells producing < 100 bbl/day	5%
Louisiana	Severance tax	Higher of: Gross receipts of first purchaser less transport costs; or posted field price	12.5%
		Except wells that are designated as incapable of producing more than 25 bbl/day of oil and that produce at least 50% salt water per day;	6.25%
	Stripper well tax	Except wells designated as incapable of producing more than 10 bbl/day	3.125%
New Mexico	Oil and gas severance tax	Gross value minus government or Indian royalties and allowance for reasonable transport costs to first market	3.75%
	Emergency school tax		2.55%
	Conservation tax		0.18%
			6.48%

Table 2.1 (Continued)

State	Type or Name of Tax	Basis	Rate
North Dakota	Production tax	Gross value	5%
	"Extraction" tax	Exemption or first 100 bbl/day of royalty owners	6.5%
			11.5%
Oklahoma	Property tax	Gross value	7.0%
	Excise tax	Gross value	0.85%
			7.85%
Texas	Occupation tax	Gross value	4.6%
	Oil conservation tax	Per barrel fee	3/16 cent
Wyoming	Excise tax for severance privilege	Gross value, except stripper properties	6.0%
	Stripper production tax	Oil from property (or lease) with average production <= 10 bbl/day	4.0%
	Oil and gas conservation charge	Per barrel charge set by Conservation Commission	$.0006

Lockyer would resolve this problem by emulating the practice of many states. It would substitute a severance tax for the local property tax on mineral resources. The rate of the severance tax would be set to yield revenues equal to those that would otherwise have been raised by the property tax on oil and gas properties. Oil producers are divided, however, on the desirability of a severance tax in lieu of property taxes. Although the new tax would be easier to administer, many fear that it would soon or later be used to generate revenues well beyond those required to offset the property tax.

States frequently levy a small charge on resource production to defray administrative costs incurred in overseeing and regulating the production. Such fees usually amount to a nominal charge per unit of productive output. These are severance taxes, nonetheless, although they are often imposed in addition to more substantial production taxes. Thus, Wyoming, for example, imposes both a conservation commission fee of 6/10 of a mill per barrel of oil produced and a 6 percent tax on the gross value of the oil. California, on the other hand, levies only a small fee (about 1.6 cents) per barrel to support the Division of Oil and Gas.

In this sense, California does in fact have a severance tax on oil, and has had one since 1939. The tax, however, is specifically not for the purpose of raising revenue (unlike the taxes of most oil-producing states), and generally cannot exceed the estimated "amount of money necessary for the support of the Division of Oil and Gas for the ensuing fiscal year" plus a reserve fund.[1]

Many local governments in California levy fees and production taxes, however. These are listed in Table 2.2. But most of these local taxes are relatively small, amounting to a few cents a barrel of oil produced. Of course, county governments in California do levy property taxes on oil reserves; these can be substantial. Over half of Kern County's property tax revenues are generated from oil properties.

New Mexico offers an interesting illustration of the variety of severance taxes that have been levied by states. That state has three different oil severance taxes. An oil and gas severance tax was first enacted in 1925, and revised in 1937, 1959, and 1978. It is currently set at 3.75 percent of the selling price of the oil, minus royalties paid to federal, state, and local governments or Indian tribes, and an allowance for reasonable costs for transporting the oil to the first purchaser. This tax collected over $83 million in 1981. This revenue is dedicated to a severance tax bonding fund that is used to repay current bond obligations incurred for state capital outlays. Any money remaining in the fund each year is transferred to a severance tax permanent fund. Only the interest from this fund can be spent.

In 1959, an Emergency School Tax was enacted. Although no longer dedicated to school finance (the emergency has since passed), this tax is set at 2.55 percent of taxable value and raised nearly $57 million in 1981. New Mexico also has an oil and gas conservation tax of 0.18 percent of taxable value. This tax funds an energy and minerals division, a state regulatory agency that establishes production levels and oversees conservation practices in the field. This tax raised over $4 million in 1981. There are also local ad valorem production taxes, and a state oil and gas production equipment ad valorem tax. The local ad valorem production tax is set at different rates depending on the county and school district. All funds raised by this tax are returned to the counties and school districts. In 1981 the statewide average for this tax was 1.7 percent of taxable value (usually 50 percent of production value) and raised nearly $23 million dollars.

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[1]California Tax Reports, p. 315, Commerce Clearing House, 1981.

Table 2.2

LOCAL TAXATION OF OIL PRODUCTION IN CALIFORNIA

City	New Well Fee	Annual Well Fee	Severance Tax (cents/bbl)
Beverly Hills	---	$1,250	14[a]
Carson	---	150	--
Culver City	$750	100	--
Fullerton	---	---	5
Inglewood	180	250	5
Lakewood	---	150	1
Long Beach	800	350	7.5[b]
Los Angeles	165	---	1.25
Montebello	---	350	8.25
Placentia	---	70	6.5
Santa Fe Springs	100	180	--
Signal Hill	400	50	7.5
Seal Beach	500	295	12
Torrance	350[c]	350	11[d]
			9[e]
			7[f]
Yorba Linda	---		3.5

SOURCE: Western Oil and Gas Association, as reported in California State Board of Equalization, 1981, p. 52.

NOTE: The City of Huntington Beach levies a fee of 8 cents a barrel on stripper wells and 10 cents a barrel on wells producing more than five barrels a day.

[a]Credited against fee.

[b]Also applies to state leases.

[c]Redrills included.

[d]Less than 1,000 bbl annually.

[e]Between 1,000 and 2,000 bbl annually.

[f]Over 2,000 bbl annually.

Severance Tax Effects

A state severance tax, like taxes generally, can be seen as having two broad effects. First, it (usually) generates new revenues for the state. Undoubtedly, this is the basis of its recent appeal in California. Some revenue estimates range as high as half a billion dollars in new tax dollars raised from a 6 percent California severance tax in the first year. Furthermore, as the price of oil has escalated, so have severance tax receipts in producing states. Even without new taxes or higher rates, oil decontrol has been estimated to add well over $100 billion to state treasuries between 1979 and 1990.[2] On the other hand, receipts will fall if oil prices decline. Revenue projections can be seriously misestimated in times of oil price uncertainty.

There has been a recent trend for states to increase their severance tax rates as well. More than half of the states have recently considered severance tax rate increases or adjustments. Alaska recently raised its severance tax from 12.5 to 15 percent, for example. Proposals to impose severance taxes for the first time have recently failed in the legislatures of Mississippi and Utah. A similar bill failed in the Kansas state Senate by only two votes.

A second, but generally less understood effect of a severance tax is important as well. Any tax influences the way taxpayers behave by changing the economic environment in which they operate. A tax on oil production *borne by those producing it* will reduce the economic incentives they have for producing it. That is, it will reduce their margin of profit on each barrel they produce and sell. This will be true especially for marginal, or high cost, production, where profit margins are, by definition, lower. This effect has important implications for California oil production. We shall return to it following a discussion of the nature of California oil production in 1981.

THE NATURE OF CALIFORNIA OIL PRODUCTION

Here we employ data from the California Division of Oil and Gas and the Conservation Committee on California Oil Production in answering the following questions:

- What kind of oil is produced in California?
- How is it produced?
- What are the constraints on its production?

[2]Senate hearings (1980).

- Where is it produced?
- Who produces it?

California is the fourth largest oil-producing state in the nation. *The kind of oil typically produced and the way it is produced are not typical of other states.* Most California crude is heavier than that produced in other parts of the country. This oil tends to be more expensive to produce, more difficult to process, and yields generally less attractive refined products.

Crude oil varies in many ways. Two of the most important variables are the levels of impurities such as sulfur and nitrogen, and the density, or gravity, of the oil. Air pollution regulations, refining needs and capabilities, and other concerns can limit the market for crudes containing high levels of impurities. The primary characteristic of crude oil, however, is usually its gravity. The selling price of crude, for instance, is determined largely by its gravity. (See App. C.)

Crude oil is often characterized as heavy oil or light oil, depending on its gravity. Heavy oil has a lower hydrogen-to-carbon ratio than lighter oil. Since carbon atoms are much heavier than hydrogen atoms, the weight per unit volume, or density, is greater for heavier crudes. Gravity is normally indicated in degrees on a scale established by the American Petroleum Institute (API). Heavy oil is usually defined as oil with an API gravity of 20 degrees or less.[3] Light oil ranges from just above 20 degrees to over 40 or 50 degrees.

Heavy Oil

The consistency of heavy oil is that of cold molasses. As a result, most heavy oil does not flow freely and must be coaxed out of the ground. Heating is the best enhancement to increase the flow of heavy oil. The most common methods involve periodic soaking or continuous flooding of the oil below the surface through the injection of steam into the oil pool. About a third of the state's oil is produced using steam heat recovery methods, most of it in the San Joaquin Valley.[4] Usually, some of the oil produced is used to fuel steam generators. One barrel of crude typically must be burned in a steam generator to produce three or four barrels of oil, resulting in a net yield of two to

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[3]There is no universally accepted definition of heavy oil. Early price control regulations defined it as 16 degrees API or below. This cutoff was later raised to 20 degrees or less, and is now commonly used to differentiate heavier crude from lighter crude. Even so, it should be remembered that the distinction is merely a relative one, employed for convenience.

[4]"New Lease on Life for Enhanced Oil Recovery," *Chemical Engineering*, June 28, 1982, pp. 47-50.

three barrels per barrel consumed as generator fuel.[5] Burning crude oil emits pollutants into the atmosphere, however, leading to important clean air concerns.

Air Quality Constraints

Especially in Kern County, and to a lesser degree in Los Angeles County, air pollution regulations pose potentially significant economic and technical constraints on expanded heavy oil production.[6] Burning crude oil to generate steam for injection into heavy oil deposits emits sulfur and nitrogen oxides and particulate matter into the atmosphere; in many cases, these emission levels exceed the standards established by the Clean Air Act and state law.[7] In Kern County in particular, oilfield steam generators are cited as the primary cause of the high levels of sulfate and sulfur dioxide in the air, and have resulted in the county's designation as a nonattainment area.[8] Although scrubbers can eliminate most sulfur emissions, concern remains over how to reduce nitrogen oxide emissions economically.

Although hotly contested through 1978-80, the California Air Resources Board (and the Kern County Air Pollution Control District) has adopted strict rules requiring proposed new pollution sources to adopt the best available pollution control technology. Further, owners of proposed new sources must more than offset emissions of any remaining pollutants from the new source by reducing emissions of those pollutants from existing sources in the area.[9] Most operators appear to have sufficient permits or emission offsets available to allow for reasonable expansion of their steam generation capacity and heavy oil recovery activities. Operators entering the county, however, may have difficulty obtaining the required offsets.

A major source of the dispute over clean air enforcement in Kern County oilfields grew out of the forced shutdown of (the equivalent of)

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[5]This "net oil to fuel" ratio has been declining over the last 13 years (Guerard, 1982).

[6]Waste disposal and water availability, which are also serious concerns, could become significant constraints in the near future.

[7]In the current session (and probably the next), Congress is considering reauthorization of the Clean Air Act. These deliberations involve significant procedural and substantive changes in how air quality is regulated throughout the country.

[8]An area may be designated "nonattainment" for one or more pollutants if it has failed to meet, or "attain," the 1975 national air quality standard. This designation invoked stricter new source review requirements and other procedures, and mandated comprehensive state plans to assure timely cleanup.

[9]Of course, this is not peculiar to Kern County. It applies generally to offset programs throughout the country.

62 Getty Oil Company steam generators in late 1978. This incident helps illustrate the recent conflicts between expanded heavy oil development and the enforcement of established air pollution standards. Although the events are now history, much of the tension between the goals of energy development and clean air remains.

Getty's 1976 operating permits specified that if the national sulfur dioxide standards were exceeded at any time, the generators would be shut down, and could be restarted only if measures were taken to reduce future emissions.[10] On December 26, 1978, an unusually cold and stagnant fog enveloped the region, the result of a severe inversion layer. Air quality analyzers installed and operated by Getty in the Kern River field measured atmospheric sulfur dioxide at 179 parts per billion (ppb)—exceeding the EPA standard of 140 ppb for the first time since monitoring began in 1971. Although on the following day the monitors showed no readings in excess of 100 ppb, EPA ordered the steam generators shutdown. These generators accounted for nearly a third of the company's production capacity.

To restart production, Getty would be required to install 18 new stack gas scrubbers, at a cost of approximately half a million dollars each. The company argued that restarting under these conditions was economically infeasible because most of their production in the area was classified as "old" oil, controlled at $5.33 per barrel. At least until the decontrol of heavy oil in the summer of 1979, Getty argued that these conditions were prohibitive. Finally, in June 1980, with Kern River oil selling for about $24 a barrel, Getty and EPA reached an agreement to permit the generators to be restarted. The latter were allowed to operate for a few months without scrubbers while waiting delivery of the units—now priced at nearly a million dollars each. The units were to be installed by early 1981. In exchange, Getty agreed to test some new pollution control equipment for the state Air Resources Board, and to pay a compliance fee to EPA that would offset the savings the company realized while operating without scrubbers (approximately $700,000).

Other Constraints on Heavy Oil

The market for California heavy crudes is restricted to some extent by several other factors as well. Once out of the ground, heavy oil is not so valuable a product as the lighter crudes. Lighter crudes yield

[10]In the absence of an approved State Implementation Plan for California, the Environmental Protection Agency retained direct authority for enforcing the provisions of the Clean Air Act. As a result, Getty's 1976 permits were issued by EPA.

considerably more "higher end" products such as naphtha, kerosene, and gasoline. Heavy oil tends to yield less desirable products such as residual fuel oil, although additional refinery processing can improve the yield.[11] Heavy oil must also compete with higher-quality crudes not only produced in California, but also imported from Alaska and Indonesia. (Alaska provides about 40 percent of California's oil supply; another 15 percent comes from Indonesia.)

While California imports the lighter crudes to use in state refineries, opportunities to ship heavier crude out of the state, or refined products into the state, are limited. No pipelines connect California oil product markets with the rest of the country, and there is only one relatively small pipeline for moving crude oil out of state. Shipping crude by tankers is expensive, especially since the Jones Act requires the use of U.S. ships for domestic trade. Alaskan crude is diverted from potential foreign markets such as Japan by the Export Administration Act of 1979, which prohibits the export of domestic oil transported by the Trans-Alaska Pipeline to nonadjacent nations—except under limited, specific conditions.

Because it has been historically difficult and costly to produce, interest in heavy oil production has been fairly recent, coinciding (at least in part) with the much higher oil prices of the past decade. This trend is evident in Fig. 2.1, which plots heavy oil production as a proportion of total state production from 1950 to 1981. Figure 2.2 traces the rise in prices from 1970 to 1982 for representative heavy and light oils in the state.[12] The oil price escalations of the past nine years have spurred new interest in tapping the vast heavy oil reserves in California. This interest was encouraged by the earlier decontrol of heavy oil prices by President Carter in August 1979, following six years of price controls which held most heavy oil prices well below $10 a barrel. By removing a significant deterrent to increased heavy oil production, decontrol marked a turning point in California oil development. The mix of petroleum reserves and production in California is uniquely dominated by heavy crude. From one-half to two-thirds of California's oil resource base lies in heavy oil, and over 80 percent of the heavy oil in the United States is in California.[13]

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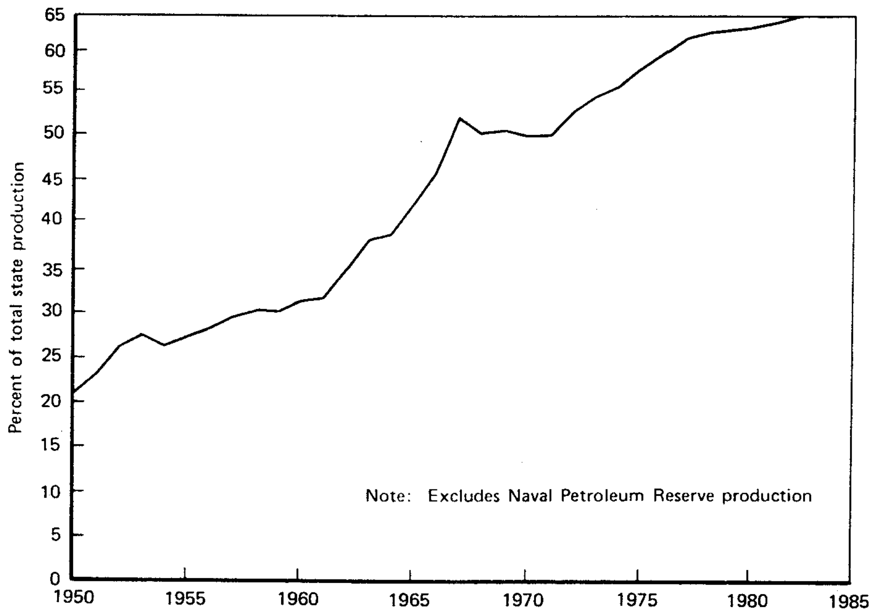
[11]Guerard (1982) provides the layman with an excellent review of heavy oil production and its problems in California.

[12]These prices are those posted for uncontrolled oil (e.g., "new" and stripper oil).

[13]Of the estimated 35 billion barrels of heavy oil remaining in place in significant heavy oil fields in the lower 48 states, over 30 billion barrels are located in California.



SOURCE; Conservation Committee of California Oil Producers 1981, p. 34.

Fig. 2.1—Contribution of heavy oil to total state oil production: 1950-1981

1981 Oil Production

California oil production in 1981 reflected this pattern. Figure 2.3 groups the crude by the average gravity of the pool from which it was produced. Nearly two-thirds of the oil was heavy: 227 million out of 354 million barrels produced. The weighted average gravity for the entire state was just over 19 degrees API—suggesting that the typical barrel produced was "filled" with relatively heavy oil.

Although there are about 650 oil producers in California, only a handful clearly dominate the state's total production. Figure 2.4 illustrates this point. Beginning with the largest producer and moving down in rank, the figure plots the proportionate contribution of each producer to the cumulative state total. Williams Brothers Engineering, Shell Oil (including Kernridge), and Getty Oil account for nearly half of the total. The top six operators produced nearly two-thirds of

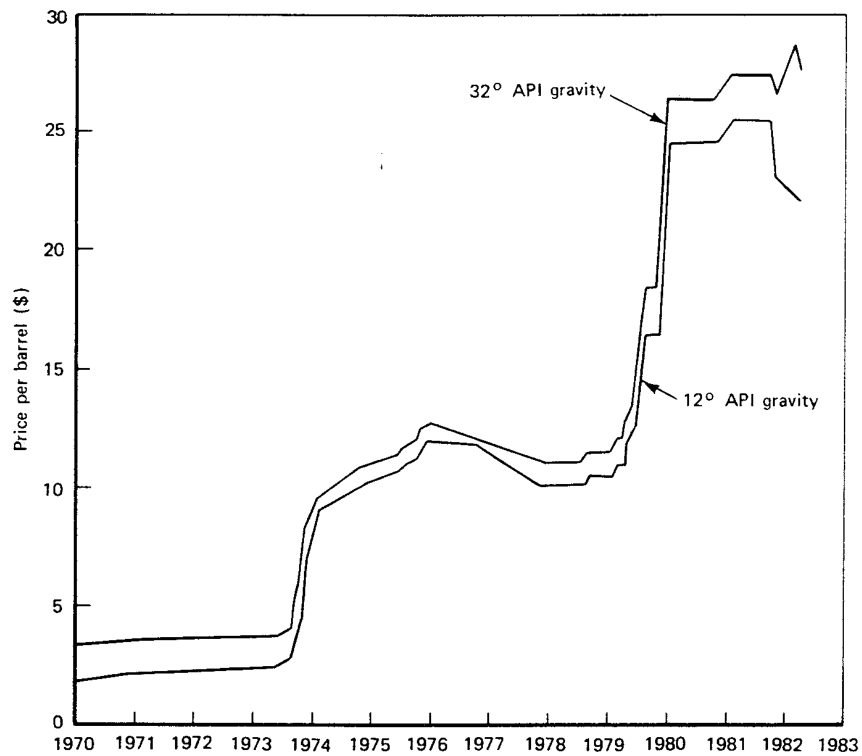


Fig. 2.2—California crude oil prices: 1970-1982

all oil produced; the top ten account for 80 percent. Table 2.3 lists the 30 largest operators; together, they represent 95 percent of the state's total 1981 production. In other words, less than 5 percent of the operators produce 95 percent of the oil in California.

The greater part of the state's oil is produced in Kern County, where more than half of all producing wells and the lion's share of the state's heavy oil are located. The largest single producer operates there. Williams Brothers Engineering produces nearly one-fifth of the state total as operator for the U.S. Naval Petroleum Reserve at Elk Hills.[14]

[14]The company also serves as operator for Chevron, which holds an approximate 21 percent interest in Elk Hills production.

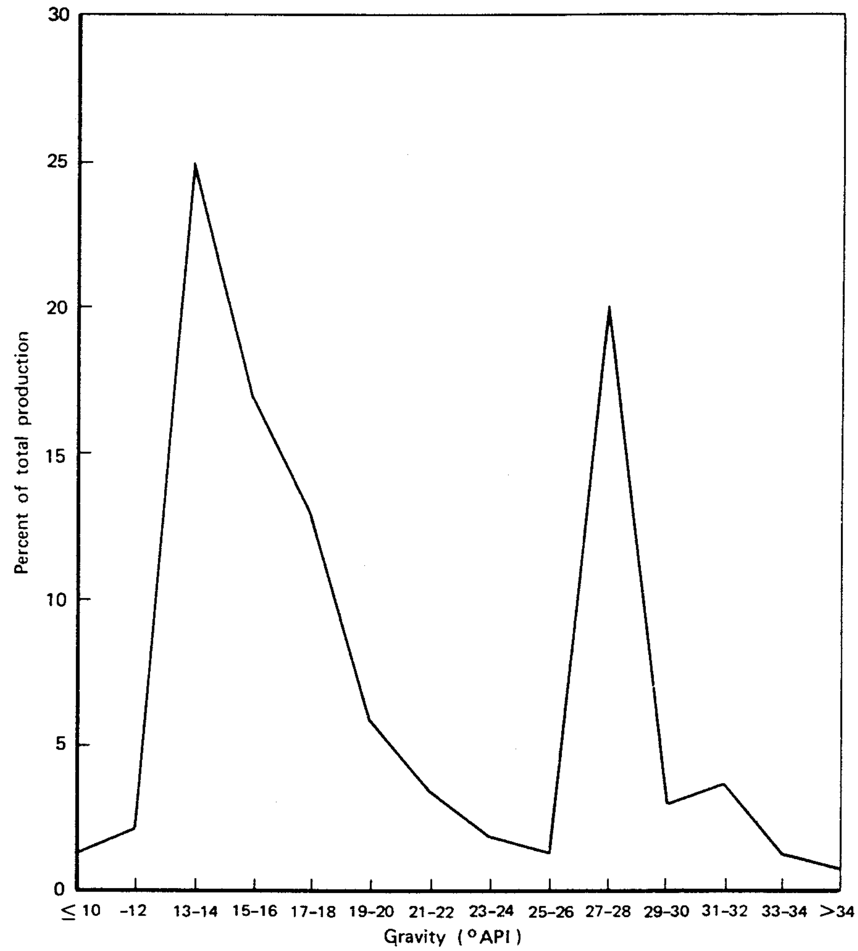


Fig. 2.3—Distribution of 1981 California oil production by gravity

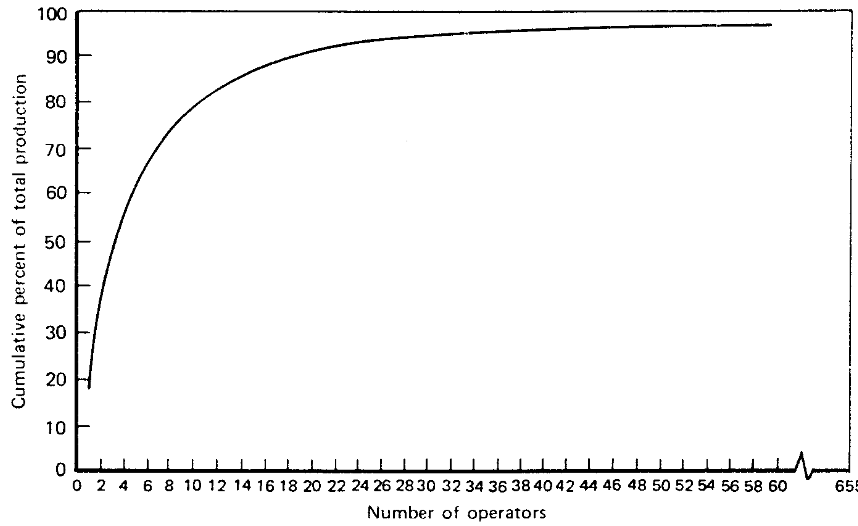


Fig. 2.4—Cumulative contribution of largest operators to 1981 California total

In addition, 40 million barrels are produced from the state's offshore tidelands, an area encompassing the first three miles offshore. All production from the tidelands yields the state significant royalty revenues—nearly $475 million in 1981 alone. State Lands Commission royalty estimates for 1980 to 1983 are presented in Table 2.4. Production from federal outer continental shelf waters is not included in the state totals used in this report, but is estimated at about 20 million barrels in 1981. The Wilmington field off Long Beach is the single largest offshore producing area in the state, accounting for two-thirds of tidelands production. State royalties for production from this area are not the "share of production" royalties typical of most oil properties. They are instead "net profits" royalties. An average of over 96 percent of all proceeds after development and production expenses belong to the state (although the City of Long Beach retains a small portion to defray its administrative costs and to fund its harbor development).

Table 2.3

CALIFORNIA'S THIRTY LARGEST OPERATORS IN 1981

	Operator	Oil Production (bbl)
1.	Williams Brothers Engineering	62,707,093
2.	Shell California Production Inc.[a]	53,733,427
3.	Getty Oil Company	44,206,993
4.	Chevron USA, Inc.	37,173,331
5.	Thums Long Beach Company	22,802,000
6.	Union Oil	15,341,216
7.	Mobil Oil	14,952,041
8.	Texaco	12,518,785
9.	Santa Fe Energy Company	11,010,746
10.	Aminoil	7,646,622
11.	ARCO	7,017,299
12.	Tenneco Oil Company	5,861,087
13.	Exxon Corporation	5,779,800
14.	Sun Exploration & Production Company	5,511,224
15.	Champlin Petroleum Company	4,177,732
16.	Conoco, Inc.	4,090,849
17.	Long Beach Oil Development Company	3,589,676
18.	Gulf Oil Corporation	3,388,037
19.	Petro-Lewis Corporation	2,158,537
20.	Occidental Petroleum Corporation	2,079,949
21.	Getty Oil Company, Operator[b]	1,451,374
22.	M.H. Whittier Corporation	1,308,348
23.	MCO Holings, Inc.	1,205,977
24.	Powerine Oil Company--Long Beach	1,147,735
25.	Tenneco Oil Company, Operator[b]	1,143,702
26.	Grace Petrolum Corporation	995,385
27.	Husky Oil Company	962,769
28.	Superior Oil Company	944,209
29.	General American Oil Company of Texas	784,561
30.	Victory Oil Company	740,932
		336,431,436 (95%)

[a] Includes Kernridge.

[b] Reported for unit operations.

Table 2.4

OIL AND GAS ROYALTIES: 1980-1983

Location	1980-81	1981-82	1982-83
State Lands			
Tracts 2, 11, 8, 39[a]	$ 11,873,862	$ 13,000,000	$ 13,000,000
Other	78,063,556	107,200,000	124,700,000
Total State Lands	89,937,418	120,200,000	137,700,000
School Lands	36,280	36,000	35,000
Long Beach Operations			
(Chapter 138/b4)[a]	385,157,755	370,000,000	370,000,000
Total[b]	$475,131,453	$490,000,000	$510,000,000

SOURCE: State Lands Commission Statement of Revenue as of 1 September 1981.

[a]Windfall profit tax being withheld pending congressional action (H.R. 6056 "Technical Corrections Act of 1982") as follows:

1980-81	27,100,000
1981-82	38,000,000
1982-83	39,000,000

These amounts are not reflected in revenue totals.

[b]Oil and gas royalties projections are rounded to the nearest $10 million to reflect 2 percent error factor.

Tax-Eligible Oil Production

Because most of the production from Elk Hills belongs to the federal government, it is unlikely to be taxed by the state of California.[15] It is also likely that production from the Long Beach unit and adjacent areas, with net profits royalty contracts belonging to the state, would be exempted from any new state severance tax. (Such a tax would simply shift revenue from the tidelands royalty fund to the general

[15]But a 21 percent interest in Elk Hills production held by Chevron, USA, may be taxable.

revenue fund, or a special fund established for severance tax receipts, with little net revenue gain. This is discussed in Sec. IV.) As a result, in the discussion that follows, we focus on all other oil production in the state, defining "tax eligible" oil as that which does not come from the Naval Petroleum Reserve or the Long Beach unit, or from federal offshore areas.[16]

Figure 2.5 illustrates the gravity distribution of 1981 "tax eligible" oil production. Removing Elk Hills significantly changes the average gravity by excluding a large portion of the state's lighter oil. Roughly one-half of the light oil in the state comes from this field. The average gravity of the 264 million barrels of "tax eligible" oil is only 17.5 degrees API. Fully three-quarters of this oil is heavy oil.

Tax eligible oil is still dominated by a small number of operators; the top 25 producers account for over 90 percent of the total.[17] To help understand the kinds of operators working in the state, we have grouped them into two categories: The largest 25, measured by total taxable production, are classed as "larger" producers, while the remaining 626 operators are grouped as "smaller" producers.[18] As seen in Table 2.5, the larger operators produced over 93 percent of the state's total, while the smaller ones accounted for just under 7 percent. These smaller producers are not so concentrated in heavy oil production as the majors are. Table 2.6 shows that while 77 percent of the larger operators' production is in heavy oil, just over a half of the smaller operators' production is in heavy oil.

Stripper-Well Oil Production

A type of oil production known as "stripper oil" deserves special attention, if only because of the special treatment accorded it by the federal windfall profit tax as well as by many state severance taxes. Based on the belief that marginally productive properties would be excessively burdened by production taxes, stripper properties are often partly exempted from these taxes. For instance, the windfall

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[16]The City of Huntington Beach operates three wells on land purchased in 1971 from the Huntington Beach Company, which retained a 1/6 royalty. This is the only city listed as an operator by the Division of Oil and Gas, and we have excluded the 16,323 barrels produced by the City in 1981 from the "tax eligible" total.

[17]Part or all of the production by four operators has been removed: Thums, Long Beach Oil Development Co., Long Beach Powerine, and Williams Brothers Engineering.

[18]This distribution is rather arbitrary, and could be made in a number of different ways. Isolating the largest 25 operators from the remaining 626 permits us to make comparisons between the relatively large oil producers and the smaller ones. Whether the top 20 or 25 operators are used as the appropriate cutoff point makes little difference in the results shown here.

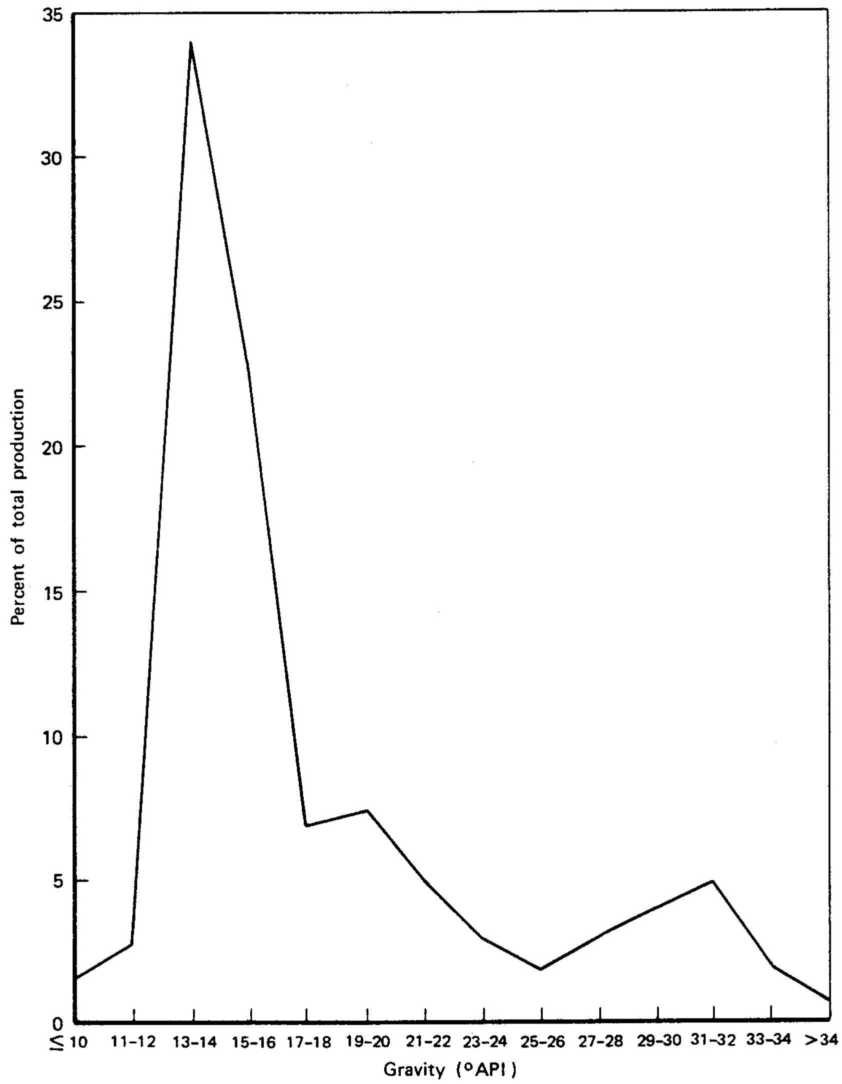

Fig. 2.5—Distribution of 1981 tax-eligible oil production by gravity

Table 2.5

1981 OIL PRODUCTION BY SIZE OF OPERATOR

Operator Group	Oil Production[a] (thousands of bbl)	Percent of Total
Larger operators[b]	245,412	93.2
Smaller operators	18,039	6.8
Total	263,451	100.0

[a]Tax eligible production only.

[b]"Larger" defined as largest 25 operators.

Table 2.6

HEAVY VS. LIGHT OIL PRODUCTION BY SIZE OF OPERATOR

	Tax Eligible Oil Production (Thousands of bbl)					
	Larger Operators		Smaller Operators		Total	
Heavy oil (<=20° API)	189,979	77.4%	9,955	55.2%	199,936	75.9%
Light oil (>20° API)	55,433	22.6%	8,084	44.8%	63,515	24.1%
Total	245,412	100.0%	18,039	100.0%	263,451	100.0%

profit tax rate is lower on oil from properties (i.e., leases) where the average production per well has been ten barrels a day or less for any previous consecutive twelve months. Stripper well oil produced by independent operators (generally those not also involved in retailing or refining) will be completely exempt from the windfall profit tax after January 1, 1983. Some states apply this definition of stripper oil only to individual wells whose average daily production is ten barrels or less, rather than averaging across all wells on the lease or property.

Using the windfall profit tax definition,[19] some 13 percent of the "tax eligible" oil produced in California in 1981 came from stripper properties. Small producers are disproportionately responsible for this production. While the top 25 operators account for over 90 percent of all "tax eligible" production, the 626 smaller producers operate almost 40 percent of the stripper wells (see Table 2.7). Smaller operators produce nearly one-third of all stripper oil in California (see Table 2.8). Moreover, stripper oil accounts for well over half of the production from the small operators, and over 85 percent of their wells.

Table 2.7

DISTRIBUTION OF 1981 STRIPPER WELLS BY SIZE OF OPERATOR

	Tax Eligible Producing Wells					
	Nonstripper		Stripper		Total	
Smaller operators	1,155 (3.9%)	(14.4)	6,884 (39.1%)	(85.6)	8,039 (18.6%)	(100%)
Larger operators	28,431 (96.1%)	(72.6)	10,713 (60.9%)	(27.4)	39,144 (81.4%)	(100%)
Total	29,586 (100%)	(62.7%)	17,597 (100%)	(37.3%)	47,183 (100%)	(100%)

[19]The windfall profit tax definition of property relies on its status in 1972. Property or leases subsequently subdivided must be reaggregated to the 1972 boundaries to determine the appropriate tier and tax rates. We have used a looser but parallel definition based on the property's 1981 status as pool-operator—that is, one operator's total activities in one pool. No precise comparison with the windfall profit tax property definition is intended.

Table 2.8

1981 STRIPPER OIL PRODUCTION BY SIZE OF OPERATOR

	Tax Eligible Oil Production (Thousands of bbl)					
	Nonstripper		Stripper		Total	
Smaller operators	7,164 (3.1%)	(39.7%)	10,875 (30.8%)	(60.3%)	18,039 (6.8%)	(100%)
Larger operators	221,013 (96.9%)	(89.9%)	24,899 (69.1%)	(10.1%)	245,912 (93.2%)	(100%)
Total	228,177 (100.0%)	(86.6%)	35,274 (100.0%)	(13.4%)	263,451 (100.0%)	(100%)

Severance Tax Implications for California Oil Production

As a result of these production patterns, a severance tax on California oil may have important implications for the type of oil and producers most affected. In general, heavier oil costs more to produce than lighter oil, and marginal, or stripper, properties incur higher relative production costs per barrel than more prolific, or productive, properties. Furthermore, not all producers face the same, or average, production costs. Some tend to be more deeply involved in marginal production than others. Thus, different types of oil production and different classes of operators would be affected in different ways by a new severance tax. Some would be affected more than others.

A severance tax may be designed to target certain types of producers, properties, or production as a way of minimizing undesired effects. Sometimes smaller producers, or "independents," are taxed at reduced rates. The definition of "independent" varies, however. It usually includes operators not engaged in refining or retailing, and thus excludes integrated oil companies. The windfall profit tax, on the other hand, provides reduced rates to small refiners and retailers as well by including them in the definition of independents. Although not currently used by any of the major producing states, another method of focusing the tax burden involves exempting smaller producers completely. This can be accomplished, for instance, by excluding from the tax any production volume below a certain threshold.

To encourage production from high-cost, marginal properties (or wells), some taxes, including the windfall profit tax, offer reduced rates for stripper oil. The windfall profit tax also provides lower rates for heavy oil production or oil produced through tertiary recovery methods.

In Sec. IX, we address these issues of revenue and production effects by examining how different exemption levels affect certain kinds of oil production and producers in California and total severance tax revenues.

III. APPROACH

Three basic characteristics distinguish the analysis in this report. First, instead of comparing taxes on oil across states, it concentrates on how a new tax in California affects incomes and behavior within California. Second, in order to discriminate the effects that a tax might have within California, it focuses on individual oil holdings on properties in California as the relevant unit of observation and analysis. Finally, wherever possible, it offers numerical estimates of the effects that a tax would be likely to have on these properties; to that end, it reports the results of five separate quantitative analyses. This section discusses the approach taken and introduces the technical analyses underlying the report.

IN-STATE EFFECTS

Oil-producing companies operating both within and outside California give careful attention to state taxes on oil within and outside California in their planning and operating decisions. But that does not suggest that we need detailed information on taxes outside California to understand how oil companies react to changes in taxes on oil within California. In fact, a strong case can be made that we need no such information beyond that on income taxes in states where unitary arrangements are used to define the base for the state income tax.[1]

Consider how an interstate oil company is likely to react to an increase in the California severance tax. The profitability of California oil production falls. The amount by which profitability within California falls *with respect to this one tax change* is unrelated to tax levels or production cost levels or any other information about oil production conditions before the tax, anywhere outside California. That is, knowing that severance, franchise, or property taxes are higher or lower in Texas than in California tells us nothing about how a prospective change in California's severance tax, *while all these other taxes remain constant,* would affect profitability in California. The rise in California taxes makes California a less attractive investment environment regardless of the level of oil taxes outside California before

[1]Unitary arrangements allow other states to tax a portion of net income earned within California. For an explanation and analysis of these arrangements, see Sec. IV.

(and after) the new California tax is imposed. Hence, the company need not worry about tax levels outside California in determining how to respond to the new California tax.[2]

Even if a state tax changed outside California, its effect on oil production within the state would be tenuous. For example, if oil taxes rose in Texas, California need not become a more attractive locale for oil investments. It would become more attractive only if the Texas tax change improved profitability in California. This could happen if the Texas tax lowered the value—and hence the cost to California well development—of mobile, specialized assets like drilling rigs, steam generators, and experienced engineers that might be transported from Texas to California. Within a company, it could happen if the Texas tax lowered the value—and hence the opportunity cost—of funds internally budgeted *only* for oil investment. Most oil company officials agree that this second possibility is unlikely, especially over any reasonable period of time. Alternatively, a new tax in Texas could raise world oil prices and hence California oil prices, making investment in California more attractive. We examine this possibility briefly in Sec. VI and conclude that it is of only minor importance. Hence, even if tax changes outside California concerned us, their effect on business behavior in California is tenuous. In fact, we examine only changes in California taxes, so even these secondary effects need not concern us.

These arguments should not be taken to suggest that cross-state comparisons of taxes on oil have no place in the policy debate on the severance tax. Information on the "equity" of California taxes on oil relative to taxes elsewhere may have strong rhetorical value in the debate. An understanding of states' relative dependence on oil taxes may also be useful in understanding their relative abilities to reduce other taxes. Such tax reductions may prove important to states competing for new employers outside the oil industry. If this is the source of interest, however, it is not the relative effects of these taxes on oil companies that is relevant to policymakers, but their relative effects on state revenues in different states. This study does not address either of these two potential concerns. It asks how a new severance tax would affect Californians and the amount of oil they consume and produce. Given this goal, it focuses on tax effects within the state and not on interstate comparisons.

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[2]The same does not apply to tax levels within California. As we shall see in Sec. IV, a detailed understanding of taxes directly applied to California oil production is critical to understanding the effects of a new severance tax.

EFFECTS ON INDIVIDUAL PROPERTIES

About 650 companies produce oil from some 750 oil pools in California. Major differences among these companies and pools make for considerable variety in the circumstances in which Californians produce oil. Hence, we should not be surprised if a new severance tax has a wide variety of effects throughout the state. Our analysis is designed to improve policymakers' understanding of this variety and to help them predict how tax effects will differ in different circumstances.

Certain of these differences among companies and pools are important to the analysis. First, geophysical conditions of oil production differ dramatically through the state. California's three major production areas have on-shore and off-shore pools, API gravities that range from 9 degrees to 37 degrees, well depths from 230 to 12,600 feet, and sulfur content from .2 to 6.8 percent—to name only a few variations of special importance in California. These variations affect the investment and operating costs of wells, as well as the revenues that a firm can expect from oil production. As a result, profitability varies sharply from one pool to the next. Because important effects of severance taxes depend on the pre- and post-tax profitability of properties, one can expect the effects of such taxes to vary.

Second, taxes and royalties vary dramatically from one property to the next. Both personal and corporation income taxes (California and federal) affect alternative properties; the importance of out-of-state state income taxes varies; windfall profit tax rates vary markedly; the level and type of royalty vary; and two property tax regimes apply. Properties in different parts of the state even face variations in *locally* imposed severance taxes. Because the tax bases for all these taxes, including state severance taxes, are closely interrelated, these variations in taxes from one property to the next markedly influence how a new severance tax will affect them.[3]

Third, producers—owners and operators—differ. Large and small partnerships, large local and multinational corporations, integrated and non-integrated producers compete side by side. And there are significant state and federal leases in the state, as well as production on private land. To some extent, differences among them are reflected in their tax treatment; but systematic differences in business strategy, attitudes toward risk or new technology, access to capital, and the like can also alter the effect of a tax. Differences among producers have traditionally received special attention in tax and regulatory legislation, suggesting that such differences deserve special attention in the policy debate.

[3]For details, see Sec. IV.

Among remaining differences, the most important is probably the effect of environmental regulation in California. Despite recent changes in this regulation, environmental concerns make the expansion of oil production in Kern and Los Angeles counties, two major production areas, as well as off-shore production, difficult with or without a severance tax.[4] This suggests that the effects of a severance tax in these areas would differ from those elsewhere. Such differences are aggravated by the fact that the distribution of rights to expand production in these areas is very uneven across producers, suggesting that even within, say, Kern County, the severance tax can affect producers located side-by-side in different ways.

Any public policy will affect different parties in different ways, but the spectrum of effects that a severance tax might have in California is exceptionally broad. Because we cannot hope to understand and predict all possible variations, we attempt here to treat the most important differences. Information on these differences should prove useful in the initial design of a tax—for example, the choice of whom to exempt—as well as in evaluating the inevitable future requests for exceptions from and alterations in the tax after it is adopted.

NUMERICAL ESTIMATES

Recent studies of potential new severance taxes in California have generated a number of important qualitative predictions.[5] For example, (a) severance taxes will not affect final consumers, (b) the federal windfall profit tax will reduce the effect of an appropriately designed severance tax on Californians, and (c) a new tax will reduce oil production in California and is more likely to have adverse effects on heavy oil than on light oil production. We reach similar qualitative conclusions, although several significant differences exist. To advance the current debate, we believe that it is important to provide quantitative results to clarify the importance of the qualitative results. For example, policy decisions about whether to tax a particular type of property, or whether to tax it at a different rate, will ultimately depend not on whether the tax reduces oil production from this type of property (and hence increases California's dependence on imports) but on *how much* the tax reduces production. The decision to tax oil from state tidelands will depend not on whether new severance taxes will reduce state royalty receipts but on *how*

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[4]See Sec. II for a discussion.

[5]For example, see California Assembly, Revenue and Taxation Committee, 1981, 1982.

much those receipts fall. Whether the windfall profit tax shifts the tax burden onto the federal government is less important than *how much* of the tax burden is shifted. Wherever possible, we attempt to estimate how much a severance tax actually does reduce production, lower state royalty receipts, and shift the tax burden to the federal government.

Our focus on individual properties is especially important to our interest in quantitative results. On the whole, qualitative effects tend to be the same for all types of properties. The policymaker's interest in differences across these properties derives from the fact that the magnitudes of qualitative effects vary dramatically across properties. Where the policymaker can probably tolerate a tax-induced 10 percent cut in state royalties from a property, a 95 percent cut is entirely different; a 6 percent severance tax can induce both effects on properties only miles apart. (See Sec. IV.) Such analysis would be impossible if we concentrated on anything but the individual property; conversely, property-specific effects likely to be helpful to policymakers with political concerns ultimately require careful quantitative analysis.

While we seek defensible numerical answers wherever possible, we do not lose sight of the fundamental importance of uncertainty in predicting the effects of a new severance tax. Two sources of uncertainty are important.

The less troublesome simply concerns the question of how individual producers will react to a tax change. The more information we can collect, the less important this uncertainty becomes; but the payoff from collecting additional information drops to zero before uncertainty is eliminated. This has two important implications for the analysis. First, we have more confidence in the more aggregated results, since errors associated with specific effects or types of producers are more likely to net out as the number of effects or types grows. This will be true no matter how detailed our analysis becomes. Second, unless we have a compelling interest in a very specific producer, we limit our analysis to the principal effects of any severance tax. Further analysis can seek more specific effects; presumably the analytical tools used here can help such efforts, even if the actual questions addressed concern dominant effects throughout the state.

The second source of uncertainty is more problematic, because the errors it generates will be strongly correlated in all the properties in the state. It is uncertainty about the future real price of oil.[6] Forecasts made by major oil producers and other informed organizations over the past three years speak of "most likely" real annual rates of change

[6]"Real" prices are prices adjusted for the rate of inflation. For example, if oil prices rise over time at the same rate as general inflation, real oil prices remain constant.

in oil prices over the next decade that range from 0 to 4 percent. Figure 3.1 presents these forecasts in terms of their implications for real price growth over the next five years. The level of price change is shown in the band across the middle of the figure. Projections based on oil company and other industry forecasts are shown at the top with the year in which they were made; projections based on forecasts from other sources are shown below. Two aspects of these numbers are worth noting. First, industry and nonindustry estimates fall in the same range; neither access to confidential data nor institutional self-interest appears to have a systematic effect on the estimates. Second, there is no apparent "drift" in the estimates over time; the range of values is not explained by dynamically changing expectations. In the end, this variation in forecasts made by knowledgeable sources appears to reflect genuine subjective uncertainty about the future of world oil prices. We believe this uncertainty to be irreducible.

Put in the context of this range of uncertainty, a severance tax of, say, 6 percent would appear to affect production much more five years hence if real oil prices do not rise than if they rise by 20 percent. Such differences could easily dwarf any numerical differences derived un-

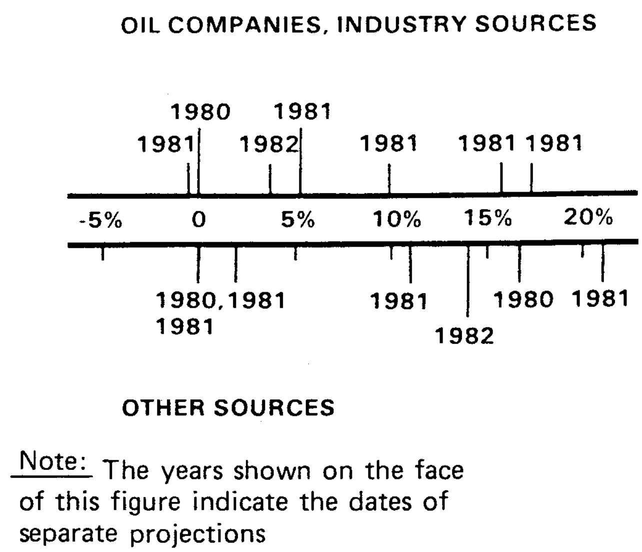

Fig. 3.1—Projections of real world oil price changes for 1982-1987

der a specific assumption about the course of future prices. We are well aware of this possibility and have sought numerical results that are robust in the face of this uncertainty. Our numerical results are particularly helpful in clarifying the *relative* effects of any tax on different kinds of properties, regardless of future oil prices. In generating specific numerical answers, we keep this unavoidable uncertainty in mind and discuss its implications for the numerical results offered.

Ultimately, we have two goals in pursuing quantitative analyses. One is to provide defensible numerical answers that will facilitate the policy debate. The second, and probably the more important, is to provide a defensible framework for thinking about tax effects in the debate. Although we have attempted to anticipate the questions that will interest policymakers, additional ones are inevitable. The analyses presented here should provide not only answers to present questions but also several paths to answers to questions that will arise in the future.

FIVE QUANTITATIVE ANALYSES

Five quantitative analyses underlie the results reported here. The first is a survey of producer characteristics in California.[7] It works from a California Department of Oil and Gas file on wells producing oil in 1981 and aggregates data on individual wells up to the level of each producing company's operation in each pool in the state. The survey considers a variety of production characteristics including the quality and location of the oil produced, factors associated with costs of its production, and specific characteristics of the producing companies themselves. The data allow us to examine the effects of alternative exemption arrangements. They could form the basis for detailed aggregations of tax effects from individual production operations up to the state level.

Second, we use a formal tax-incidence model.[8] It measures how a new severance tax affects revenue collection from seven major taxes relevant to oil production in California. By examining these tax effects in different ways, we can calculate how a severance tax affects net revenue generation for state and local governments; how it affects the (joint) profits of refiners, producers, and private royalty owners; and ultimately how much of the burden of the new tax falls within California.

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[7]Sections II and IX present the results of this analysis.

[8]Results are in Secs. IV and V; documentation is in App. A.

Third, we examine how California crude oil and product prices compare with prices elsewhere in the country.[9] This analysis helps us understand the extent of California's integration into the market in the rest of the country, and hence the world; the extent of this integration has important implications for who within California pays a portion of a new severance tax. The analysis lays out the relationship between California crude prices, adjusted for gravity, and crude prices in Texas. Wholesale prices for two key products in California, gasoline and No. 2 fuel oil, are compared with prices in Texas. The crude price analysis helps us understand tax effects on refiners; product price analyses tell us about effects on final consumers.

Fourth, we use a formal production-planning model.[10] It allows us to examine how oil prices, the expected rate of increase in oil prices, investment and operating costs, taxes, and the like affect an oil producer's decisions about how to produce oil over time and when to terminate production. In particular, the model allows us to determine the likelihood that a new severance tax will affect producers' decisions to shut-in existing oil production.

The final analysis is a statistical examination of investment decisions in 1981.[11] Drawing on the same Division of Oil and Gas data used in the first analysis, it examines how differential characteristics of producers' operations in individual pools affect producers' decisions to start new wells in those pools. By helping us understand some of the determinants of new investment, this analysis should throw light on how a new tax would affect new investment in various kinds of oil properties.

SUMMARY

Three basic characteristics distinguish our approach to determining how a new severance tax would affect Californians. First, we emphasize in-state tax effects; cross-state comparisons of tax effects do not provide the information we need to understand the effect of a severance tax on oil consumption, production, revenue generation, and tax burden within California. Second, we focus on how a tax affects individual oil properties. The effects of uniform tax—particularly the *magnitudes* of these effects—would differ dramatically across proper-

[9]Results appear in Sec. VI; additional material is in App. C.

[10]Results appear in Sec. VII; documentation is in App. D.

[11]Results appear in Sec. VIII; additional material is in App. E.

ties. Information on such differences should help policymakers design the tax and respond to requests for modifications. Finally, while we critically review predictions, in the literature, of a tax's *qualitative* effects, we concentrate here on developing estimates of probable *quantitative* effects. Much uncertainty inheres in such estimates, but ultimately it is the general magnitude of a tax effect—not merely its direction—that is likely to concern the policymaker responsible for design and maintenance of the tax.

Part 2

PRINCIPAL TAX EFFECTS

FOREWORD TO PART 2

Five key questions are important to policymakers considering the use of a severance tax on oil:

- How much *net* revenue will it raise for state and local governments in California?
- How much of its *net* tax burden will fall within California, and how much can be exported?
- Who pays the portion of the tax that falls within California?
- How will the tax affect the production of oil within California?
- How do alternative exemption arrangements affect revenue collection under a severance tax?

Part 2 addresses these five questions and reports the results of a series of formal analytic exercises. Supporting technical information is presented in Appendixes A, D, and E.

Section IV shows how a new severance tax affects the collection of other taxes inside and outside California. The severance tax affects the tax bases for other taxes—and hence the revenue collected from them—in two ways: through deductibles in the tax bases and through effects on oil production. Section IV discusses these effects in detail for the state income tax, state royalties, and local property taxes; calculates the net yield of a new severance tax under a wide variety of circumstances within the state; and reviews the effects of a new tax on taxes collected outside California.

Section V goes one step beyond this level of net revenue. It asks what portion of the new revenues raised comes from Californians. Taking as given the fact (discussed below) that the tax is unlikely to affect final consumers in California, it examines how a new severance tax affects profits in California. It explains why the ratio of lost profits to new net revenue is a good measure of Californians' share of the tax, and presents estimates of this measure under a wide set of circumstances in the state.

Section VI studies the three basic groups within California most likely to be affected by a new severance tax—final consumers, refiners, and oil producers—and examines the probable effects of a new severance tax on each. It investigates the well-known argument that, because product prices and crude oil prices are set in world markets, a new tax in California cannot change these prices; hence, oil producers cannot pass the tax forward. It finds that this is not likely to be true for heavy oil producers, and explains under what conditions such producers can pass a portion of the tax to refiners. Elsewhere, world prices appear likely to prevail, although a California tax may raise these slightly. This section provides a preliminary look at relevant price data that broadly support this theoretical argument.

Sections VII and VIII discuss how producers can be expected to respond to their portion of the tax, and hence how the tax can be expected to affect production. Producers can respond to a new tax in three ways. First, they can change their profile of production from existing wells over time; we consider this to be improbable, and explain why in App. D. Second, they can shut-in existing wells earlier than they otherwise would have. Section VII reports the results from a simple production planning analysis that allows us to estimate the proportion of oil from existing production capacity lost in this way under a wide variety of circumstances in California. Finally, oil producers can change their plans for future capacity additions by delaying new investment, sizing new investment for production farther in the future, and even cancelling some new wells. Section VIII spells out the basic factors affecting these decisions, emphasizes that irreducible subjective uncertainty about future world oil prices makes any formal treatment of these factors difficult, and presents some suggestive data on new investment patterns in California in 1981.

Section IX examines the effects of two exemption proposals that have been considered in a number of severance tax proposals in Sacramento. It examines the number of producers of different sizes which each proposal affects and the proportions of heavy oil and stripper oil which are exempted under each proposal. It suggests how successful each proposal would be in achieving several stated policy goals often used to justify exemptions.

Taken together, these sections provide a framework for formal discussions of severance tax design and a wide range of numerical results that should prove useful in such design. The actual design of a new severance tax is ultimately a political concern and lies beyond the scope of this report.

IV. NET REVENUE YIELD FROM THE SEVERANCE TAX

When the state government of California imposes a severance tax, it will receive all the revenues from the tax. But the imposition of this tax will reduce the state's receipts from other taxes. Local governments will suffer too, as will other state governments and the federal government.

This is true for two reasons. First, the severance tax is deductible from the tax bases for the state income tax and some state royalties. Directly and indirectly, through interaction with other taxes, it also affects the tax base for local property taxes. The net result is that any increase in the severance tax reduces these tax bases and hence the revenues that state and local governments can collect from them at existing tax rates. Second, to the extent that a severance tax reduces the production of oil in California, it reduces the tax bases for almost *all* taxes and fees on oil in the state. Both effects are potentially important. To determine how much new revenue a severance tax can bring to California, we must first determine how much it reduces these other sources of revenue.

BACKGROUND

Many taxes and fees affect oil production in California; we will concentrate on the seven most important ones. They are listed in Table 4.1 with a simplified summary of their marginal rates and the nature of their tax bases. Although we are concerned only with the severance tax, an understanding of all these taxes is necessary, because changes in the severance tax affect all the others, directly or indirectly. As Table 4.2 indicates, severance taxes are deductible from the tax bases for all other key taxes paid in California and even from the base for certain types of royalties.[1] Hence, a rise in the severance tax will potentially affect all of these other taxes. Further, these taxes are in turn interrelated. The key point here is that we need an understanding of how taxes interact.

We also need an understanding of how new severance taxes will affect the level of production *relative* to its level in the absence of

[1]Though not technically deductible from the property tax base, the severance tax depresses the property tax base in the same way that it would if it were deductible.

Table 4.1

PRINCIPAL TAXES AND FEES RELEVANT TO OIL PRODUCTION IN CALIFORNIA

Tax	Marginal Tax Rate (percent)	Relevant Tax Base
Federal income tax		
Corporate	46	Net income
Personal	Varies	Net income
Federal windfall profit tax	0-35	Gross revenue
California income tax		
Corporation (or franchise tax)	9.6	Net income
Personal	Varies	Net income
Non California state income tax (relevant only for interstate firms)		
Corporation	6-8	Net income
Personal	Varies	Net income
California state severance tax (proposed)	0-7	Gross revenue
California state royalties		
Long Beach Tidelands	90-100	Net income
Most other state lands	16-50	Gross revenue
California local property tax	1	Estimated current market value or value based on 1975-76 property value (see text)

severance taxes.[2] As explained in Secs. VII and VIII, severance taxes tend to have very small effects on production in the very short run, but these effects can grow over time. *Statewide,* we expect a 6 percent tax to cause production to fall less than 1 percent in the few years following a tax, and perhaps up to 4 percent after a decade. Circumstances on individual properties, of course, can differ. Expectations about the rate at which real oil prices grow over time *can* be important in predicting how severance taxes will affect

[2]Appendix A explains this concept in detail.

Table 4.2

Tax Interdependencies Based on Deductibility

Tax Base	Taxes Deductible from Tax Base						
	Federal Income Tax	Federal Windfall Profit Tax	California Income Tax	Other State Income Tax	California Severance Tax	California State/Local Royalties	California Local Property Tax
Federal income tax		×	×	×	×	×	×
Federal windfall profit tax							
--Private lands					×		
--Long Beach Tidelands			×	×	×		×
--Most other state lands					×	×	
California income tax		×			×	×	×
Other state income taxes (Relevant only under unitary arrangements)		×			×	×	×
California severance tax							
California state/local royalties							
--Long Beach Tidelands		×			×		×
--Most other state land							
California local property tax							
--Property value fixed							
--Property value senstiive		×			×	×	×

production over the longer term; higher expectations about the growth rate of prices *tend* to be associated with somewhat smaller production cuts. If production were unaffected by severance taxes, we should have only the tax interactions (suggested above) that result when one tax is deductible from the base of another tax. When a severance tax cuts production, *all* tax bases fall except that established for the property tax when it is fixed under Proposition 13. That is, even in the absence of these deduction-induced interactions, the severance tax would be closely linked to these other taxes. Hence, we also need to know how a production cut affects each of these taxes.

We have developed a simple model to simulate the direct and indirect effects of a new severance tax on other taxes and fees paid on any particular property. (See App. A for details.) The model assumes, as we do throughout this report, that free-market competition prevails in California oil markets.[3] We emphasize effects at the property level because appropriate marginal tax rates and tax bases vary from one property to the next. With this model, we can simulate the effects of a new severance tax on California state income taxes and royalties and local property taxes, and thereby estimate how much *net* revenue a dollar of new severance taxes raises for governments in California. We can also examine how it affects revenue collection outside the state.

RANGE OF PARAMETER VALUES CONSIDERED

As Tables 4.1 and 4.2 imply, oil properties can face a wide variety of tax conditions even within California. For our analysis, we seek to represent the implications of this variety without getting lost in it. To do this, we will bring out the principal sources of variation in the numerical results offered below.

Federal Income Tax

Federal income taxes affect both oil companies and the stockholders of those companies. Consider each in turn.

While many small partnerships, subject to the personal income tax, produce oil in California, the vast majority of the oil is produced by large corporations. The top 30 producers account for 95 percent of total production (see Sec. II). Hence, we will concentrate on corporate

[3]This is a matter of some current controversy in California. For some empirical information on pricing in California, see App. C.

producers. Though oil firms are well known for paying low levels of U.S. corporation income taxes, almost all continue to face a 46 percent rate at the margin. We assume throughout that this rate applies.

To the extent that severance taxes affect corporate profits, they must ultimately affect the level of dividends distributed or the value of corporate stock. Since the federal government taxes dividend income and capital gains, a severance tax will affect federal revenues at this level as well. The effect of the severance tax depends on how changes in corporate profits are "distributed" to stockholders. This can be complex and will differ from one company to the next. We shall seek the *maximum* effect the severance tax can have. To do this, we assume that all profits are distributed to individuals in the year they are earned and taxed as dividend income. We further assume a marginal personal income tax rate on individual income of 50 percent.

Federal Windfall Profit Tax

This tax varies substantially from one property to the next and over time. Two basic taxation systems are used.

The first applies so long as net income is large enough that administratively defined "windfall profits" do not exceed 90 percent of net income. Table 4.3 represents the tax that emerges from this system as a simple excise tax. While this is in fact what it is, for the most part determining the tax rate applicable in any particular case is complicated. Different effective rates apply to different tiers of oil and types of producers. Table 4.3 displays the statutory rates and estimates of the effective rates, as percentages of gross revenues, for each tier and producer type in California in June 1982. If world oil prices remain constant, these rates will tend to fall over time until the tax is ultimately phased out in 1993. If world oil prices rise fast enough, the rates could rise but will ultimately fall to zero in 1993.[4] To reflect the range of effective tax rates likely to apply under the windfall profit tax, we shall consider effective rates of 5, 15, 25, and 35 percent.

The second system applies when windfall profits exceed 90 percent of net income. In this case, the statutory tax rate is applied directly to 90 percent of net income. While this system can be important on many marginal properties, it is most important in the Long Beach Tidelands, where most windfall profit taxes are calculated using this system. Circumstances in the Long Beach Tidelands are complicated by

[4]The phaseout schedule for the windfall profit tax is complex; it could begin as early as 1987. For details, see P.L. 96-223, Section 101, 2 April 1980. New legislation, of course, could easily change this schedule, potentially postponing phaseout indefinitely.

Table 4.3

STATUTORY AND EFFECTIVE MARGINAL WINDFALL PROFIT TAX RATES

Tier	Base Price (per barrel) in June 1979[a]	Statutory Rate (%)		Effective Rate Applied to Gross Revenue, June 1982(%)[b]	
		Majors	Independents	Majors	Independents
1	Upper tier price in March 1979, minus 21 cents	70	50	31.20	22.29
2	$15.20	60	30	20.48	10.24
3	$16.55	30	30	8.49	8.49

[a]See F. R. 45, #236, 8 December 1980; PL 96.223, 94 STAT 234,§101.

[b]This quantity is equal to $t_W(1 - p_B/p)$, where t_W is the statutory rate shown in columns 2 and 3; p_B is the base price, derived from the prices in column 1 which rises via an explicit escalation formula over time and is adjusted for quality; and p is the actual price of oil from a property.

the use of net income royalty arrangements, discussed below. Both the state and the operator on state land have an "economic interest" in the oil produced from the property. The state's economic interest is exempt from windfall profit taxation while the operator's is not. Unfortunately, the state, the federal government, and the operators disagree on how to determine operators' economic interests for tax purposes. THUMS, the dominant producer in the area, now uses a definition approved by the federal government and pays taxes based on an economic interest of 15-20 percent. We refer to this below as the "current status" of the windfall profit tax in this area.[5] A proposed amendment to the Windfall Profit Tax Act, now represented by HR

[5]Not all producers in the Long Beach Tidelands accept this interpretation. But because THUMS is the dominant producer in the area, its represents the most important interpretation there.

6056[6] in the U.S. Congress, would reduce the average operator share to 3.75 percent, their average net income interest in the Long Beach Tidelands. We refer to this below as the "HR 6056 Status" of the tax. Because most oil in the area is Tier 1 oil from major producers, we assume a statutory windfall profit tax rate of 70 percent in both cases. We do not consider this second system outside the Long Beach Tidelands.

State Income Taxes

As with federal taxes, the income of both companies and their stockholders is relevant to state taxes.

For reasons discussed under the federal income tax, we treat only corporate oil production. The effective tax rate on such production depends on whether the producer has properties outside California in states with unitary tax arrangements. Under unitary tax arrangements, individual states can tax a share of a corporation's U.S. or worldwide net income. The share is typically determined for the *ith* state by a formula very much like the following:

$$1/3(S_i/S + R_i/R + W_i/W)$$

where S is total sales, R is total payments to owners of all types of property, W is total wage bill, and S_i, R_i, and W_i are the firm's values within the *ith* state.[7] For any oil property within California, this formula means that California taxes a share of income from this property equal to California's established share of the owner's income, and other states do the same. Hence, California oil properties are subject to income taxes in other states when unitary rules are used. According to the Multistate Tax Commission, twenty states now apply such rules to oil companies. Excluding California, these states produce about 11 percent and consume about 32 percent of the nation's oil.

Effective tax rates can obviously vary substantially from one firm to the next, even if we concern ourselves only with corporations. To illustrate the importance of this variation, we consider two cases. In the first, a producer is located wholly within California. It faces only the 9.6 percent California tax rate. This is our "in-state" case. In the second, 10 percent of the producer's income is generated within California. The effective California tax rate falls by assumption to .96

[6]"Technical Corrections Act of 1982," *HR 6056* (Bill introduced in the House of Representatives, April 1, 1982, by Mr. Rostenkowski).

[7]For an elaboration, see McClure, 1980.

percent. We then assume that 20 percent of the firm's income is taxed at an average rate of 7 percent in other states with unitary arrangements, leading to an effective marginal state income tax rate outside California of 1.4 percent. This is our "interstate" case. We also assume that the *ith* state's share of income does not change in response to the severance tax.[8] Other assumptions are obviously possible, but these should adequately demonstrate the importance of this distinction in the way state income taxes are applied.

All of the state personal income taxes in states in which stockholders live are relevant to us. As with federal taxes, we seek the *maximum* effects that a severance tax can have on revenues on these taxes. Hence, we assume that all profits are distributed to stockholders in the year they are earned. Within California, we assume that these profits face a marginal tax rate of 11 percent. Outside California, we assume a rate of 6 percent, which represents a rough average of state personal income tax rates on high-income individuals, weighted by state incomes. As with state corporation taxes, we consider two cases. In the in-state case, for firms operating wholly within California, we assume that stockholders also all live in California. The effective tax rate is 11 percent. In the interstate case, we assume that 11 percent of stockholders live in California and the remainder live elsewhere, yielding effective tax rates inside and outside California of 1.21 and 5.34 percent, respectively.

California Severance Taxes

Current state severance taxes on oil in California are trivial. For the purposes of analysis, we can easily assume them away. A number of local severance taxes exist but none of them is significant. (See Table 2.8.) We shall not concern ourselves with them. We shall concentrate on characterizing the effects of an *ad valorem* severance tax in the range of 0-7 percent, the range most often discussed in the state. As a general rule, we shall focus on a 6 percent rate and indicate how results for alternative tax rates compare with this one.

California State and Private Royalties

Two basic types of royalties are paid on oil production in California. The first is simply an *ad valorem* payment, tied to the value of gross

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[8]If a severance tax induces a firm to relocate sales, property, or employment across state lines or simply to change the level of any of these, the shares of income that states can tax will change. For simplicity, we treat this as a second-order effect.

revenues.[9] On private land, the rate typically varies from 1/8 to 1/6 of gross revenue. On state land, it is higher, ranging from 1/6 to 1/2 of gross revenue. The second type of royalty occurs only in the Long Beach Tidelands and on a few other publicly owned properties in Long Beach and elsewhere. This type applies an *ad valorem* charge to a version of net income that allows the deduction of most nontax costs and "excise taxes." Excise taxes are defined to include the property tax, the windfall profit tax, and the severance tax. Royalty rates in the Tidelands, which account for almost all the oil of this type, range from 90 to 100 percent and average 96.25 percent. They generally collect from 30 to 35 percent of the *gross* revenue generated in the Tidelands.

Because royalties and severance taxes are so similar in character, the royalty rate is important to the determination of the effects of a severance tax. But it would be inappropriate to spend too much time here characterizing the effects of the full range of royalties in the state. We seek only to understand the key sources of variation. For royalties on private land, we assume a rate of 1/7. For royalties on state land other than the Tidelands, we assume a rate of 30 percent, close to the volume-weighted average of royalties collected from these properties. For royalties from the Tidelands, we assume a marginal rate on net income of 96.25 percent.

Local Property Taxes

The relevance of the property tax to changes in the severance tax depends on a property's status under Proposition 13.[10] For tax purposes, a property's value is *fixed* to its assessed value in 1975, its "base value," plus a 2 percent escalation per year unless one of the following occurs:

- The property is transferred
- Reserves are added to or subtracted from the property
- The property's market value falls below this fixed value

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[9]This is too simplistic. Certain preliminary processing or transportation costs are sometimes deducted before the royalty is calculated. And, most commonly, the royalty is legally an in-kind payment; the producer simply acts as the royalty-owner's agent in disposing of his share of the oil produced and returning the revenue, net of assessed taxes and the like, to the royalty-owners. Assuming such subtleties away should not do much violence to our results.

[10]Our discussion of Proposition 13 draws heavily on a personal communication from Raymond Reinhard, Legislative Analyst's Office, 19 August 1982. See also California Board of Equalization, 1981; Assembly Revenue and Taxation Committee, 1982.

When any of these events occurs, an estimate of current net present value (based on projected gross income, costs, and taxes other than income taxes) is used to adjust the property's base value to reflect, at least in part, current circumstances. The value of the property, for tax purposes, is *sensitive* to changes in the severance tax only when one of these events occurs. Since Proposition 13 was passed, about a third of California's oil properties have experienced one or more of these events. The most common is an addition of new reserves, which has enhanced the assessed value of oil properties by about 26 percent a year since 1978-79. Much of this is a product of the rapid oil price increases in 1979, which are not expected to continue in the future. Hence, this represents an upper limit on what proportion of oil will be sensitive to changes in severance taxes in any year.

For the purposes of our analysis, we assume a 1 percent property tax rate on all oil properties. We set the rate at which assessed property value responds to changes in income, costs, and taxes equal to zero when that property value is *fixed* under Proposition 13; we set it equal to 6.5 when property value is *sensitive* to such changes under Proposition 13.[11]

The basic assumptions used in the analysis about each of the taxes discussed above are listed in Table 4.4.

TAX EFFECTS

As noted above, increased severance taxes affect revenues from other revenue sources within California in two ways: by reducing the tax bases from which severance taxes are deductible, and by reducing oil production and hence the bases for all taxes and fees in the state. To understand these two channels of influence better, let us proceed in two steps. Assume first, that the severance tax has no effect on oil production. Under this assumption, a severance tax can reduce receipts from the state income tax, local property taxes, and royalties like those in the Long Beach Tidelands. In the second step we let production fall. After considering revenue changes within California in detail, we summarize effects outside the state.

Effects of Deductibility

As noted above, a severance tax is deductible from income and property taxes as well as from some royalties. The relationship of the severance tax to royalties is the simplest of these. We consider this

[11]See App. A for an explanation of the choice of 6.5.

Table 4.4

Basic Assumptions Used in the Tax Incidence Model

Tax or Fee	Treatment in the Analysis
Federal corporation income tax	Marginal rate on net income is 46 percent.
Federal personal income tax	Marginal rate on net income is 50 percent.
Federal windfall profit tax	Effective marginal rate on gross revenue is 0, 5, 15, 25, 35 for high-net-income properties. Where the 90 percent income limitation applies, the effective marginal rate on net income is 0, .023625, and .0945.
State corporation income tax	For interstate firms, the effective California marginal rate is .96 percent, and the effective non-California marginal rate is 1.4 percent on net income. For in-state firms, the only tax is a 9.6 percent California tax on net income.
State personal income tax	For interstate firms, the effective marginal rates on corporate profits net of all corporate taxes is 1.21 percent within California and 5.34 pecent outside California. For in-state firms, the only tax is an 11 percent California tax on corporate profits net of all other taxes.
California severance taxes	No severance taxes currently exist; focus on a new 6 percent tax on gross revenue.
Royalties	On private land, a 1/7 rate on gross revenue. On state land other than the Long Beach Tidelands, a 30 percent rate on gross revenue. In the Long Beach Tidelands, a 96.25 percent rate on net income.
California local property taxes	If assessed value is "fixed," property taxes are unaffected by changes in other taxes. If assessed value is "sensitive," a 1 percent marginal tax rate on a simple proxy for net present value, which sets property value equal to 6.5 times current gross revenues less costs and some taxes.

relationship first, then consider how severance taxes affect income and property taxes, and finally summarize tax effects within California when the tax does not affect production. Tables 4.5 and 4.6, respectively, report these results for properties in the Long Beach Tidelands and properties elsewhere. Our analysis allows us to present results in the format offered in these tables because the effects shown do not depend on the new severance tax rate.[12]

The effect of severance taxes on state and local royalties is simple when production does not change. Only royalties paid from the Long Beach Tidelands are affected. Recall that elsewhere royalties are a simple fraction of gross revenues, which do not change so long as production remains constant; hence, a severance tax has no effect on royalties. In the Long Beach Tidelands, however, royalties are 90 to 100 percent of net income on these properties. Many observers have suggested that, because severance taxes are deductible from the royalty base here, an additional dollar of severance tax revenue will reduce royalty payments in proportion to the royalty rate by an average of $0.9625. This would be true if the severance tax had no effect on other taxes deductible from the royalty base. As Table 4.5 shows, we obtain the result above in the absence of the windfall profit tax when property values are fixed. When property values are sensitive to severance taxes, however, or when operators must pay a windfall profit tax, the severance tax's effect on royalties falls off. Even under the current definition of economic interest, under which the windfall profit tax has its greatest influence, royalty losses offset most gains from severance taxes.

Effects on two income taxes are relevant. The larger effects fall on corporation income taxes, but, while they can differ significantly from one property to another, none of the effects is very large. At most, state corporation income tax receipts fall 9.6 cents for every dollar of new severance tax collected. The marginal corporation tax rate is, of course, .096. Effects on personal income taxes are even smaller. (This is particularly important because we are estimating the maximum level of these effects.)

Second, effects on corporation income taxes for interstate firms are only about a tenth the size of effects on properties taxed only by the California state income tax. This is because, under unitary arrangements, income from this property is taxed both by California and by other states that use the unitary system. Hence, an increase in Cali-

[12]None of the results in this section depend on the new severance tax rate. Strictly speaking, this is a result of some simplifications in our modeling. Even if more sophisticated assumptions were made, however, we should not expect any of these results to be especially sensitive to the tax rate. For a full discussion of these points, see App. A. Of course, the probability that production will be affected rises as the tax rate rises.

Table 4.5

Effects on Tax Revenues in the Long Beach Tidelands When Production Does Not Fall[a]

(Cents per dollar of severance tax revenue)

Tax-Relevant Property Value[b]	Type	Status of Windfall Profit Tax (WPT)[c]	Corporation Income Tax	Personal Income Tax	Property Tax	Royalty	Total
Fixed	In-state	Current	-.3	-.2	0	-87.0	12.3
		HR 6056	-.4	-.2	0	-94.0	5.4
		No WPT	-.4	-.2	0	-96.3	3.2
	Interstate	Current	d	d	0	-87.2	12.8
		HR 6056	d	d	0	-94.0	6.0
		No WPT	d	d	0	-96.3	3.7
Sensitive	In-state	Current	-.3	-.2	-.2	-87.0	12.2
		HR 6056	-.4	-.2	-.2	-93.8	5.4
		No WPT	-.4	-.2	-.2	-96.0	3.2
	Interstate	Current	d	d	-.2	-87.0	12.8
		HR 6056	d	d	-.2	-93.8	6.0
		No WPT	d	d	-.2	-96.0	3.7

[a] For a full explanation of cases in the table, see Table 4.4 and accompanying text.
[b] If fixed, tax-relevant property value is invariant to tax changes; if sensitive, property value varies with other tax levels.
[c] Current status is that on THUMS property; HR 6056 proposes private economic interest equal to private share in net income royalty agreement with state.
[d] Less than .1 in absolute value.

Table 4.6

Effects on Tax Revenues Outside the Long Beach Tidelands When Production Does Not Fall[a]

(Cents per dollar of severance tax revenue)

Tax-Relevant Property Value[b]	Firm Type	Effective WPT Rate[c] (%)	State Corporation Income Tax		State Personal Income Tax		Local Property Tax		Total	
			State	Private	State	Private	State	Private	State	Private
Fixed	In-state	0	-9.6	-9.6	-5.4	-5.4	0	0	85	85
		5	-9.3	-9.1	-5.2	-5.1	0	0	85	86
		15	-8.6	-8.2	-4.8	-4.6	0	0	87	87
		25	-7.9	-7.2	-4.4	-4.0	0	0	88	88
		35	-7.2	-6.2	-4.1	-3.5	0	0	89	90
	Interstate	0	-1.0	-1.0	-.6	-.6	0	0	98	98
		5	-.9	-.9	-.6	-.6	0	0	98	98
		15	-.9	-.8	-.6	-.5	0	0	99	99
		25	-.8	-.7	-.5	-.5	0	0	99	99
		35	-.7	-.6	-.5	-.4	0	0	99	99
Sensitive	In-state	0	-9.0	-9.0	-5.1	-5.1	-6.1	-6.1	80	80
		5	-8.7	-8.6	-4.9	-4.8	-5.9	-5.8	81	81
		15	-8.1	-7.7	-4.5	-4.3	-5.5	-5.2	82	83
		25	-7.4	-6.8	-4.2	-3.8	-5.0	-4.6	83	85
		35	-6.8	-5.9	-3.8	-3.3	-4.6	-4.0	85	87
	Interstate	0	-.9	-.9	-.6	-.6	-6.1	-6.1	92	92
		5	-.9	-.9	-.6	-.6	-5.9	-5.8	93	93
		15	-.8	-.8	-.5	-.5	-5.5	-5.2	93	94
		25	-.7	-.7	-.5	-.4	-5.0	-4.6	94	94
		35	-.7	-.6	-.4	-.4	-4.6	-4.0	94	95

[a] For a full explanation of cases in the table, see Table 4.4 and accompanying text.
[b] If fixed, tax-relevant property value is invariant to tax changes; if sensitive, property value varies with other tax levels.
[c] Windfall profit tax, see Table 4.3 and accompanying text.

fornia severance taxes reduces income tax receipts in all these states. The example shown here assumes that about one-tenth of taxable income is allocated to California for taxation, meaning that California suffers from only one-tenth of the reduction in state income tax receipts paid by interstate firms. This fraction, of course, varies from property to property. On properties taxed only by California, California bears the full brunt of this drop in income tax revenue. A similar variation occurs for personal income taxes for similar reasons.

Third, the effect on properties in the Long Beach Tidelands differs dramatically from that on properties elsewhere in the state. The reason is that relatively little state income tax is collected on the Long Beach Tidelands operations to begin with. Most of the revenue from these properties not received by operators themselves goes to the state and the City of Long Beach in the form of royalties.

The final revenue source affected by severance taxes is property taxes themselves. Note first that property tax receipts are affected only if the assessed property is sensitive to current changes. Second, even where severance taxes do affect property tax revenues, the effect is small. At most, an extra dollar of severance tax revenue cuts property tax revenues by less than six cents. Third, the Long Beach Tidelands once again stand out. Effects on property tax revenues from the Long Beach Tidelands are substantially lower than elsewhere because of the low level of property taxes here in the first place.

Let us bring these effects on California royalties, income taxes, and property taxes together. So long as production is unaffected, the *net* revenue raised when the state receives an additional dollar of severance taxes is low—3 to 13 cents—in the Long Beach Tidelands and high—84 to 99 cents—everywhere else. The yield is markedly higher from properties affected by multi-state unitary income taxes than from those taxed only by California. The yield rises as the effective windfall profit tax rate rises. All of these results are insensitive to the severance tax rate.

Effects of Production Cutbacks

While severance taxes will probably not affect production much in the very short run, production effects can become important over time. In Secs. VII and VIII we estimate that, *for the state as a whole,* a 6 percent tax will cut production less than 1 percent in the first few years after the tax; production could fall as much as 4 percent after a decade. The range of possibilities for individual properties is, of course, much broader.

The net yield of the severance tax is quite sensitive to reductions in production, because these reduce nearly all tax bases below the levels they would have obtained without a tax and hence tend to reduce receipts from all other types of taxes and fees in California. Hence, it will be important for us to determine what range of production cuts is reasonable. After doing this, we can examine how different production cuts affect individual and total effects on tax revenues within California.

In the tables below, we examine a range of production effects, from $-.5$ to -1.5, where $\Delta Q/Q$ is the percentage change in production, and Δt_S is the change in the severance tax rate. How reasonable are these adjustments? To develop a feeling for this, implied elasticities of supply are shown in Table 4.7.[13]

For example, in the first row, the profit-maximizing response to a 1 percent severance tax will be a .5 percent cut in production if the supply elasticity is 24-28 in the Long Beach Tidelands, .6 on other state land, and .5 on private land. Larger production cuts are prompted by larger elasticities. We expect elasticities relevant to our analysis to be about unity or less.[14] For individual properties, elasticities can be higher or lower, but *on average* they will be less than unity as well. Hence, the production cuts here easily span the relevant range of possibilities for typical properties.

Note the dramatic difference between the Long Beach Tidelands and other parts of the state. This difference results from the net income basis of state royalties in the Long Beach Tidelands. A 96.25 percent partner, the state shares additional revenues and additional costs, including taxes. As we saw above, new severance taxes raise little new tax revenue here; they also impose little new tax burden. As a result, an operator's supply elasticity must be enormous for production to be cut even 3 percent in response to a 6 percent tax. The elasticities reported in Table 4.7 are so high that we expect little production response in the Long Beach Tidelands. Hence, we shall concentrate our analysis of production response on properties in other parts of the state.

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[13]The elasticity of supply is the profit-maximizing percentage change in production in response to a 1 percent change in price, *net* of all taxes and fees. Hence, it effectively measures the underlying technical cost structure, abstracting from taxes, for an individual oil property.

[14]Reliable empirical estimates for disaggregated supply sources are rare. Estimates of the elasticity of *cumulative* supply from *new* wells for prices relevant to our analysis ($25 and higher per barrel) tend to be about one or less. (For example, see Anderson, 1979; Eckbo, 1979; Meyer et al., 1980.) These are most appropriate to discussions of very-long-term production cuts associated with tax-induced changes in new investment plans. In post-investment decisions, exploration and investment costs are sunk; hence, elasticities for cuts from existing production stock will be smaller. In the short term, most production is from existing stock, suggesting that the shorter-term elasticities likely to interest policymakers—elasticities for the next five to eight years, say—will be smaller and are quite likely to lie below unity.

Table 4.7

SUPPLY ELASTICITIES IMPLIED BY VARIOUS LEVELS OF $(\Delta Q/Q)/\Delta t_S$[a]

$\frac{\Delta Q/Q}{\Delta t_S}$	Implied Supply Elasticity: Long Beach Tidelands	Other State Lands	Private Lands
-.5	24-28	.6	.5
-1.0	48-57	1.1-1.2	.9
-1.5	71-85	1.7-1.9	1.2

[a] $(\Delta Q/Q)/\Delta t_S$ is the percentage reduction in output caused by each percentage point change in the severance tax. The effective windfall profit tax rate is 15 percent. For a full explanation of cases in the table, see Table 4.4 and accompanying text.

Table 4.8 shows how a severance tax affects the principal revenue sources in California. As above, the effect of a severance tax on state corporation income receipts depends primarily on whether the company is located wholly within California or not. The effect is about ten times greater when only the California tax applies, because then California suffers the full drop in state income tax revenues. Otherwise, effects on income tax revenues are more or less uniform across assumptions. Effects on private lands are slightly greater and more responsive because state royalties are deductible from income taxes. As a result they temper the effect of severance taxes on state lands. Income tax collection starts lower on state lands than on private lands; as the severance tax cuts production, the resulting fall in state royalties increases the tax base for state income taxes on state land *relative* to that on private land. Effects on personal income taxes are smaller but show similar patterns for similar reasons. Keep in mind that these are *maximum* effects on personal income tax revenues.

Table 4.8

EFFECTS ON TAX REVENUES OUTSIDE THE LONG BEACH TIDELANDS WHEN PRODUCTION FALLS[a]

(Cents per dollar of severance tax revenue)

Tax-Relevant Property Value[b]	Firm Type	$\frac{\Delta Q/Q}{\Delta t_S}$[c]	State Corporation Income Tax		State Personal Income Tax		Local Property Tax		State Royalty		Total	
			State	Private	State	Private	State	Private	State	Private	State	Private
Fixed	In-state	-.5	-8.9	-9.9	-5.9	-6.2	0	0	-15.5	0	71	84
		-1.0	-9.1	-11.7	-5.0	-8.0	0	0	-31.9	0	54	80
		-1.5	-9.4	-13.6	-5.0	-9.9	0	0	-49.5	0	36	76
	Interstate	-.5	-.9	-1.0	-.6	-.7	0	0	-15.5	0	83	98
		-1.0	-.9	-1.1	-.6	-.9	0	0	-31.9	0	67	98
		-1.5	-.9	-1.3	-.6	-1.1	0	0	-49.5	0	49	98
Sensitive	In-state	-.5	-8.3	-9.3	-4.6	-6.0	-5.6	-5.9	-15.5	0	66	79
		-1.0	-8.6	-11.1	-4.7	-7.7	-5.8	-6.6	-31.9	0	49	74
		-1.5	-8.9	-13.1	-4.7	-9.6	-6.0	-7.3	-49.5	0	31	71
	Interstate	-.5	-.8	-.9	-.5	-.7	-5.6	-5.8	-15.5	0	78	93
		-1.0	-.9	-1.1	-.6	-.9	-5.8	-6.4	-31.9	0	61	92
		-1.5	-.9	-1.3	-.6	-1.1	-6.0	-7.1	-49.5	0	43	91

[a] The effective Windfall profit tax rate is 15 percent. For a full explanation of cases in the table, see Table 4.4 and accompanying text.

[b] If fixed, tax-relevant property value is invariant to tax changes; if sensitive, property value varies with other tax levels.

[c] Percentage reduction in output caused by each percentage point change in the severance tax.

Effects on property tax revenues are simpler. Where Proposition 13 determines the tax-relevant value of properties without reference to current market values, severance taxes have no effect. Elsewhere, they reduce property tax revenues by up to a more or less uniform 5-7 cents per dollar over a wide range of assumptions.

Effects on state royalties are also simple to understand. Because no such royalties are collected on private land, we observe no effect there. On state lands, royalty revenues fall in proportion to output. The rate of decline depends only on the royalty rate, shown at a typical rate of 30 percent in Table 4.8. Effects would be proportionally larger with higher royalty rates and smaller with lower royalties.

When we put all these effects together, the most striking result is that the net yield on properties *outside* the Long Beach Tidelands is almost uniformly significant. While the effects on individual revenue sources vary substantially from one property to the next, the effects are all sufficiently small that, taken together, they tend not to dilute the total effect of new severance tax revenue.

Identifiable variations do remain, of course. Taxes on interstate firms producing on private lands on properties whose values are fixed under Proposition 13 lead to almost no reduction of other revenue sources. Where property values are sensitive to current events, the net yield falls about 5-6 cents on the dollar. Moving to firms located entirely in-state cuts the yield by another 8-13 cents. Most serious, moving from private to state land can cut yield by up to an additional 50 cents under the assumptions in the table. Even in the worst case shown, however, severance taxes collect more than 30 cents on the dollar of new revenue.

Effects on Tax Revenues Outside California

The focus of our analysis is on tax effects within California, since these are the effects of greatest substantive concern to the state policymakers who must decide whether a severance tax is worthwhile. But our methods produce information on effects outside California as well. This information may prove useful to policymakers seeking a broader point of view. At the very least, policymakers should be aware of the magnitude of likely tax effects outside California. They are sufficiently large that simply to maintain its revenues, the federal government might well seek additional tax vehicles that could offset some of the net revenues discussed above. Less likely but still conceivable, the federal government, or perhaps states affected by the severance tax, could consider retaliatory taxes that could offset some of the net tax revenues. We do not speculate on the form these offsetting policies might take. We simply report out-of-state effects of a new severance tax in California if policy outside California remains stable.

Tables 4.9 and 4.10 summarize the effects of severance taxes on, respectively, private and state land (other than the Long Beach Tidelands) operated by interstate firms when property values are fixed by Proposition 13.

Effects on other states are small, especially in the range of production cuts (0-4 percent for a 6 percent tax) which we expect for California as a whole over time. Generally, personal income taxes are affected more than corporation income taxes, because personal income taxes are affected throughout the country. Only states with unitary income arrangements see effects on corporation income taxes. All of these effects would fall to zero for firms located and owned wholly within California.

The big effects come at the federal level. The federal government can easily lose $1.80 for every dollar of severance tax collected in California on certain properties. The effects of a severance tax on all California properties are less dramatic, but still large. For a 6 percent tax, recall that we expect production cuts of 0-4 percent, at most, over time. At an average, effective windfall profit tax rate of 15 percent, we expect losses of $.65 to $.80 in federal revenues for every dollar of severance tax collected in California.[15] Losses of windfall profit tax revenue will be significant, but the greatest losses will fall as the windfall profit tax phases out—although by less than the amount of the tax itself, for it offsets losses of corporation income taxes. The effects on personal income taxes reported here are also large, but one should keep in mind that they are *maximum* levels of this effect. In all likelihood, the effect here will be half that reported, or smaller.[16]

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[15]The net revenue yield of the severance tax for the nation as a whole can easily be—and may well turn out to be—smaller than the tax burden on taxed firms, because the tax induces large "dead weight losses." When a tax encourages producers to cut output, they stop selling a certain amount of oil that would otherwise have formed the basis for a mutually advantageous exchange because buyers valued the oil more than it cost to produce. The net value of exchanges eliminated by a tax is lost to society and reduces either the revenues it can generate, the after-tax profits firms can retain, or both. This loss is known as dead-weight loss. Section V discusses this point further and shows a simple graphical way to measure dead-weight loss.

[16]A new severance tax in California could conceivably raise world oil prices slightly. We discuss this possibility in detail in Sec. VI. It is relevant here because such a change could increase taxable oil industry income and hence federal income tax receipts, thereby offsetting some of the losses discussed above. To see how important this is, let us estimate the largest change in federal revenues possible. Use a low value (justified in Sec. VI) of -5.3 for the elasticity of excess demand for oil produced in California. Then, assuming an oil price of $25 per barrel, a 1 percent production cut raises California (and world) oil prices $.047 per barrel. Given U.S. production of nine million barrels per day, this raises taxable income $423,000 per day. Under our assumptions, a 6 percent sever-

Table 4.9

REDUCTIONS IN OUT-OF-STATE TAX REVENUES WHEN PROPERTIES ON PRIVATE LAND IN CALIFORNIA ARE TAXED[a]

(Cents per dollar of severance tax revenue)

Effective WPT Rate[b] (%)	$\Delta Q/Q$[c] / Δt_s	Other State Income Tax Revenues			Federal Tax Revenues			
		Corporation	Personal	Total	Corporation Income	Windfall Profit	Personal Income	Total
0	0	1.4	2.8	4.2	45	0	25	70
	-.5	1.6	3.6	5.3	53	0	32	84
	-1.0	1.9	4.5	6.4	61	0	39	100
	-1.5	2.2	5.4	7.6	69	0	47	117
5	0	1.4	2.7	4.1	43	5	23	71
	-.5	1.7	3.5	5.2	50	8	31	88
	-1.0	2.0	4.4	6.3	58	10	38	107
	-1.5	2.3	5.3	7.5	67	13	46	126
15	0	1.4	2.4	3.8	38	15	21	74
	-.5	1.7	3.2	4.9	46	23	28	96
	-1.0	2.1	4.1	6.2	54	31	36	120
	-1.5	2.5	5.0	7.5	62	40	43	145
25	0	1.4	2.1	3.5	34	25	18	77
	-.5	1.8	2.9	4.7	41	38	25	105
	-1.0	2.3	3.8	6.0	49	52	33	134
	-1.5	2.7	4.5	7.2	55	66	40	161
35	0	1.4	1.8	3.2	29	35	16	80
	-.5	1.9	2.6	4.5	37	53	23	113
	-1.0	2.4	3.5	5.9	44	72	30	147
	-1.5	2.9	4.4	7.3	53	93	38	184

[a] Operator is an interstate firm; tax-relevant property value is fixed. For a full explanation of cases in the table, see Table 4.4 and accompanying text.

[b] Windfall profit tax; see Table 4.3 and accompanying text.

[c] Percentage reduction in output caused by each percentage point change in the severance tax.

Table 4.10

REDUCTIONS IN OUT-OF-STATE TAX REVENUES WHEN PROPERTIES ON CALIFORNIA STATE LAND OUTSIDE THE LONG BEACH TIDELANDS ARE TAXED[a]

(Cents per dollar of severance tax revenue)

Effective WPT Rate[b] (%)	$\Delta Q/Q$[c] / Δts	Other State Income Tax Revenues			Federal Tax Revenues			
		Corporation	Personal	Total	Corporation Income	Windfall Profit	Personal Income	Total
0	0	1.4	2.8	4.2	45	0	25	70
	-.5	1.4	2.9	4.3	46	0	25	71
	-1.0	1.5	2.9	4.4	48	0	25	73
	-1.5	1.5	3.0	4.5	49	0	26	75
5	0	1.4	2.7	4.1	43	3.5	24	71
	-.5	1.5	2.8	4.2	45	5.3	24	74
	-1.0	1.5	2.8	4.3	46	7.2	25	78
	-1.5	1.6	2.8	4.5	48	9.3	25	82
15	0	1.4	2.5	3.9	40	11	22	73
	-.5	1.5	2.6	4.1	42	15	22	80
	-1.0	1.6	2.6	4.2	43	22	23	87
	-1.5	1.8	2.6	4.4	44	28	23	95
25	0	1.4	2.3	3.7	37	18	20	75
	-.5	1.6	2.3	3.9	38	27	21	85
	-1.0	1.7	2.4	4.1	40	36	21	97
	-1.5	1.9	2.4	4.4	41	46	21	109
35	0	1.4	2.1	3.5	34	25	18	77
	-.5	1.6	2.1	3.8	35	37	19	91
	-1.0	1.8	2.2	4.0	36	51	19	106
	-1.5	2.1	2.2	4.3	38	65	19	122

[a] Operator is an interstate firm; tax-relevant property value is fixed. For a full explanation of cases in the table, see Table 4.4 and accompanying text.
[b] Windfall profit tax; see Table 4.3 and accompanying text.
[c] Percentage reduction in output caused by each percentage point change in the severance tax.

Effects on other types of properties are similar to those reported here with the exception of the Long Beach Tidelands. Losses of up to 10 cents in the federal windfall profit tax per dollar of severance tax occur at high effective levels of the windfall profit tax; otherwise, effects outside the state are trivial.

SUMMARY

Our analysis isolates a number of clear distinctions in net tax yields from different kinds of properties. The most dramatic, first, is the difference in yields between the Long Beach Tidelands and other properties in the state, resulting from the unique type of royalty used on these properties. A severance tax is unlikely to have any effect on production there; despite this, it will gather little net tax revenue from these properties. A severance tax on these properties could pose a threat to the approximately $370 million that the state of California and the city of Long Beach annually collect in royalties from these properties.

Second, by contrast, other properties on state lands tend to yield substantial net revenues when a severance tax is imposed. Again, state royalties are the key factor. So long as production is unaffected, royalties play no part. Nor do they have a role on private land. But they force net yields on state lands down as tax-induced production cuts rise; their effect rises as the size of the royalty rises. No other revenue source is as seriously affected by new severance taxes. Given the close similarity of severance taxes and royalties, this result should not come as a surprise. More important, however, is the very high level of royalties on state lands. Over the range of production cuts that appear reasonable, even properties with these high state royalties yield additional new net revenues.

Third, the net yield from private lands is also quite robust and high. It is little affected by the windfall profit tax, whether or not Proposition 13 fixes property values on a property, or by the level of tax-induced cutbacks. Only the percentage of income taxed within California is important; net yield falls as the percentage in-state rises. This is important on state lands also, but it is diminished there by effects on royalties. Even on private lands, however, properties owned by a

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ance tax in California would raise severance tax revenues of $1.08 million per day. If (a) federal taxes fall $.65 per dollar of severance tax (a low number) and (b) federal taxes capture 90 percent of new revenues (a high number), then the tax induced price rise could allow the federal government to recover about half the revenue loss discussed in the text. Using less extreme assumptions would reduce this fraction dramatically.

firm located entirely within California yield 80 cents or more per dollar of severance tax. Because private lands produce about 95 percent of the oil likely to be taxed in California, this general level of yield will characterize the state as a whole.[17] On balance, then, we expect that a new severance tax can raise substantial new revenues for the state.

Fourth, our results on property taxes are robust. A serious concern has been raised in the policy debate that a new severance tax could cut property tax revenues. Our analysis reveals that, while property tax revenues will fall, they will fall by very little. Where Proposition 13 excludes current market values from the calculation of the tax base, they are unaffected; elsewhere they fall, but they will not fall very far, only by 5-6 cents per dollar of severance tax revenue at most. This outcome holds whether production changes or not, on state and private lands, for in-state and interstate firms, and across all levels of the windfall profit tax. The counties will lose revenue, but the state will be able to compensate them from its new revenues. Formulating an equitable compensation mechanism, of course, still poses a difficult challenge.

Finally, the effects of a severance tax do not stop at the state boundaries. The large firms that produce most oil in California have stockholders in many states whose income from oil production in California is ultimately taxed outside California. More directly, profits earned in California are taxed in states with unitary arrangements for their state income taxes. The effects on tax revenues of this kind are small —a few cents per dollar of severance tax—when compared with the effects on federal revenues. These could well total 65 to 80 cents per dollar of severance tax, enough to provoke serious resistance in Washington if the effect were well understood there. Of course, a major appeal of a severance tax within California is the opportunity to export a substantial share of it outside the state. In the next section we turn to the question of how much of the tax will ultimately be paid within California.

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[17]This share assumes that the Long Beach Tidelands will not be taxed. Federal offshore and Elk Hills production are also excluded.

V. CALIFORNIANS' SHARE OF THE TAX BURDEN

One of the principal sources of interest in the severance tax is the fact that a substantial portion of the tax may be paid outside the state. In most discussions, the deductibility of a portion of certain types of severance taxes from the federal windfall profit tax is stressed to explain how tax burdens can be exported. Because a severance tax reduces the tax base used for the windfall profit tax, and hence the obligation of oil producers in California to pay a portion of that tax, the net tax burden on California goes up by less than a dollar for every dollar of net revenue received by the state. In effect, the federal government pays a portion of the tax. In fact, the windfall profit tax is only one of several factors that would determine how much of the tax burden of a severance tax falls within the state of California. This section explains a simple way to define the share of the tax borne by California consumers, refiners, and producers and then provides estimates of the tax burden over a broad range of circumstances.

BACKGROUND

Who Is a "Californian"?

As we shall see in Sec. VI, oil producers and refiners would carry most of the severance tax burden borne by the private sector within California. Some readers may find it difficult to think of these firms as "Californian," particularly when names like Shell, Mobil, Texaco, and Exxon figure prominently in the group (see Table 2.3). Not only are many producing and refining companies in California multinational enterprises, but their stockholders, in particular, live throughout the United States and beyond. It might be argued that if these were the only "Californians" paying the severance tax, almost all the tax could be said to have been successfully exported from the state. Ultimately, the full tax burden would fall on the stockholders of these firms, only some of whom actually live in California. While all of this is technically correct, it is officials of these companies with whom California policymakers must deal when making decisions about the adoption or design of a severance tax. Managers in California have a direct fiduciary responsibility to represent the interests of their non-California stockholders in the California policymaking forum, as well as a tangible personal interest to do so. In sum, although the headquarters of these firms may be located elsewhere, and most of their stockholders may live outside California, these firms have a very real, concrete presence in California. This presence and the corporate interest in California affairs that it represents form the basis for our decision to treat these firms as Californian. Readers uncomfortable with this designation should at least keep it in mind in the discussion of what we call Californians' interests, below.

Tax Burden Defined

We can most easily define the tax burden of producing and refining firms operating in California as being *the amount by which a new severance tax would reduce their profits.* Figure 5.1 illustrates the determinants of this amount. Here t_0 is the level of the effective rate for all taxes taken together before a severance tax is imposed. Under this tax, our assumption of competition allows us to postulate that a firm produces a quantity, Q_0, at which the sum of its marginal nontax costs and its taxes, t_0, equals the exogenously determined world price.[1] At this quantity, the firm pays t_0Q_0, equal to the sum of areas I and II, in taxes and receives the sum of areas III, IV, and V as profits.[2] When the severance tax is added, the effective rate for all taxes taken together rises to t_1. Note that the severance tax rate need not be—and probably is not—the quantity $t_1 - t_0$. Now the firm produces at Q_1. Its tax rises by area III and falls by area II; its profits fall by the sum of areas III and IV,[3] leaving profits equal to area V. We *define* the tax burden on Californians of such a tax change as the sum of areas III and IV, the amount by which it reduces after-tax profits.

By comparing a severance tax's effects on net state and local taxes collected (discussed in the last section) with its effects on profits, we obtain a convenient summary measure of the proportion of net tax reve-

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[1]As we explain in Sec. VI, a severance tax in California could potentially affect world oil prices. The effect would be so small, however, that we can effectively assume the world price to be exogenously fixed. None of our results relies heavily on this assumption. If the tax significantly affected world prices, we would simply have to include consumers among the Californians affected by the tax. Reductions in their consumer surplus would account for a portion of the share of the tax paid by Californians that we measure here. We discuss this possibility in Sec. VI.

[2]Setting fixed costs aside, III + IV + V represents the difference between the firm's net-of-tax revenues and its costs. Below, we see that fixed costs are not important to us in this situation.

[3]Note that any fixed costs are the same before and after the tax change. Hence, we can neglect them in calculating tax-induced *changes* in profits.

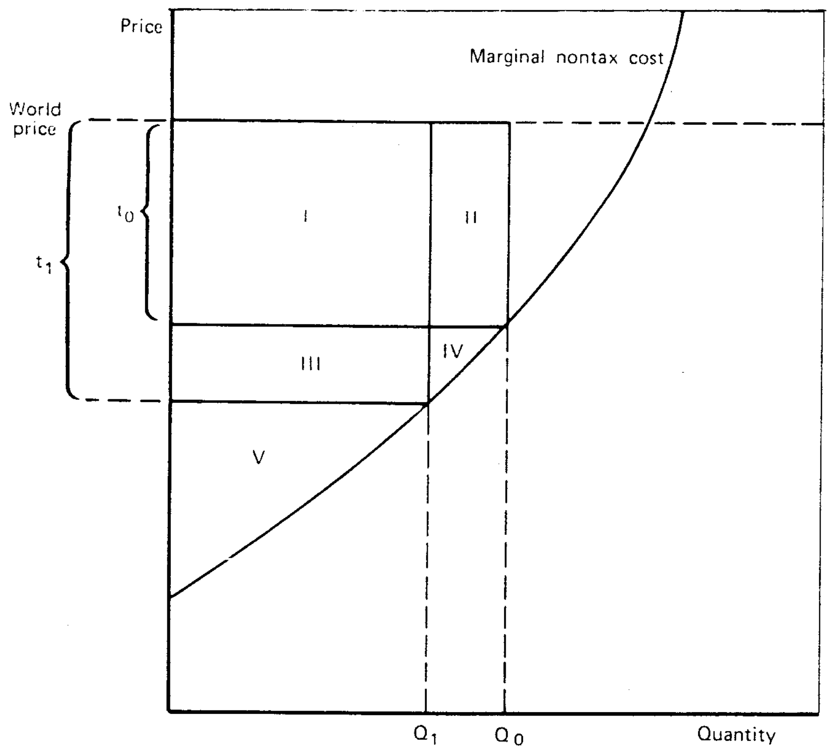

Fig. 5.1—Effect of a new revenue tax on profits and total tax revenues

nues collected within California that Californians actually pay in the form of reduced profits. That is, if California profits fall 50 cents when net California tax revenues rise by one dollar, we can say that half of the severance tax actually falls on Californians.

It is important to keep in mind that the "share" borne by Californians can rise above 100 percent. This is true for two reasons. First, a rise in severance taxes can potentially interact with other taxes in a way that increases Californians' tax payments to the federal government and other state governments. Second, new severance taxes can potentially lower the value of oil properties without generating any net revenue for the state. For example, suppose in Fig. 5.1 that areas II and III were just equal. Then the new severance tax would increase the effective tax *rate* but would have no effect on total taxes collected and transferred to the state (and other claimants). Despite the absence of any new revenues, however, profits would still fall by the sum of areas III and IV. In the extreme, the new tax would injure producers and refiners and gather no new taxes; more probably, the injury to the producers and refiners would be greater than the new tax revenues generated. In these circumstances, the ratio of lost profits to new net tax receipts would register a tax burden of more than 100 percent on Californians.

In economic terms, the tax would impose a deadweight loss equal to the sum of areas II and IV. This quantity represents a permanent reduction in the social value of oil produced in California, a reduction that must be borne by California producers or those taxing the oil. This is because, under our operating assumptions, the consumer price of oil does not change; hence, consumers feel no effect from the tax change. We discuss this in more detail in Sec. VI.

The definition of Californians' tax share offered here has important applications in tax design. Policymakers can collect any level of net revenue through a severance tax, with a lower level of tax burden within California if the marginal tax shares for all properties in the state are equal than if they are not. The justification for this result, which is somewhat complicated, is offered in App. B. For now, it will be useful to note in our numerical results (to be described shortly) that a uniform tax yields a wide variety of tax shares. Marginal tax shares are also likely to differ. This suggests that a differentiated tax that narrows the range of marginal tax shares could reduce net tax burden in the state.

TAX EFFECTS

With this background, we can now look at what share of a new severance tax Californians are likely to bear on various types of properties. We use the same set of parameter values and assumptions as those used in Sec. IV.[4] As above, we discuss properties in the Long Beach Tidelands first and then consider more typical properties elsewhere in the state.

Table 5.1 summarizes tax shares in the Long Beach Tidelands. As earlier, effects of the severance tax are independent of its rate; results in Table 5.1 apply for any rate so long as production is unaffected. Because we expect no significant production effects here, we do not examine them. Table 5.1 shows that the only factor important to com-

[4]The results reported here also derive from the same model. It is described in App. A.

Table 5.1

SHARE OF SEVERANCE TAX BORNE BY CALIFORNIANS IN THE LONG BEACH TIDELANDS[a]

Type of Firm	Status[b] of Windfall Profit Tax (WPT)	Tax-relevant Property Value[c]	
		Fixed	Sensitive
In-state	Current	13	13
	HR 6056	32	32
	No WPT	54	54
Interstate	Current	13	13
	HR 6056	32	32
	No WPT	54	54

[a]For a full explanation of cases in the table, see Table 4.4 and accompanying text.

[b]Current status is that on THUMS property; HR 6056 proposes private economic interest equal to private share in net income royalty agreement with state.

[c]If fixed, tax-relevant property value is invariant to tax changes; if sensitive, property value varies with other tax levels.

panies' share of the tax is the status of the windfall profit tax. The share falls as windfall profit taxes paid on these properties rise. This outcome arises from two effects. First, the windfall profit tax, like any tax, tempers the effects of other taxes deductible from it on profits net of all taxes. Moving from no windfall profit tax to current arrangements cuts the effect of severance taxes on net profits by about 15 percent. Second, and more important, the windfall profit tax increases the net revenue that the state can collect from a severance tax through the interactions of severance tax, royalty, and windfall profit tax. Because the state collects so little net revenue from the Long Beach Tidelands, any change can potentially yield a large *relative* increase in net revenue. Moving from no windfall profit tax to current arrangements increases net state revenues from a severance tax almost 3.5 times. With the effects of a severance tax on profits falling and those on net revenues growing, we ultimately arrive at the pattern in Fig. 5.1.

We do not observe such large effects outside the Long Beach Tidelands. Effects elsewhere are summarized in Tables 5.2 and 5.3 for a 6 percent severance tax rate. Note that production changes are expressed as percentage output cutbacks associated with a one-percentage-point increase in the severance tax rate. Recall that we expect a 6 percent tax to induce state wide cuts of, at most, 0-4 percent over time. Larger cuts are possible on individual properties. These changes may be slightly higher if we assume low real rates of oil price escalation than if we assume high rates.

As the effective rate of the windfall profit tax rises, the burden on California profits falls. It is important to note, however, that even if no windfall profit tax existed, Californians could pay only half of a 6 percent severance tax. The remainder would be "paid" by reductions in Californians' obligations to pay the federal and other state income taxes. Over the range of marginal tax rates now relevant to the windfall profit tax, its presence can reduce Californians' share of the severance tax by as much as 60 percentage points. Tables 5.2 and 5.3 reveal, however, that we should expect its effect to be substantially smaller. In fact, other factors are probably at least as important as the windfall profit tax in determining the share of a severance tax that Californians will pay on various kinds of oil properties.

The most important determinant of Californians' share of the severance tax is their ability to adjust output to avoid the tax. To understand this factor, examine Fig. 5.2. We start, as in Fig. 5.1, with a marginal tax rate of t_0 and production level of Q_0. Now consider how a firm responds to a tax change that moves the marginal tax rate to t_1. If its nontax costs lie along MC_A, it will move to $Q_1{}^A$ and lose profits equal to the sum of areas III, IV, V, VI, and VII. The tax will reduce the social value of oil by an amount equal to areas II, VI, and VII. If, on the other hand, its nontax costs lie along MC_B, the firm will be more flexible. It will move to $Q_1{}^B$, lower than $Q_1{}^A$, and hold its losses to an amount equal to the sum of areas III, IV, and VI. Unfortunately, the firm's gain (from its flexibility) is society's loss. The social value of oil produced from the property falls by an amount equal to the sum of areas I, II, IV, and VI, an amount significantly higher than that associated with MC_A (II, VI, and VII). The net result is that the firm best able to reduce production in the face of the tax to maximize profits can minimize its tax burden. But it also causes a maximal reduction in the social value of oil produced. Because the tax does not affect consumers (consumer prices are insensitive to the tax), state, local, and

Table 5.2

SHARE OF NET SEVERANCE TAX BORNE BY CALIFORNIANS ON PRIVATE LANDS[a]

(Percent)

Effective WPT[b] Rate (%)	$\frac{\Delta Q/Q}{\Delta t}$[c]	Tax-relevant Property Value is Fixed		Tax-relevant Property Value is Sensitive	
		In-state	Interstate	In-state	Interstate
	0	54	54	54	54
	- .5	74	70	77	73
0	-1.0	95	86	101	91
	-1.5	119	104	130	113
	0	51	51	51	51
	- .5	70	67	73	69
5	-1.0	91	83	96	88
	-1.5	114	101	123	109
	0	45	45	45	45
	- .5	63	61	64	62
15	-1.0	83	78	86	80
	-1.5	105	95	111	99
	0	40	40	39	39
	- .5	58	55	58	56
25	-1.0	77	72	78	74
	-1.5	99	87	102	95
	0	34	34	33	33
	- .5	51	50	50	50
35	-1.0	69	66	71	68
	-1.5	90	83	91	88

[a]The severance tax rate is 6 percent. For a full explanation of cases in the table, see Table 4.4 and accompanying text.

[b]Windfall profit tax; see Table 4.3 and accompanying text.

[c]Percentage reduction in output caused by each percentage point change in the severance tax.

Table 5.3

SHARE OF NET SEVERANCE TAX BORNE BY CALIFORNIANS ON STATE LANDS OUTSIDE THE LONG BEACH TIDELANDS[a]

(Percent)

Effective WPT[b] Rate (%)	$\frac{\Delta Q/Q}{\Delta t_S}$[c]	Tax-relevant Property Value is Fixed		Tax-relevant Property Value is Sensitive	
		In-state	Interstate	In-state	Interstate
	0	54	54	54	54
	- .5	68	65	70	67
0	-1.0	89	82	96	87
	-1.5	135	113	155	128
	0	52	52	52	52
	- .5	65	62	66	64
5	-1.0	85	79	90	83
	-1.5	128	109	143	122
	0	48	48	48	47
	- .5	59	58	59	58
15	-1.0	77	73	80	75
	-1.5	113	101	122	108
	0	44	44	43	43
	- .5	53	53	53	53
25	-1.0	68	67	70	69
	-1.5	100	92	102	100
	0	40	40	39	39
	- .5	47	48	48	47
35	-1.0	61	61	62	63
	-1.5	87	84	88	90

[a]The severance tax rate is 6 percent. For a full explanation of cases in the table, see Table 4.4 and accompanying text.

[b]Windfall profit tax; see Table 4.3 and accompanying text.

[c]Percentage reduction in output caused by each percentage point change in the severance tax.

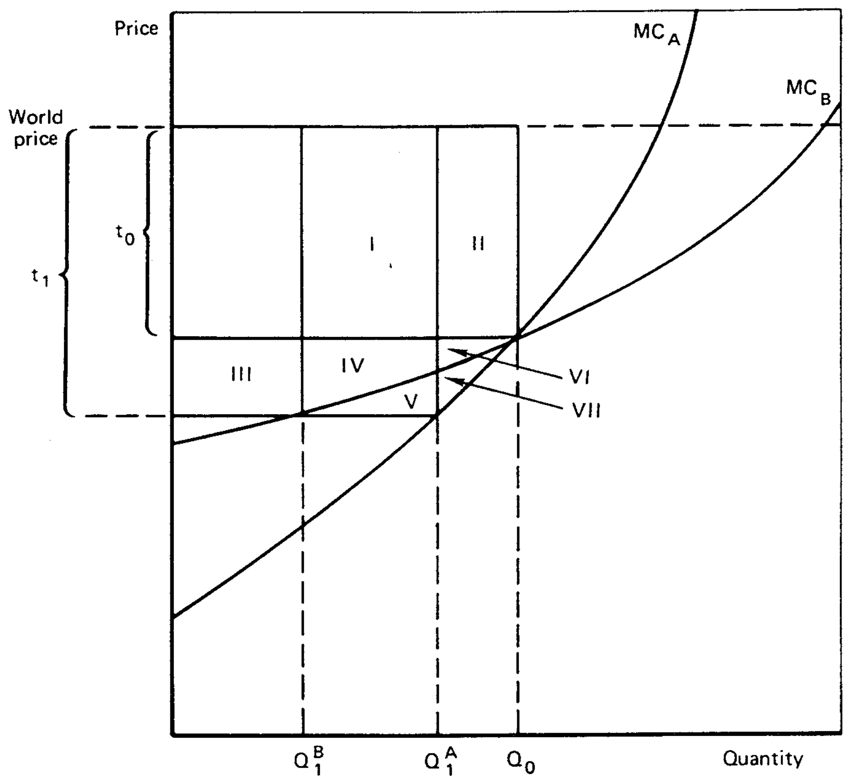

Fig. 5.2—Tax effects on profits under two different cost functions

federal agencies taxing oil must bear the brunt of this social loss. The more that oil producers can cut their production in response to new severance taxes, the more rapidly their revenues from oil taxes will fall. The net result is that the ratio of profit losses to net state and local tax receipts—our measure of Californians' share of the severance tax—will rise as firms are better able to respond to the severance tax. It happens because their efforts to cut their own losses cut tax receipts even faster than their losses fall.

Tables 5.2 and 5.3 confirm this result. Under all circumstances found outside the Long Beach Tidelands, the tax burden is highest on properties best able to adjust to a tax. The properties best able to adjust do not suffer the most; they simply yield the least net revenues for California state and local governments.

One other factor shown in Tables 5.2 and 5.3 affects tax burden significantly. It is the distinction between properties taxed under unitary arrangements and those subject only to California income taxes. The tax burden grows faster on properties subject only to California income as production adjustment grows. This effect stems directly from the fact that a severance tax has about ten times the effect on California income taxes under straight California taxation than it has under unitary arrangements; as a result, California revenues fall less rapidly under unitary arrangements as production falls.

One final factor affecting the tax share is the level of the severance tax itself. Recall that in our results on net yield a severance tax had the same marginal effect on each tax relevant to net yield, no matter how large the severance tax rate was. This allowed us to present a ratio of such tax effects that was independent of the severance tax rate. The marginal effect of severance taxes on losses in profits, however, is not constant; it rises as the severance tax rate rises.[5] Hence, the ratio of this to the marginal tax effect on net revenues—itself independent of the severance tax rate—rises as the severance tax rate rises.

Table 5.4 indicates how important this effect is. It shows the percentage drop in tax share, under a variety of circumstances, if we drop the severance tax rate from the 6 percent level assumed in Tables 5.2 and 5.3 to 3 percent. It should be clear that even the largest effects of cutting the severance tax rate in half are not large. They grow with the level of production response and are higher on state land than on private land. But the severance tax rate itself is not one of the most important determinants of Californians' tax share.

SUMMARY

A number of factors play important roles in determining what share of the severance tax collected from a given property in California Californians in fact pay. The profit-maximizing production response to the tax is the most important determinant. With no cutbacks, Californians' share outside the Long Beach Tidelands lies in the range of 30-55 percent. Under current arrangements in the Long Beach Tidelands, the net income contracts there drive it as low as 13 percent. The share outside the Long Beach Tidelands rises as production cuts rise. Higher expectations about the real rate of oil price escalation may suggest somewhat smaller production cuts over the longer run. Over the range of production cuts that appears reasonable for typical

[5]This characteristic is important in tax design. See App. B.

Table 5.4

DROP IN CALIFORNIANS' TAX SHARE WHEN SEVERANCE TAX RATE CHANGES FROM 6 TO 3 PERCENT[a]
(Percent)

Proposition 13[b]	Firm Type	$\frac{\Delta Q/Q}{\Delta t_S}$[c]	State Lands	Private Lands
	In-state	0	0	0
		-.5	1.3	1.1
Yes		-1.0	3.8	2.4
		-1.5	9.2	4.0
	Interstate	0	0	0
		-.5	1.3	.9
		-1.0	3.1	1.9
		-1.5	7.5	3.1
	In-state	0	0	0
		-.5	1.4	1.1
No		-1.0	4.2	2.6
		-1.5	10.5	4.2
	Interstate	0	0	0
		-.5	1.1	1.0
		-1.0	3.4	2.1
		-1.5	7.8	3.4

[a] Effective windfall profit tax rate is 15 percent; results similar for other effective rates. For a full explanation of cases in the table, see Table 4.4 and accompanying text.

[b] If yes, tax-relevant property value is determined only by non-market factors under Proposition 13; if no, property value varies with other tax levels.

[c] Percentage reduction in output caused by each percentage point change in the severance tax.

properties, at least over the longer run, that share can rise to 100 percent or higher. For the state as a whole, however, we expect it to be around 45 to 65 percent.

The windfall profit tax is also significant. It tempers the burden of the tax, although Californians' share can remain as low as 50 percent even in its absence. In the end, production cuts can affect Californians' share of the severance tax far more than can the windfall profit tax.

Other effects are smaller. Tax burden rises more slowly with production cuts in properties taxed under unitary arrangements. The status of a property under Proposition 13 has a small but relatively unimportant effect.

VI. INCIDENCE OF THE TAX THAT FALLS ON CALIFORNIANS

After we net out a severance tax's effect on other tax obligations, inside and outside the state, a portion remains to be paid by some private party within California. Although the tax is formally imposed on the producers of oil, they need not bear the full portion. For example, they could potentially pass the full tax on to refiners, who in turn could pass the full tax on to consumers. The question of which of these groups ends up paying the tax depends on what each group can do to avoid the tax if it is asked to pay it. This section explains this notion in more formal terms and then discusses how much of the tax would be borne by oil producers, refiners, and final consumers.

BACKGROUND

A tax simply drives a wedge between the price a seller receives and the price a buyer pays. How these prices compare with price levels in the absence of the tax depends on how sellers and buyers react to the prices they receive.[1] Suppose, first, that any attempt to raise the buyer's price by passing on the tax encourages the buyer to stop buying completely and to take his business elsewhere; the buyer is *very* price-responsive. Then the seller can pass on none of the tax and must bear the full burden of it. Alternatively, suppose that if the supplier must pay any new tax whatsoever, production is no longer profitable and the supplier withdraws from the market; the seller is very price-responsive. In this case, we cannot expect the seller to bear any of the tax and the buyer must bear its full brunt.[2] In less extreme

[1]Formally, let $D = D(P_D)$ be the demand for a good, expressed as a function of the demand price, and $S = S(P_S)$ be the supply of a good, a function of supply price. In equilibrium, $D = S$. With a tax, t, $P_D = P_S + t$. Putting all this together yields

$$D(P_S + t) = S(P_S).$$

Fully differentiating and rearranging,

$$dP_S = [D'/(S' - D')]dt$$

where D' and S' are the rates at which demand and supply change in response to a price change. By a fully analogous approach, we can derive

$$dP_D = [S'/(S' - D')]dt.$$

That is, responses of buyer and seller prices to the tax are proportioned to *relative* price responsiveness of the supply and demand functions, respectively.

[2]In the first case, $D' \lozenge -\infty$ and $D'/(S' - D') \lozenge -1$; $dP_S = -dt$. In the second case, $S' \lozenge \infty$, $S'/(S' - D') \lozenge 1$, and $dP_D = dt$.

cases, the portion of the tax borne by buyer or seller will rise as his relative willingness to cut use or production in response to the tax falls.

In the case of the severance tax, two basic transactions concern us: that between producers and refiners and that between refiners and final consumers. To examine these transactions, let us start where the tax is actually imposed, on the producer, and ask how easily the producer can pass the tax forward.

THE PRODUCER-REFINER TRANSACTION

Suppose that a producer attempts to pass a new severance tax on to refiners buying his oil. Refiners can reduce purchases of his oil either by finding alternative sources or by reducing their actual use of oil. Their reactions will depend on whether the oil involved is heavy or light.

Light Crude Oil

If the producer is selling relatively light oil, alternative sources are easy to find. Indonesian oil, which accounts for about 15 percent of the oil used in California refineries, has an API gravity of 37 degrees. Alaskan oil, accounting for 40 percent of California refinery input, has an API gravity of 28 degrees.[3] Imports of either type of oil could easily be expanded. In the past, California refiners have bought significant quantities of light oil from several Persian Gulf nations; they also offer potential substitutes for Californian light production. In sum, the range of alternatives to California light oil production is so broad that a refiner should have little difficulty finding alternatives. This suggests that California producers cannot drive the price of their product above prices charged elsewhere. If so, producers cannot pass on any tax on light oil unless the tax affects prices everywhere.[4]

In effect, the argument claims that prices for light oils are set in the world market and would be unperturbed by new California taxes unless these taxes were to change world prices. We tested this notion in two stages. First, we sought evidence that California is integrated

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[3]Volume weighted averages, based on 1978 refinery charges, for oil from Attaka, Minas, and Seria in Indonesia and Brunei, and Cook Inlet and North Slope in Alaska (Bonner and Moore, 1980, pp. 4-8).

[4]When we speak of light oil here, we are speaking from a California perspective. In most contexts, Alaskan crude is considered relatively heavy.

into the world crude market. Second, we considered under what circumstances a tax in California could affect world prices.

We started by comparing prices in California and Texas for similar oil over the past five years. Texas is an important link to the world market for California. California and Texas are the two principal destinations for Alaskan crude. Alaskan producers will presumably ship oil past California only if the price in Texas is high enough to justify the additional transportation costs. If the Texas price is very high relative to the California price, however, all Alaskan oil will go to Texas. Hence, we expect the prices in California and Texas for similar crude to differ by merely the cost of moving crude from California to Texas.[5]

Figure 6.1 compares prices in California and Texas during the period 1977 to 1982.[6] Three things about these prices are important to us. First, from the beginning of the period to the world price shock associated with the Iranian Revolution in 1979, both crude oil price levels and the difference between California and Texas prices were stable. The price difference, about $1.75 per barrel, closely reflected the difference between shipping costs from Alaska to Texas and from Alaska to California. This stability is important to us because the California market underwent some dramatic changes during this period. In particular, in 1977, California's external sources of crude began a sharp shift away from non-American sources to Alaskan sources. As Fig. 6.2 indicates, by 1979, Alaskan crude had displaced almost 70 percent of the oil California imported. Despite these changes, California's crude oil price remained strongly linked to the Texas price and hence to the world market price. Remarkable "local" events in California had no effect on crude oil prices, in California relative to those in Texas, suggesting that California is well enough integrated into the world market to minimize the influence of any local occurrence on prices.

The second point of interest in Fig. 6.1 is the end of stability between California and Texas prices that came with the world price

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[5]California is also linked to the mid-continental United States via the 16-inch Four Corners pipeline, but relatively little oil flows from California to the mid-continent or vice versa. The principal link is achieved through the tanker trade in Alaskan crude.

[6]The prices are adjusted posted prices for Mobil Oil's purchases of (a) Texas-West-Sweet-Intermediate oil in Texas and (b) Belgian Anticline oil in California. Belgian Anticline's posted price for 35 degrees API gravity is adjusted upward by the posted price adjustment factor to the 40 degree standard reflected in the Texas price. Mobil Oil's posted price for Belgian Anticline is a reliable proxy for the price of any "light oil" produced in California. For an explanation, see App. C. The tanker rate is based on the U.S. Gulf-to-New York Average Freight Rate Assessment (AFRA) rate reported in Platt's, various issues. It is adjusted by American Tanker Rate Scale (ATRS) rates for Alaska-to-California and Alaska-to-U.S. Gulf reported in Getty Oil Co., n.d.

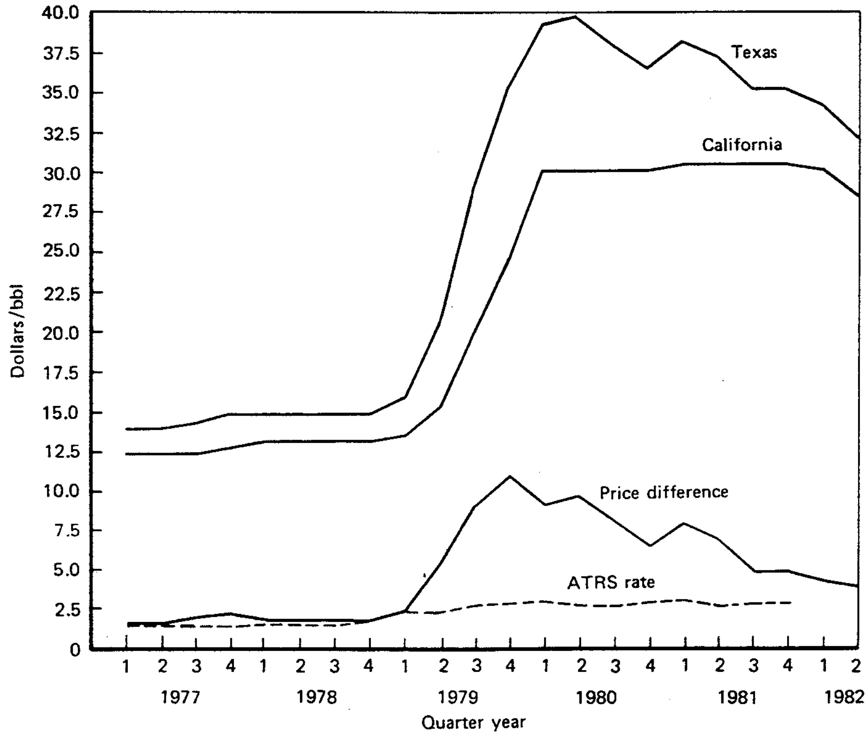

Fig. 6.1—Crude oil prices in California and Texas

escalation of 1979. In a year, the price of Texan crude climbed from $15.85 to $39 per barrel; California light crude prices also rose rapidly, but only from $13.53 to $29.90 per barrel. The difference between California and Texas rose from $1.75 to as much as $10.84. That is, the price differential rose almost three times as fast as prices. From 1979 to the present, the difference has gradually dropped back to $3.75, a level whose significance we will discuss in a moment.

We do not understand what allowed this dramatic and persistent divergence in prices. In particular, it is unclear why Alaskan producers would not bypass the California market for Texas unless the cost of transportation had risen pronouncedly during the period. As shown in Fig. 6.1, posted world-scale tanker rates rose, but not enough to account for the difference. Demand for tankers rose steeply in 1979,

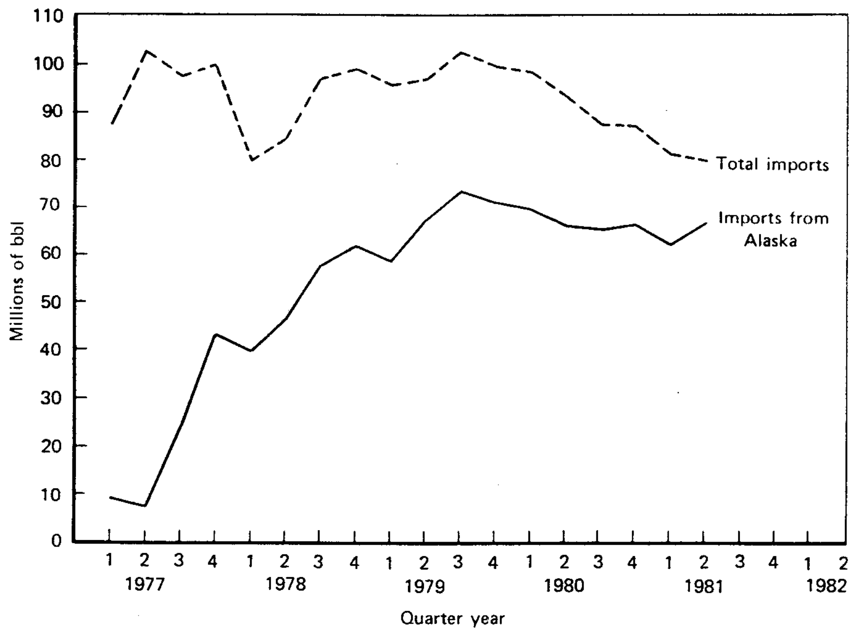

Fig. 6.2—Total and Alaskan imports of crude to California

with speculators using them as storage containers to inventory oil as prices rose. But spot prices for tanker services did not rise much above the posted world-scale rate, and this transitory spike in demand did not continue beyond 1979. It is possible that the California prices represent transfer prices within the integrated majors that quote prices, and that the shadow prices of oil within these firms were much higher. Why all the firms would quote similar transfer prices so different from their shadow prices is hard to understand without positing collusion. But the period in question offers the worst possible circumstances in which to maintain collusion; why would it suddenly appear in this unlikely period? Alaskan integrated producers may have wanted to supply their refineries in California regardless of price, but this still does not explain the uniformity of prices across refiners during the period. The stability of (nominal) California prices as Texas prices fell with world market prices over the period also adds to the mystery. We are left (for now) with the simple observation that California crude oil prices do not always track those elsewhere in the world. The California crude oil market can become isolated, at least for short periods and in exceptional times.

This brings us to the third point of interest in Fig. 6.1. The difference between California and Texas prices is just now returning to a level consistent with posted world-scale tanker rates. We would expect the difference in prices to stop declining and to stabilize around the new implicit cost of transporting oil from California to Texas. Though we cannot test this hypothesis now, accumulating experience should allow a test soon.

Over the longer term, then, prices for California light crudes will remain in line with those elsewhere in the world. In the short term, however, considerable latitude exists. Because 1979 was an unusual year for the oil market by any standard, we might expect unusual effects. Nonetheless, we do not yet understand either the magnitude of the price differential that developed between California and Texas as world prices rose or the time period over which this differential persisted. These matters suggest a degree of Californian independence from the world market that could allow producers to pass a portion of the tax on light oil on to refiners in the short run.

Over the longer term, when California and world prices move together, can policy changes in California change world prices? The answer depends on how a production cut in California affects prices. We need information on the "elasticity of excess demand" for California production. The elasticity of excess demand is the percentage change in demand for California production induced by a 1 percent change in world price. The higher this elasticity (in absolute value), the smaller the influence of production cuts on world price. The absolute value of the elasticity rises as the elasticities of world demand and supply outside California rise (in absolute value) and the share of California production in the world market falls. This elasticity is explicitly defined as

$$\eta_{ED} = (1/s_C)\eta_W - (1/s_C - 1)\epsilon_O$$

where η_{ED} is the elasticity of excess demand, s_C is California's share of the market, η_W is the elasticity of world demand, and ϵ_O is the elasticity of supply outside California.

Let us consider the smallest absolute value that this elasticity might reasonably take. This will tell us the largest price effect of a given production cut. Free world production and consumption is about 40 million barrels a day. Of this, California produces about 1 million, of which about three-quarters is likely to be taxable. Hence, California's effective share of the world market is .75/40 = .01875. The elasticity of world demand depends on the time horizon. In the short run of a year or so, it is customary to assume a level of −.1; this level is also generally consistent with available data. Over the longer term of, say, ten years, the elasticity is much higher. No good measures are available; we assume $-.75$. To obtain a conservative estimate of the excess demand elasticity, we assume no supply response outside California. Then our excess demand elasticity is $-.1/.01875 = -5.3$ in the short run and -40 in the long run. These are effectively lower-bound estimates of the elasticity.

We can combine these estimates with our estimates of supply response within California to determine the effect of the severance tax on world prices. As explained in Sec. VII, we would be surprised to see a response as large as 1 percent in the first few years following a 6 percent tax. Hence, the largest short-run price effect that we could expect is $1/5.3 = .1875$ percent. At an average price of $25 per barrel for California oil, this comes to 4.7 cents per barrel or, when ultimately translated into products, .11 mill per gallon. Over the longer term, Sec. VIII suggests that a 4 percent production cut is possible. In this case, the tax would raise world prices by 0.1 percent or 2.5 cents per barrel and .06 mill per gallon. These small effects are the largest ones we could expect. For example, a short-run supply elasticity of .1, still a *very* conservative estimate, halves the short-run effect reported here.

Viewed in terms of a 6 percent tax, these estimates tell us that, *at most,* refiners and consumers of light oil pay $.1875/6 = 3.1$ percent of the tax paid by Californians in the short run and 1.7 percent of the tax after a decade. Based on current consumption levels, and the shares paid by Californians as calculated in Sec. V, these numbers imply the following *maximum* potential effects on consumers and refiners of light oil. In the short run, we have

(1.8 million barrels per day, California consumption)
× (365 days per year)
× (.99, to reflect the drop in production)
× (.06 × $25, the dollar value of the tax per barrel)
× (.45, Californians' share of the tax)
× (.031, consumers' share of the tax)
= $13.6 million per year.

In the longer run of a decade or so, we have

(1.8 million barrels per day)
× (365 days per year)
× (.96, to reflect the drop in production)
× (.06 × $25 per barrel)
× (.65, Californian's share of the tax)
× (.017, consumers' share of the tax)
= $10.5 million per year.

While these sums are nontrivial, they are small relative to the total amount of revenue presumably collected in each case—$393 and $381 million, respectively. And they represent maximum possible effects. Actual effects will probably be much smaller. As a practical matter, we conclude that little of the tax on light oil is likely to be passed on to refiners and consumers.

Heavy Crude Oil

When a producer of heavy oil attempts to pass taxes on to refiners purchasing the oil, we face a very different situation. The refiner has nowhere else to turn for heavy oil. How he reacts to higher prices will depend on how he wants to use equipment that he typically devotes to processing heavy crudes. The equipment in question is primarily used in coking and hydrotreating process units.[7] A refiner can reduce purchases of taxed California heavy crudes only by allowing this equipment to stand idle or by using the equipment to process lighter non-California crudes. Let us consider each in turn.

Assume first that switching to lighter oil is impossible. Consider the market for coking capacity in California under these circumstances. California refiners' demand for coking capacity depends only on the value it adds to heavy oil. The value added allowed by an increment in capacity is shown as curve V in Fig. 6.3. It slopes downward because increased coking capacity allows more heavy oil to be processed and thereby increases demand for heavy oil, driving up its price. Because cokers convert heavy oil into a close substitute for lighter oils, whose prices are linked to the world market and hence are more or less independent of coking capacity in California, the rise in heavy oil price reduces marginal value added from coking capacity. C_O represents the current operating costs of coking capacity. The flat section represents the costs associated with new units; the rising section shows the costs of older units in the state. The circumstances in Fig. 6.3 call for capacity to be utilized up to the level Q_O. Value added from an increment to capacity is v_O.

A severance tax enters this diagram by reducing the value added from capacity, thereby moving V to the left. As long as refiners can cover operating costs and earn any quasi-rents from the use of existing capacity, they will continue to operate despite the tax. Hence, a

[7]Such units are typically used to process heavy crudes into unfinished oils that can then be processed into distillate fuel oils of various kinds. For a discussion of how refiners plan the use of these processes, see Griffin, 1968, or Bonner and Moore, 1980.

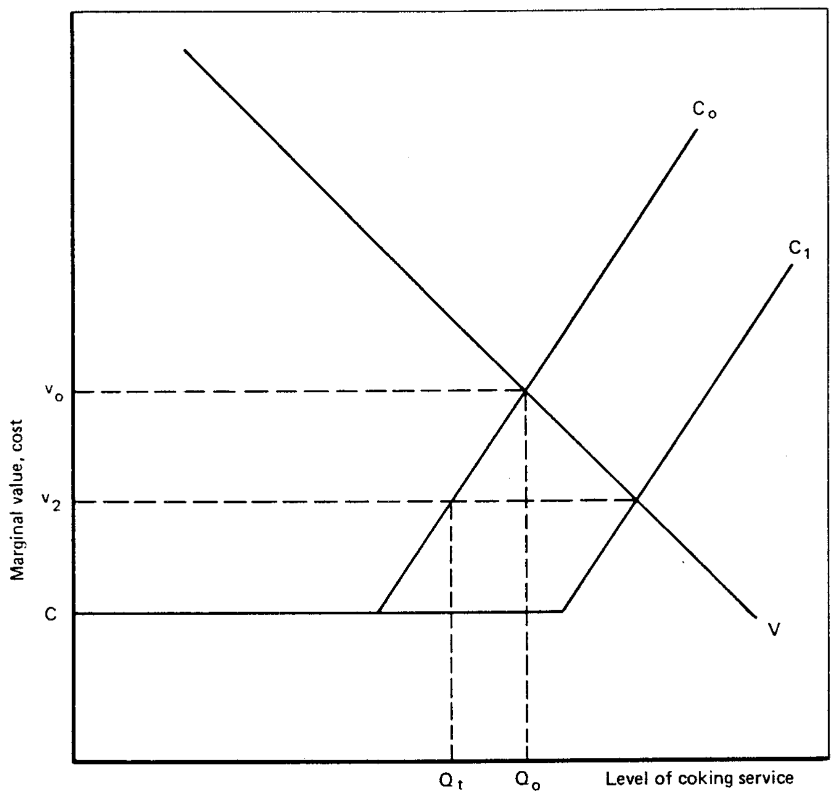

Fig. 6.3—California market for coking services

tax will force older units along the upward-sloping portion of C_O to shut down, but efficient units along the flat portion can continue to refine heavy oil profitably even under heavy taxes. Most observers agree that it is possible to extract taxes from existing facilities after they are built and paid for, so this comes as no surprise. What may be surprising is that an opportunity appears to exist to raise taxes from refiners and still allow them to recover their investment costs on existing facilities. Such a tax arrangement obviously has important implications for future investment when compared with the possibility of taxes that do not allow the recovery of investment costs.

To understand this opportunity, note that most California refiners believe that at the current level of capacity utilization the California market could support additional coking capacity; $v_0 - C$ is large enough to cover the investment costs of new capacity. Capacity will continue to expand in the future until this marginal *net* value added just covers investment costs. C_1 represents this situation. New capacity equal to the horizontal distance $C_1 - C_0$ is added. Old capacity equal to $Q_0 - Q_t$ is retired. The amount $v - C$ falls because the new coking capacity drives up the price of heavy crude. This is important to us because refiners continue to make a normal return on investment in cokers to process heavy crude despite this price rise; presumably they would also continue to earn normal profits from *existing* cokers to process heavy crude if new severance taxes raised oil prices. In fact, a severance tax that increased heavy oil prices by exactly the same amount would shift V to the left until it intersected C_0 at precisely v_2. It would have precisely the same effects on *existing* coking capacity that decisions to expand capacity would have had; of course, the refiners would no longer have an incentive to expand capacity. There is no reason to think that a severance tax would exactly offset the effects associated with planned expansions; different taxes obviously affect value added differently. The key point is that, as long as an incentive exists to expand coking capacity, a portion of a severance tax can be permanently passed on to refiners, without driving the rate of return of their existing investments below a competitive return.

This result assumes that refiners cannot switch cokers to lighter oils. Does it change if they can? When asked how they would react to a new tax on heavy oil, oil company officials typically suggest that switching to lighter oils is a viable option. In fact, lighter oils are occasionally scheduled into existing coking and hydrotreating units when relative oil costs or marketing commitments warrant it. This suggests that both heavy and lighter oils play a part in the level of V in Fig. 6.3. A severance tax would not shift V to the left as much if, in reaction to it, refiners switched some cokers to lighter oils. In the extreme, light oil would simply displace heavy oil, the refiner would no longer feel any tax, and V would be unaffected. For this to occur, V would have to lie at a level high enough to justify using expanded coking capacity even if no heavy oil were ever processed—that is, solely to process lighter oils. No such plans are being considered. This strongly suggests that a severance tax can shift V, perhaps substantially, and hence that some portion of the severance tax can be passed on to refiners. As long as refiners desire to expand coking capacity *in order to process heavy crude,* they anticipate that cokers will be better used to process heavy crude than light crude despite the higher heavy crude oil price that expanded capacity will bring. In fact, with regard to how they operate existing capacity, refiners should be indifferent as to whether higher heavy crude oil prices result from industry decisions to expand capacity or from political decisions to raise taxes. Their actions suggest that they will not switch to lighter oils until taxes rise enough to discourage all capacity expansion.

The dependence of the present argument on refiners' interest in expanding their capacity to process heavy crude oil raises two important issues. First, what has prevented refiners from achieving their desired level of capacity in the past? We have no definitive answer, but the most reasonable one states that the dramatic increases in world oil prices over the last decade, coupled with (a) California's disproportionately heavy production of crude oil and (b) the favored treatment granted heavy oil in the price decontrol decisions of 1979, have led to more heavy oil production in California than refiners anticipated.[8] While this point of view is consistent with views that we have heard from oil company officials, we have no conclusive evidence to support it. It suggests, however, that the California refinery industry is adjusting its capital stock now and should, given time, achieve its desired stock.

The second question concerns whether refiners' share of the severance tax will differ when they have achieved this desired level of processing capacity. If the incidence on refiners depends on their willingness to expand capacity, will their attainment of desired capacity allow them to shed the tax? No. The incidence of a portion of the tax on refiners ultimately depends on the fact that a portion of C_0 (or C_1) in Fig. 6.3 is upward sloping.[9] As long as refiners earn more revenue by processing heavy crude oil than is required to cover operating costs, the severance tax can extract a portion of the excess. If an excess sufficient to cover *new* capital costs does not continue, refiners will gradually disinvest, slowly escaping the tax as their willingness to process heavy crude falls. But as long as the tax allows sufficient net revenue to cover operating costs, refiners will continue to bear a portion of the tax indefinitely. That will be true as long as older, expensive coking and hydrotreating units continue to operate at the margin in California.

The fact that heavy oil refining is likely to bear more of the severance tax than light oil refining has an important implication. Final consumers and producers of heavy crude oil must bear relatively less of any uniform tax than final consumers and producers of light oil. As we shall see below, this is most important to producers, in part because final consumers do not distinguish most products of light and heavy oil. That is, a uniform severance tax will tend to fall least

[8]Cf. Bonner and Moore, 1980; State Lands Commission, 1981.

[9]S′ (the rate at which supply changes in response to a price change) is small.

heavily on producers of heavy oil, the producers with some of the highest costs in the state. Both efficiency and many equity goals suggest that this is a desirable outcome.

This effect also bears on the important policy issue of how integrated and nonintegrated producing companies will fare under a new severance tax. To the extent that refiners bear a portion of the tax, integrated producers will be more heavily affected than nonintegrated producers. Independent producers, who are typically nonintegrated, claim that they will be more severely hurt by a tax than (integrated) majors because the majors are better able to escape the tax by passing it on. Our analysis strongly suggests that this argument is inappropriate with regard to transactions between refiners and producers. If anything, independents fare better in this transaction.[10] As we shall see, it also makes little sense with regard to transactions between refiners and final consumers.

In sum, the California crude oil market is closely tied to the world market for light oils, at least in the longer term. This places prices for light crude oil produced in California beyond the influence of events within California unless those events affect worldwide prices. Because California taxes cannot affect these prices much, producers of light oil cannot pass more than a small fraction of a severance tax forward; for practical purposes, they must bear its full brunt. California producers of heavy oil face a different environment. Heavy oil can only be transformed into an effective substitute for the light oils tied to the world market with process units in short supply in California. This transitory shortage of capacity effectively depresses the price for heavy crude oil, opening a gap that severance taxes can fill at the refiners' expense, but without driving their rates of return on existing assets below a normal level. As long as refiners earn *any* more than is required to cover the operating costs of coking and hydrotreating units, they must bear at least a portion of the severance tax. How large a portion will depend on the nature of existing capacity in the state to process heavy oil.

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[10]A variation on this argument suggests that major producers in California successfully collude and price crude oil monopsonistically. Their market power would allow them to "force" independent producers to bear the full burden of the tax. It is easy to show that it would not be in the self interest of colluding refiners to do this, suggesting that, even if collusion occurs (contrary to our assumptions), we are unlikely to observe such behavior.

This is not to deny that majors may have some advantages that independents do not have. As noted above, the tax incidence on producers is greatest in the short run. If majors have better access to capital than independents, they may also be better able to weather the early effects of taxes while they seek strategies to avoid the tax. Such considerations are important only when a tax cuts cash flow enough to increase significantly an independent firm's reliance on external financing.

THE REFINER-FINAL CONSUMER TRANSACTION

The relationship between refiners and final consumers—households, commercial and industrial firms, utilities, transportation companies, and the like—is easier to understand than that between refiners and producers. As a general rule, California's final consumption markets are not so well integrated with markets elsewhere as its crude market is. Nonetheless, as Table 6.1 indicates, California exchanges significant quantities of all major products across its state lines. One out of eight gallons of gasoline leaves the state. One out of five gallons of distillate fuel oil enters interstate trade. One out of of four barrels of high-sulfur residual fuel oil is exported; one out of four barrels of low-sulfur residual fuel oil is imported. It is not so much the size as the clear economic viability of trades that concerns us here. The existence of these trades, and their persistence over time, tells us that California product prices must bear some relation to prices outside the state. This tempers the effect that California taxes can have on final product prices; any attempt by refiners to pass the tax forward will encourage final consumers—inside or outside California—to seek sources outside California. And such sources are not hard to find. To the extent that increasing demand for sources outside California drives up their prices, refiners can pass some portion of the tax on. But, with only one exception, California's share in world product markets is small enough that we should not expect effects on consumers any larger than those discussed with regard to light crude oil, above.

The real proof of California's integration into world markets must lie in the close correspondence of product prices within and outside California. For example, consider two of the most important products in California—motor gasoline and No. 2 fuel oil. Figures 6.4 and 6.5 display, respectively, wholesale gasoline prices and wholesale distillate fuel oil prices in Los Angeles and Houston.[11] The close correlation of prices in these cities even during the disruptive events of 1979, is clearly consistent with the hypothesis of strong interdependence with the rest of the country.

It might be argued that these correspondences are artifacts of the price controls on petroleum products that prevailed through most of this period. But the Department of Energy did not control prices for No. 2 fuel oil during this period. Further, these controls never bound the wholesale gasoline market as a whole.[12] Only the Council on

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[11]The prices shown here are refinery terminal prices, reported in Platt's, various issues.

[12]When refiners did not want to post wholesale prices as high as the price controls permitted them to, they could "bank" the difference between the prices they charged and those they were allowed to charge. As long as a firm had any "banked costs," it was

Table 6.1

CALIFORNIA PRODUCTION, IMPORT, AND EXPORT OF PRODUCTS, 1980
(Thousands of barrels)

Product	Production	Import	Import Ratio[a] (%)	Export	Export Ratio[b] (%)
Motor gasoline	294,390	3,568	1.4	36,017	12.2
Aviation gasoline	74,973	1,589	2.4	10,739	14.3
Fuel Oils:	238,970	25,177	11.3	40,945	17.1
Distillates	79,825	1,642	2.5	16,594	20.8
Resid, low sulfur	58,614	22,624	28.2	1,005	1.7
Resid, high sulfur	76,918	166	0	17,596	22.9
Bunker C	23,613	745	4.0	5,750	24.4
Other products	144,553	1,992	1.5	9,797	6.8
Total products	752,886	32,323	4.7	97,498	12.6

SOURCE: California Energy Commission

[a]Import ratio = import/consumption, consumption = production + import - Export.

[b]Export ratio = export/production.

Wage and Price Control Guidelines of 1979-80 could have had any effect. If anything, however, it increased the likelihood that prices for a given product would diverge in different cities (see Camm, Phelps, and Stan, 1981). Hence, these close correspondences are ultimately a reflection of free market decisions. Those decisions yield prices beyond the influence of any tax change within California unless a tax change affects world prices.

We expect a tax change in California to have significant effects on world prices only in the market for bunker fuel oil, a low-valued product of heavy oil refining that is used primarily to power ships. It is important in California because it is a product of the refining of heavy oil. In fact, California refiners would prefer not to produce this product because of its low value, but because heavy oil constitutes about

free to raise prices—it was uncontrolled. While individual firms periodically exhausted their banked costs and were forced to charge prices lower than they wished to, the industry as a whole always had some banked costs. (For details, see Phelps and Smith, 1977; Kalt, 1981.) That is, at the margin, the pricing of the U.S. refining industry was unconstrained during this period. Hence, price controls cannot explain the close correspondence observed in Fig. 6.4.

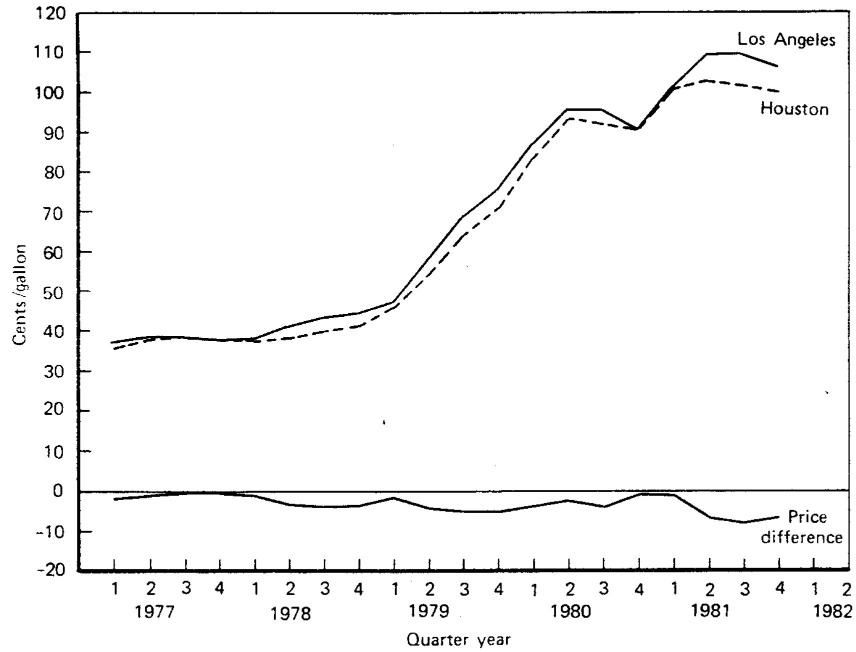

Fig. 6.4—Wholesale gasoline prices in Los Angeles and Houston

half of California oil production and because refiners lack the capacity to process all of this heavy oil into higher-value product, they produce a great deal of bunker fuel. The dominance of California in heavy oil production in its region of the world drives the California price for bunker fuel below prices elsewhere. To the extent that a severance tax reduces the production of heavy oil in California, it will also tend to reduce the supply of bunker fuel oil. This will increase the price of this product, effectively passing a portion of the tax onto the consumers of bunker fuel oil.

This fact should not concern California policymakers greatly. First, bunker fuel oil accounts for only about 3 percent of California refinery output. Second, a substantial portion of bunker fuel oil is directly exported from the state or sold to ships that make port in California harbors. For these reasons, consumers within California will feel relatively little of the increase in the price of bunker fuel oil.

In sum, with the exception of the few final consumers buying bunker fuel oil to power ships, final consumers in California will feel few of the effects of any new severance tax imposed on producers. A portion

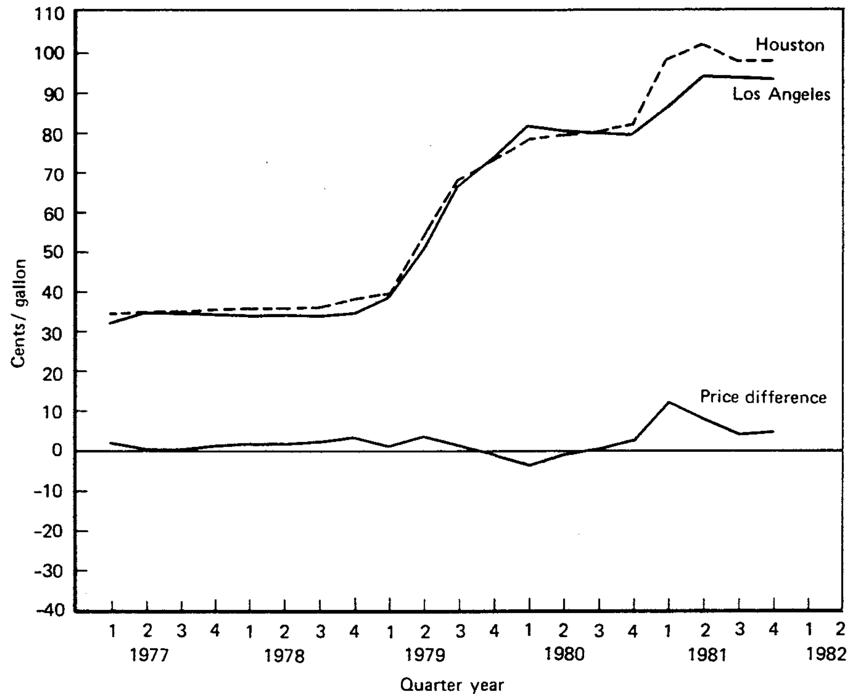

Fig. 6.5—Wholesale distillate fuel oil (No. 2) prices in Los Angeles and Houston

can pass through to refiners; they can pass little of this on to final consumers. For most final products Californians enjoy an active trade with other using and producing areas. Any attempt to change the prices of California-produced goods would simply lead to shifts in this pattern of trade that would allow final consumers inside and outside California to escape the tax. Consumers bear a portion of the tax only if it affects world prices.

SUMMARY

Which Californians bear the tax burden that falls within California? Among final consumers, only those buying bunker fuel oil will be affected significantly; few of them actually reside within California. A 6 percent tax should raise prices of other products no more than two-tenths of 1 percent and is likely to affect them much less than this. Refiners will bear a portion of the tax on heavy crude oil and may, for short periods of time, bear a portion of the tax imposed on lighter crude oils. The remainder will fall on producers. Integrated producers and producers of light oil will bear more of a uniform tax over the long run than nonintegrated producers and heavy oil producers. We cannot determine, with the information now available to us, what portion of the tax will fall on refiners and heavy oil producers over the longer term. Information on the distribution of costs of processing heavy oil, the substitutability of light and heavy oil in refining, and the long-term price responsiveness of producers would be required to produce a defensible estimate of this split.

VII. EFFECTS ON PRODUCTION FROM ACCELERATED SHUT-IN OF EXISTING WELLS

In Sec. V we examined what share of a severance tax oil companies in California would pay, given different assumptions about how much they cut back production in response to the tax. We now return to this issue from a slightly different angle: Given the share of the tax likely to be paid on different types of properties, how large should we expect the production response to be on these properties? This section examines the issue of short-term response. The next section examines longer-term response.

In the near term, the principal way in which oil producers can react to an increase in taxation is to increase the rate at which they shut-in old existing wells. Even after new production is planned, capital construction and other preparation delay its start for one to two years. New investment planning to make long-term adjustments to the tax change in itself adds additional delay. Hence, in the first few years after a tax is in place, any production cutback will likely take the form of early shut-in.

BACKGROUND

In the period 1977 to 1980, California oil firms on average shut in 2.6 percent of the producing wells in the state each year. (See Table 7.1.) Wells are shut in for a number of reasons, including temporary repair, cleaning out, building up pressure, planning for secondary or other injection projects, and failure of the present value of anticipated revenues to cover the present value of anticipated costs. A severance tax can affect shut-ins by cutting the present value of anticipated revenues. Hence, this last reason is of greatest interest to us.

We can identify when this happens by looking at a simple model of production from a well over time. Production from a well typically starts one or two years after construction starts. Production climbs rapidly to maximum capacity and then declines at an approximately constant percentage rate over the life of the well. Without additional investment or the use of secondary or tertiary recovery techniques, it is very costly to alter such a pattern. Ultimately, declining production cannot yield sufficient revenues to cover operating costs and the well

Table 7.1

SHUT-INS AS A PERCENT OF EXISTING PRODUCTION WELLS

Area	1977	1978	1979	1980
San Joaquin Valley	1.76	3.23	2.78	1.47
Coastal Region	3.76	4.69	2.37	3.16
Los Angeles Region	4.37	3.78	2.67	.91
Total	2.46	3.66	2.75	1.44

SOURCE: Compiled from CCCOP 1976, 1977, 1978, 1979, and 1980 Annual Reports

is shut in. With secondary and tertiary recovery, additional flexibility exists in this schedule over time. Steam flooding, for example, allows rather close control over production through time. In this case, production costs rise dynamically as the oil resource is exhausted and the well is shut in when revenues from produced oil cannot cover these rising operating costs.

As a rule, then, we expect net revenue from a well to be at a maximum early in its life and to fall over its lifetime until it drops to zero. If production proceeded beyond this point, losses would only grow over time. Oil firms stop production when net revenues fall to zero. Figure 7.1 illustrates this point. Panel (a) shows a typical time profile of oil production with a constant (exponential) rate of decline over time.[1] Panel (b) shows the net operating revenue associated with this production profile. Net revenues before a new severance tax are shown by N_0, which falls to zero at T_0. This is the point of shut-in before the tax. The tax reduces net revenues in every period, yielding a net revenue profile of N_1. This reaches zero at T_1, less than T_0. Shut-in at T_1, instead of T_0, leads to a loss of the oil that would have

[1]"Rate of decline" or "decline rate" is a key parameter in our analysis. It is the rate at which oil production from a given well or property falls over time. We approximate the average rate of decline for all wells in California in Table 7.2, below, by using the rate at which production from existing wells in any year falls from one year to the next.

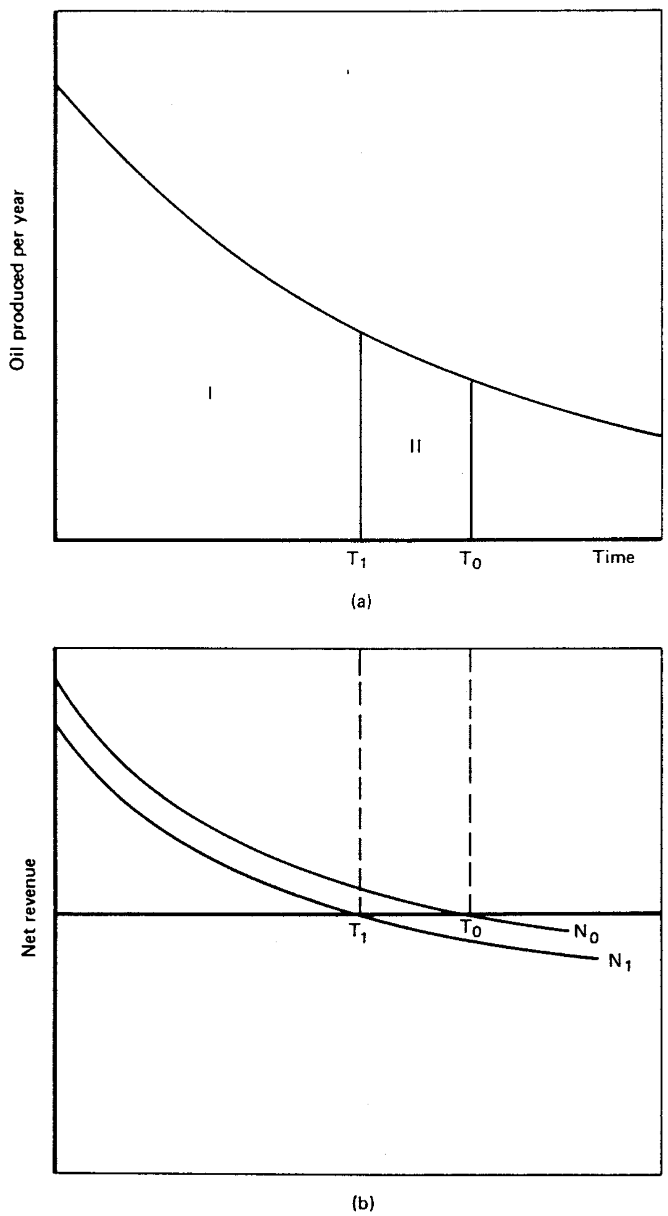

Fig. 7.1—Oil production and net revenue over time

been produced during this period, shown by area II. Because taken together the sum of areas I and II shows the total oil that would be produced from a well, the ratio of area II to the sum of areas I and II tells us the proportional loss in eventual production from this well caused by the tax.

Note that, because N_1 must lie below N_0, a new tax must accelerate the date of shut-in. It is sometimes argued that because the real price of oil is likely to rise over time, the net revenues from wells of this type will also rise over time. Hence, even if a severance tax drives net revenues to zero in this period, they may well become positive again in the future. If shut-in is costly, oil firms may accept short-term operating losses following the introduction of the tax to gain the positive net revenues available in the future.[2] That is, a severance tax need not accelerate shut-ins in this case.

This argument has a significant difficulty. To work, it requires that the net revenue profile be rising over time, at least during the period when the severance tax is introduced. Under such circumstances, oil firms would never shut in a well for economic reasons. Net revenues from a well must be falling over time to justify a shut-in for economic reasons. Even if prices are rising rapidly, costs rise even faster as a well approaches the end of its useful life. New severance taxes will inevitably accelerate the rate at which such wells are shut in.

That is not to say that rising real prices of oil will not affect the shut-in of wells. They will, but their effect will be indirect. As oil prices rise faster, net revenues from a well decline more slowly. Figure 7.2 illustrates this. N_t represent net revenue profiles for the real prices of oil prevailing in different periods, t. In fact, only one point on each of these profiles is important—the point that measures net revenues in the year in which the real oil prices underlying the profile prevail. For example, for year t_1, this is n_1 on N_1; for t_2 it is n_2, and so on. These points trace out a locus of net revenue, $\bar{N}$, which the owner of the oil will actually realize. This is the net revenue profile used above in Fig. 7.1. As prices rise faster, the space between the N_t grows and $\bar{N}$ becomes flatter. It could even potentially rise. The firm responds to this flattening net revenue profile by slowing planned production from any new well and saving production for future years when the oil produced will be worth more.[3] If $\bar{N}$ becomes too flat, a firm may delay the start of a well and simply store oil in the ground for future production.

[2]Note that "shut-in" and "abandonment" are different. Abandonment, a closely regulated process of permanently closing a well, is costly. Shut-in is a more routine activity and, as noted above, often occurs while a well changes status. Though there are costs associated with shut-ins, they are not nearly so severe as abandonment costs.

[3]See Appendix D.

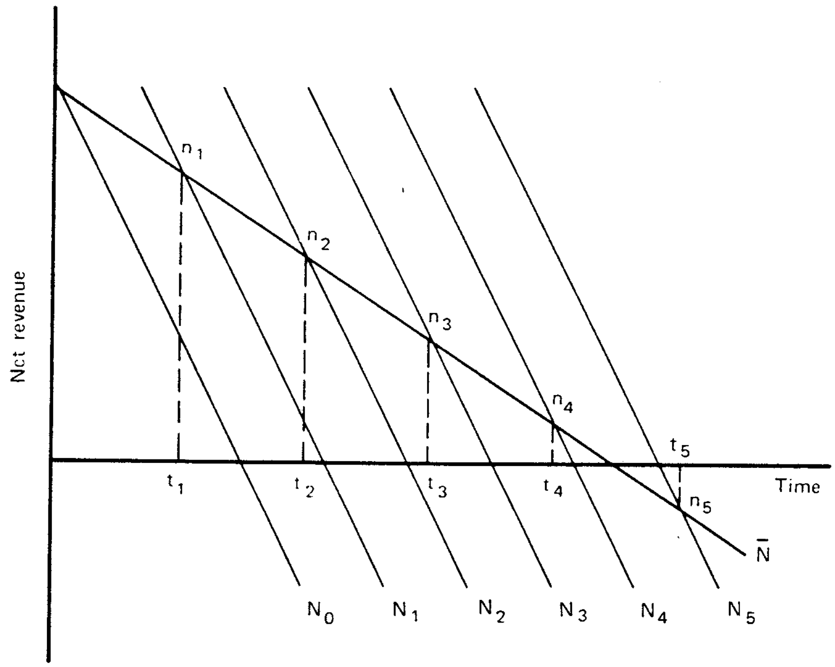

Fig. 7.2—Net revenue when the real oil price rises over time

From our point of view, the key points here are that (a) the effects of rising real oil prices are incorporated into our net revenue profile; (b) both the net revenue and production profiles from a well become flatter as real oil prices rise faster; and (c) the end of a well comes when net revenues are falling over time despite rising real oil prices. Hence, it is the wells approaching the end of their useful lives that interest us, and severance taxes will always accelerate their shut-in. The questions we must answer involve how much shut-in is accelerated, how many wells are involved, and how much oil is lost as a result.

To get some answers to these questions, return to Fig. 7.1 (a). Suppose that every well on a property had the production profile shown in Fig. 7.1 (a) over its lifetime and that equal numbers of wells were started in every year of the property's life. Then, with appropriate changes in the axes, the profile in Fig. 7.1 (a) could represent production from this *property* in any given year. Young wells would produce a great deal; their production would appear toward the left in the figure. Older wells would produce progressively less and appear progressively to the right. In fact a severance tax would induce the property's owner to shut in the oldest wells in the field, those with ages between T_1 and T_0. Production from the *property* would fall by an amount equal to area II; the proportion of production lost from the *property* in any *year* (as opposed to a *well* over the well's *life*) would be the ratio of area II to the sum of areas I and II. In short, Fig. 7.1 (a) potentially provides the basis for understanding how much shutting-in is accelerated in any year, how many wells on a property are involved, and how much oil is involved.

Suppose that we interpret Fig. 7.1 (a) in the following way. Rank all the wells in a field by their rates of production in a given year. Take the most productive well first, then the next, and so on, and chart production per well against the rank of a well, as in Fig. 7.3. Finally, assume that productivity falls with age and that the least productive wells will be those first shut in under a severance tax. The main difference between Fig. 7.1 (a) and Fig. 7.3 is that Fig. 7.3 effectively weights production per year from a well by the proportion of wells on the property started in the same year. Once this weighting is done, we can use net revenue functions like those in Fig. 7.1 (b) to determine how many wells on a property are shut in and use areas I and II to determine the effect on production.

RANGE OF PARAMETER VALUES CONSIDERED

The numerical results shown below were obtained in just such a way. We can derive simple functions like those in Fig. 7.1 for a property if we know how fast its wells are declining, the typical life of the wells, and the distribution of wells of different ages on the property.

The results of simple optimizing models and of our discussions with engineers knowledgeable about California oil production suggested that the combinations of decline rates and well lives shown in the shaded area of Fig. 7.4 were relevant in California. Which part of this shaded area is most relevant depends on one's assumptions. For example, the relevant life of a well rises as one's assumption about the real rate of increase in oil prices over time rises.[4] The combinations in Fig.

[4]Holding well life constant in *new* wells, decline rates fall as the rate of real oil price rises. We are concerned with existing wells here. As App. D explains, it is costly to change the decline rate in existing wells. Hence, the principal response to a recent change in expectations about oil prices—and this is what concerns us—is to change the lives of wells. Note that even for new wells, where lives and decline rates can change together, the set of likely combinations still moves to the "northeast" in Fig. 7.4 This

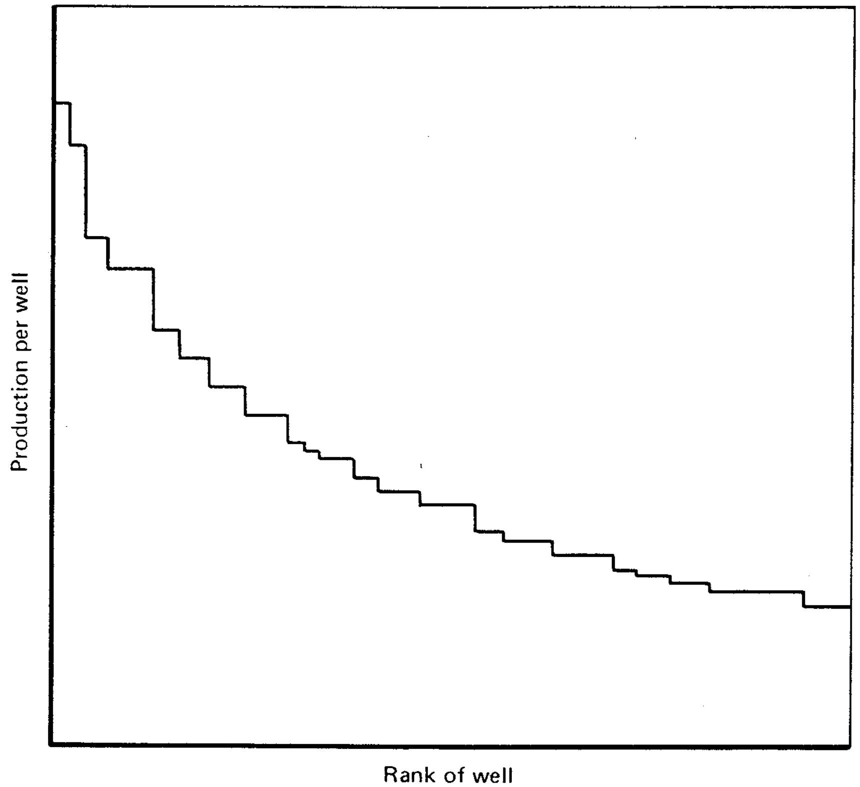

Fig. 7.3—Production per well in a field

7.4 cover real rates of change of 0 to 4 percent a year, the range represented in recent forecasts made by oil firms and other knowledgeable groups. Similarly, as oil price net of taxes rises relative to investment and operating costs, one moves to higher decline rates and shorter well lives. The average decline rate in California as a whole has been about 11 percent, but, as Table 7.2 shows, that has been falling in recent years. Higher real oil prices and expectations about a higher rate of increase of real oil prices over time probably account for this change (cf. CCCOP, 1980). In any case, note

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occurs because operators tend to react to a higher rate of price increase by extending the life of wells rather than by reducing decline rates.

Table 7.2

HISTORICAL AVERAGE DECLINE RATE FOR WELLS IN CALIFORNIA[a]

Year	Decline Rate in Existing Wells (percent)	Year	Decline Rate in Existing Wells (percent)
1960	11.94	1970	8.95
1961	10.92	1971	8.17
1962	13.71	1972	8.89
1963	13.69	1973	10.20
1964	9.94	1974	8.67
1965	6.47	1975	8.22
1966	13.11	1976	3.09
1967	12.22	1977	7.24
1968	12.98	1978	5.72
1969	7.58	1979	5.02

SOURCE: CCCOP, 1980, p. 2, others.

[a]Annual fall in production from existing wells.

that average decline rates for the last two decades fall well within the range shown in Fig. 7.4. This rate, of course, and the life of wells can vary substantially for different properties. The squares in Fig. 7.4 represent the specific combinations of decline rate and well age considered here to reflect these variations in the results presented below.

The simplest way to think about the distribution by age of wells on a property is to think about the rate at which capacity is expanded on the property. Where capacity expands rapidly, most of it will be of recent vintage; the property will be "young." Where capacity is falling, it will tend to be older on average. In sum, the rate of capacity expansion on a property provides a simple way to characterize the age distribution of wells in a field.

The rate of capacity addition is likely to vary significantly from one

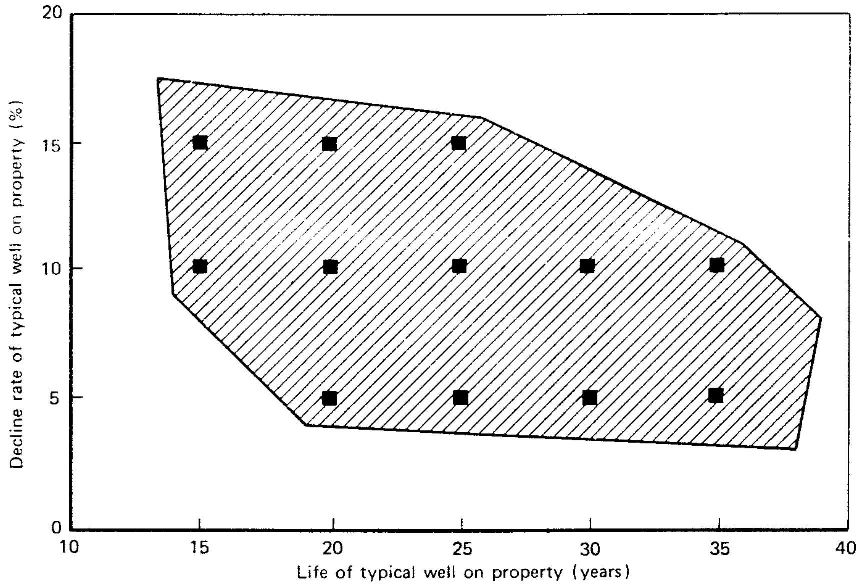

Fig. 7.4—Decline rates and well lives treated in the production-planning analysis

property to another. New capacity additions in California as a whole have fluctuated significantly, but over the post-World War II period annual capacity additions have fallen by about 2.9 percent a year.[5] This appears to be a reasonable middle-range value for capacity change. We choose a low value of -10 percent and a high value of 5 percent to allow for property-to-property variation. While rapidly expanding properties like Shell Oil Company's Belridge property are growing faster than this, they are truly exceptional.

Combining this range of values for the rate of capacity expansion with our earlier choice of assumptions about decline rate and well life defines the distribution of productivity among wells in a field. We can represent such a distribution as a functional relationship between cumulative numbers of "vintages"—starting dates—on a property and

[5]Calculated from "initial production from new wells" reported in CCCOP, 1980, p. 117. While new wells typically do not reach their full capacity in the first full year of operation, we have no reason to believe that the relationship between first year's production and capacity has changed systematically over this period. Hence, the rate of decline calculated should serve as an adequate proxy for the number we want.

the cumulative production associated with these vintages. Figure 7.5 displays well age distributions in this form. The horizontal axis shows cumulative percentages of vintages—the oldest 10 percent of starting dates, the oldest 20 percent, 30 percent, and so on. The vertical axis shows cumulative production from these vintages. For example, along the curve labeled "0," the oldest 10 percent of vintages produces 10 percent of the oil on the property. Along the curve labeled "2," the oldest 10 percent of vintages produces only about 3 percent of the oil on the property. Each curve describes the distribution of productivity on a property in which the quantity $(\delta + \theta)T$ is a constant, where δ is the decline rate (defined positive), θ is the rate of capacity expansion, and T is the typical well life.[6] Distributions consistent with the range of the values of these parameters fall into the shaded area of Fig. 7.5. Note that as any of these parameters rises, we move from "northwest" to "southeast" in the diagram, suggesting that the share of production becomes increasingly concentrated in newer, more productive wells. Note also that distributions like the specific curves shown should be easy to observe in individual properties and would assist in relating any set of values for the parameters above to such properties.

TAX EFFECTS

We are now in a position to estimate how much a severance tax would affect oil production by accelerating well shut-ins. To start, we report our results for a 6 percent tax *realized by producers.* Six percent is the tax rate most often discussed in California today; to start, we implicitly assume that producers bear the full tax.[7] Table 7.3 reports these results.

Two aspects of these results are important. First and foremost, the vast majority of numbers in Table 7.3 are small. Ninety percent are less than 5 percent; the median is only 1.21 percent. That is, over the range of what appear to be reasonable conditions for California, a severance tax has relatively little effect on production. Figure 7.6 emphasizes this by assigning values from Table 7.3 to intervals. The frequencies displayed in Fig. 7.6 cannot be extrapolated directly to the state as a whole.[8] But they do help us establish a subjective

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[6]For an explanation, see App. D.

[7]Recall in Secs. IV and VI that the federal government, state governments, and refiners bear a substantial portion of the tax. We assume here, for the sake of argument, that a 6 percent tax reduces the price that producers receive by a full 6 percent.

[8]We have made no attempt to define a joint probability distribution for our key parameter values in the state. Using Fig. 7.6 to characterize the state directly would implicitly assume that each parameter was uniformly distributed across the ranges

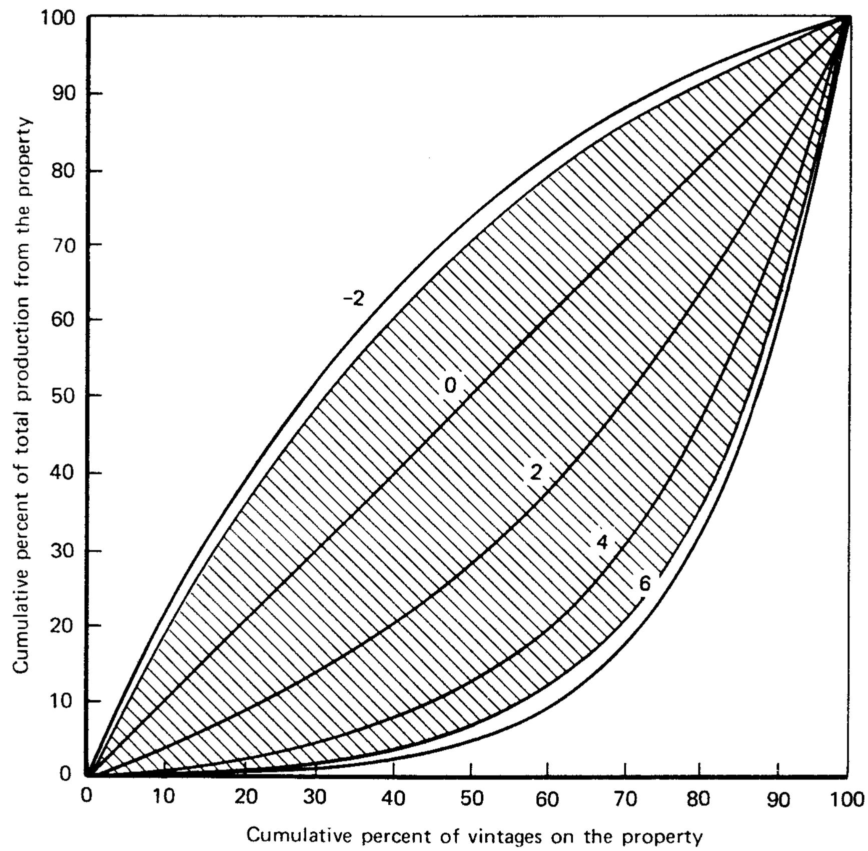

Fig. 7.5—Relationship between cumulative percent of vintages and cumulative percent of production for decline rates, well lives, and distributions of well vintages treated in the production-planning analysis

[a]Values shown in figure show the level of $(\delta + \theta)$ T along each curve, where δ = production decline rate, θ = implied capacity growth rate, T = well life in a field.

Table 7.3

CUT IN PRODUCTION CAUSED BY THE WELL SHUT-INS INDUCED BY AN EFFECTIVE 6 PERCENT SEVERANCE TAX
(Percent)

		Θ			
δ	T	-.10	-.05	0	+.05
.05	20	9.49	6.19	3.71	2.06
	25	8.41	4.95	2.56	1.18
	30	7.72	4.13	1.83	.69
	35	7.26	3.54	1.34	.41
.10	15	4.13	2.81	1.83	1.15
	20	3.09	1.83	1.00	.51
	25	2.48	1.26	.57	.23
	30	2.06	.90	.33	.11
	35	1.77	.66	.20	.05
.15	15	1.87	1.21	.75	.45
	20	1.21	.66	.33	.16
	25	.84	.38	.15	.06

δ = production decline rate
Θ = implied capacity growth rate
T = well life in a field. (See text for full explanation.)

understanding of the probable effect of a severance tax. Unless the parameter values we have chosen are totally out of line, the tax effect on production will be small. Expressed in terms of $(\Delta Q/Q)/\Delta t_S$, from Secs. IV and V, the median production response shown is $-1.21/6 = -.2$.

Second, the expected tax effects are monotonic in each parameter; the tax effect through shut-ins rises as well life falls, well decline rate falls, and capacity expansion rate falls. The well life effect occurs be-

represented and that no values outside these ranges occur. Neither assumption can be justified.

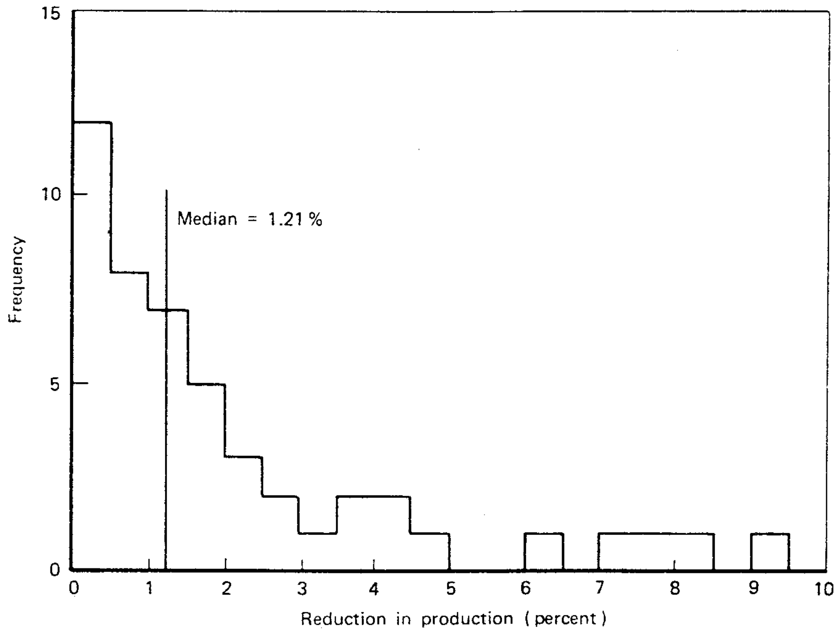

Fig. 7.6—Frequencies of levels of production cuts for cases treated in the production-planning model (effective 6 percent severance tax)

cause the number of well vintages eliminated by a severance tax is independent of the number represented on a property. Hence, as typical well life falls, a tax affects a growing fraction of vintages in the field. The decline rate effect occurs because the productivity of wells of different vintages approaches equality as the decline rate falls toward zero. As wells become more alike, a tax effect on the oldest, least productive wells becomes relatively more important in terms of the property as a whole. Finally, the capacity expansion effect occurs because higher expansion rates lead to younger fields in which a tax affects a smaller proportion of the wells on a property. The common sense reflected in these individual effects increases our confidence in the general results. An understanding of these effects also underscores the point that different types of properties will be affected differently and allows us to predict the *relative* effects of any tax on different properties if we have some simple information on their characteristics.

As emphasized in the sections above, of course, the effective tax rate experienced by oil firms will probably be much lower than the statutory rate. The federal government, and to a lesser extent state and local governments, in effect, would pay about half the tax. This is especially true in the short term when accelerated shut-ins represent the principal tax effect on production. To give an indication of how this effect changes when we lower the tax rate to reflect a rate that producers will actually experience, Table 7.4 repeats the information in Table 7.3 for a lower tax rate (3 percent). A few comparisons will confirm that the effects reported in Table 7.4 are almost exactly half those reported in Table 7.3. A 6 percent tax will have only half the production effect of the already low levels discussed in detail above. For example, at the median production response of −.59, $(\Delta Q/Q)/\Delta t_S = -.1$. A 6 percent severance tax will probably reduce production through the accelerated shut-in of existing wells by about half a percent a year. In general, over this range of tax rates, effects on accelerated shut-ins are very close to being linear. Hence, it is simple to extrapolate the effects of any effective tax rate of this magnitude from the results in Tables 7.3 or 7.4.[9]

SUMMARY

In sum, different properties can have very different experiences under a severance tax, but accelerated shut-ins should have relatively little effect on production in the state as a whole. Given the brief history of well shut-ins shown in Table 7.1, perhaps this should not surprise us. Fewer than 4 percent of wells are shut-in yearly; substantially less production is affected. Any significant statewide reaction to the severance tax would require significant movement outside this range. Our parametric analysis confirms that any such movement is in fact unlikely, at least in the face of the levels of severance taxes now being considered.

Individual properties, of course, could be hard hit. Properties with a disproportionate share of old wells, low decline rates, and relatively short-lived wells could be hard hit. With the information now available to us, we cannot name specific fields, but the approach used here could help policymakers judge the legitimacy of claims for exceptional treatment under the severance tax. On the whole, our results strongly suggest that a tax can have severe effects on well shut-ins in individual cases, but that those individual cases will be exceptional.

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[9]For example, if the relevant effective tax rate, expressed as a percentage, is X, its effect is X/6 times the effect shown in Table 7.3.

Table 7.4

CUT IN PRODUCTION CAUSED BY THE WELL SHUT-INS INDUCED BY AN EFFECTIVE 3 PERCENT SEVERANCE TAX
(Percent)

		θ			
δ	T	-.10	-.05	0	+.05
.05	20	4.75	3.05	1.80	.98
	25	4.20	2.44	1.24	.56
	30	3.86	2.03	.89	.33
	35	3.63	1.74	.65	.20
.10	15	2.03	1.37	.89	.55
	20	1.52	.89	.48	.24
	25	1.22	.62	.28	.11
	30	1.02	.44	.16	.05
	35	.87	.32	.10	.02
.15	15	.91	.59	.36	.22
	20	.59	.32	.16	.08
	25	.41	.18	.07	.03

δ = production decline rate
θ = implied capacity growth rate
T = well life in a field. (See text for full explanation.)

VIII. EFFECTS ON PRODUCTION FROM THE CANCELLATION AND DELAY OF NEW WELLS

Over the longer term, a new severance tax will tend to cut production not only by accelerating well shut-ins, but also by reducing the profitability of new investment. The tax reduces the profitability of every new well in the state, causing the cancellation of investments in some and delays of investments in others. This section addresses the problem of predicting the effects of a tax on long-term investment.

BACKGROUND

Three factors are important to an understanding of investment in new wells. The first is the notion of a relationship between supplier price and the cumulative amounts of oil that can be provided from *new* wells at various price levels over the long run. Second, given such a relationship, we want to know when, in time, production of this "new" oil actually occurs, if ever. Finally, the amount of oil produced from these new wells over a period of time must be understood in relation to the amount of oil that will be produced over the same period from wells that existed before the tax was imposed.

Figure 8.1 shows the *cumulative* production available from new wells at various levels of price received by suppliers. It is labeled C. For example, if the current real price[1] received by producers is p_0 and we expect this price to persist, we can expect Q_0 from new wells over the indefinite future. C slopes upward because different types of oil differ in production costs. As p_0 rises, development of oil deeper in the earth, farther offshore, with higher viscosity or sulfur content, in smaller pools, and so on becomes viable. p_0 effectively defines a limit in each of these dimensions and hence a limit on total cumulative production, Q_0. If a severance tax reduces the real price received by producers to p_1 (over the foreseeable future), the amount of oil we can now expect to be produced from new wells falls to Q_1. The tax effectively limits how deep we can drill, how far offshore we can go, and so on. To determine the effect that a tax will have over the very long run, we need to know the drop in real price, Δp, that the tax

[1]Throughout this discussion we use the term "real prices" to mean prices adjusted for the rate of inflation.

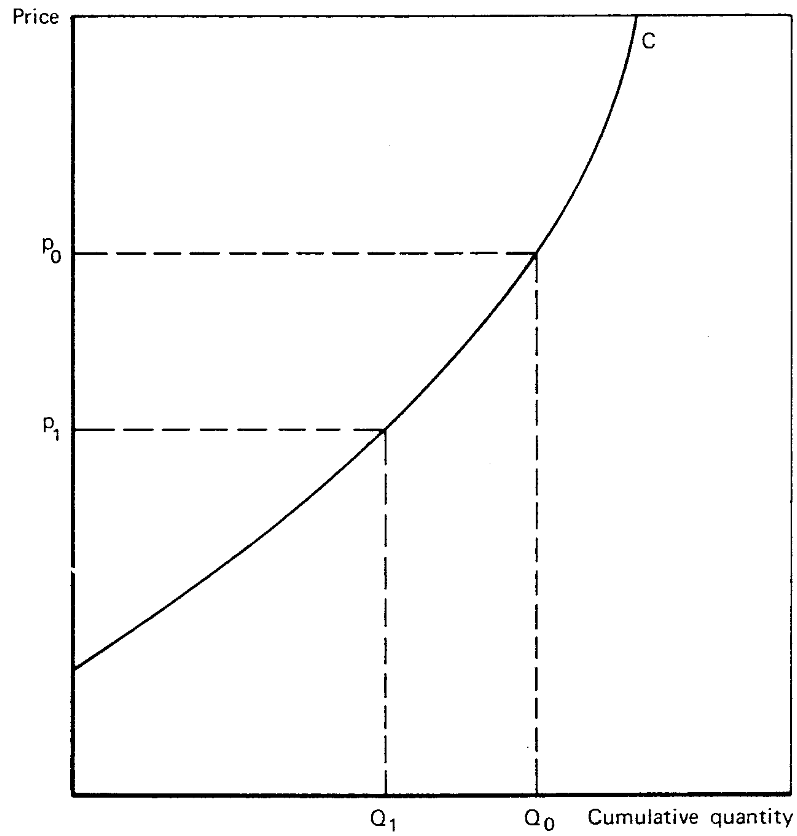

Fig. 8.1—Cumulative economically feasible production from new wells

effects and the change in cumulative production, ΔQ, that this price change induces. We can calculate ΔQ from Δp if we know $\epsilon_C \equiv (\Delta Q/Q)/(\Delta p/p)$, the very-long-run elasticity of supply for cumulative production from new wells.

ϵ_C is a summary statistic that allows us to reduce a great deal of information about production conditions to a single number. Estimates of ϵ_C based on good production information are rare; to our knowledge, none exist in California. To gain some idea of what they might look like, we can examine recent estimates for another mature production area, the Permian Basin of western Texas and eastern New Mexico.[2] Estimates of ϵ_C for the Permian Basin range from .04 to 2.4, falling as producer price rises. At current world prices, the elasticity is about 1. This suggests that a 6 percent reduction in supplier price would cut cumulative production from new wells by 6 percent. This elasticity need not—and probably does not—hold for California; a 6 percent severance tax need not cut a supplier's price by 6 percent.[3] We offer these data on the Permian Basin as illustrations only.

Knowing how much oil will ultimately be recovered from new wells does not tell us when that oil will be produced. This latter information depends on two factors.

The most obvious is the real rate of change in oil prices. Figure 8.2 illustrates the effect of this factor with data from the Permian Basin.[4] If real prices remain constant, the tax merely reduces once and for all the total amount of oil that can be economically recovered. In Fig. 8.2, a 6 percent tax makes cumulative production available from new wells fall by 7.3 percent, from $C_{b,0}$ to $C_{a,0}$, and remain there indefinitely. Future cumulative oil production is permanently reduced by this amount.

If, on the other hand, real prices rise, the economic feasibility of producing new oil is delayed, but not eliminated. The highest rate of sustainable growth in real oil prices taken seriously today is about 4 percent per year. $C_{b,4}$, and $C_{a,4}$ in Fig. 8.2 display the profile of cumulative feasible production before and after a 6 percent tax when real oil prices rise at 4 percent annually. Two aspects of these curves are important to us.

First, the horizontal distance between them is constant and equal to $-\Delta p/p_0\pi$, where Δp is the tax-induced change in supplier price, p_0 is the pre-tax supplier price, and π is the annual real rate of change in oil prices. In Fig. 8.2, this number is .06/.04 = 1.5 years. Investments appropriate in any year before the tax will again be *equally* appropriate, but only at a future date, $-\Delta p/p_0\pi$ years from today. This gives

[2]A mature production area is one in which most production, current and prospective, comes from fields already known. The Permian Basin is a classic example of such an area. Data on the Permian Basin are from Meyer et al., 1980.

[3]The correspondence between tax and change in supplier price, however, is probably reasonable. Above, we have seen that California producers will bear about half the severance tax burden. For heavy oil, the supplier price is about half the gross price to which the tax is applied (Lewin and Associates, 1981). These two factors just net out.

[4]It shows number of years after the tax on the abscissa and *cumulative* production that is economically feasible from wells started after the tax, *relative* to its level at the pre-tax price, on the ordinate. The cumulative production shown includes future production from undiscovered oil fields as well as indicated and inferred reserves in known fields. These reserves include reserves made available by enhanced oil recovery. We assume a pre-tax price of $25 per barrel.

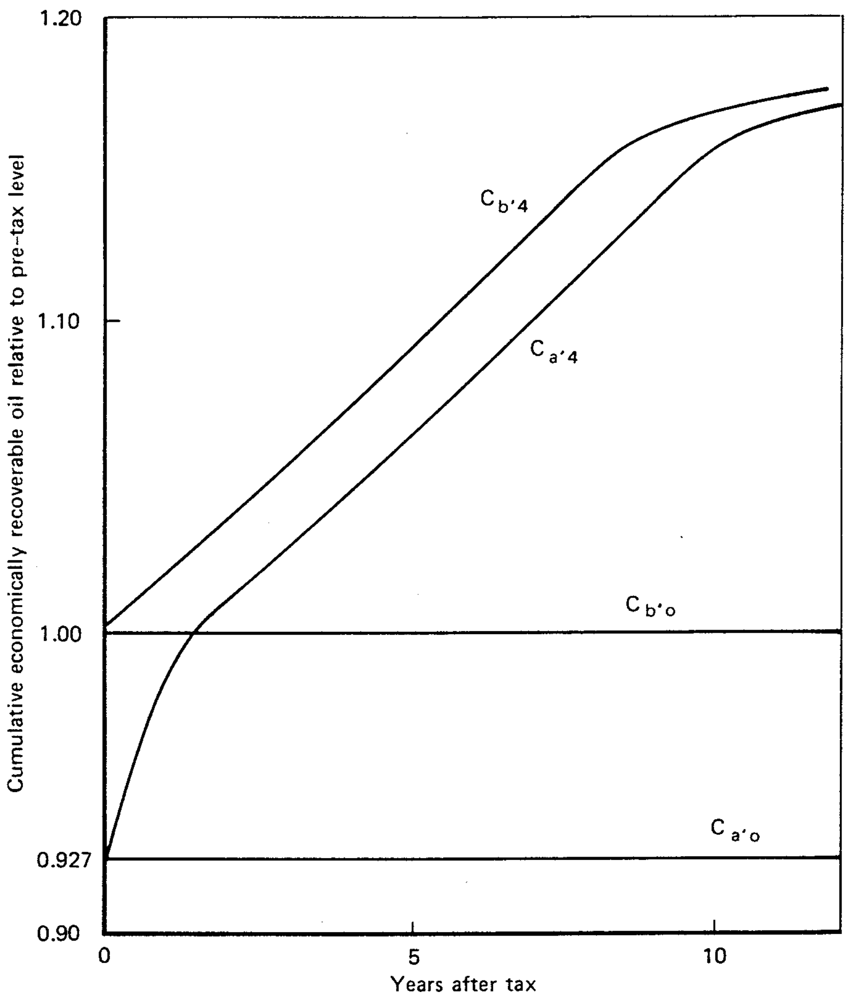

Fig. 8.2—Tax effects on cumulative economic production: an illustration using Permian Basin data

the strong impression that the tax simply delays the date at which development becomes attractive and hence the date of production. This is true. But is is equally true that for any horizon likely to look reasonable to a policymaker, the tax reduces the total amount of production that occurs before that horizon. This point brings us to the second aspect of interest.

The vertical difference between $C_{b,4}$ and $C_{a,4}$ shows how much the tax cuts the level of oil *available* for economic production in each year. This difference falls over time as price rises and additional price rises bring forth less and less new oil. This shortfall in each year presumably also cuts production in each year and such production cuts accumulate over time. The vertical difference between $C_{b,4}$ and $C_{a,4}$ is fully analogous to that between $C_{b,0}$ and $C_{a,0}$ as a measure of the tax's effect on oil available for production up to any point in time. Hence, viewing $C_{b,4}$ as the appropriate starting point from which to examine tax effects, a tax has the same *qualitative* effect on oil available for production under all assumptions about how fast real oil prices rise. The *magnitude* of the tax effect is smaller for higher rates of real price escalation in our example only because cumulative supply becomes less responsive to price at the price *levels* relevant under more rapid escalation *rates* from the same pre-tax price. This is a typical characteristic of cumulative supply curves.

In sum, a severance tax cuts the amount of economic oil available for new developments in any year. If real oil prices are not rising, future development of new wells slows and projects are cancelled. If real oil prices are rising, future development of new wells slows, but not by as much, and project delays are more likely than project cancellations. Nonetheless, over any reasonable planning horizon, a new tax cuts production from new wells no matter what the real escalation rate of oil prices.

The second factor derives from the fact that the pace at which oil wells are developed in a field affects their net profitability; rapid development hurts profits. Hence, a tax will tend to slow development of all new wells. Rapid development hurts profits for three reasons. First, like any economic activity, oil production experiences growth limits. As certain managers and engineers familiar with the firm's goals attempt to expand their spans of control or the numbers of levels under their control, organizational performance will suffer; it will improve only as members of the new organization gain mutual experience. Speed aggravates the process of profiting from the accumulation of mutual experience. The second reason is more specialized to oil production. While considerable latitude exists in choosing production patterns in a field over time, economic limits do exist. When speed pushes these limits, costs rise and profits fall.

The third reason is even more specific to oil production. The continuing performance of each well in a field increases field management understanding of the underlying geological structure of the field and hence of how best to expand the field. Speeding this process raises the cost of producing any amount of oil from the field. When a tax reduces profitability in a field, costs of all three types associated with the pre-tax pace of development become more difficult to justify and the rate of development slows. A tax affects the development of all new wells in this way, not just wells near the margin of production implied by Q_0 or Q_1 in Fig. 8.1. Hence, a new tax delays production from new wells, even if they remain individually profitable immediately after the tax's imposition. This is true whether real oil prices are rising or not.[5]

If a policymaker could know how a new tax affects the cumulative production from new wells that is economical and the rate at which such production is to be pursued, he must know one last factor to put the effects of the tax in perspective. He must know what role production from new wells plays in total oil production in the state. As noted above, statewide production from existing wells has been declining at a rate of about 7.4 percent per year over the last decade. State production has fallen about .2 percent a year. (This does not account for increased offshore, Elk Hills, and enhanced oil recovery, which have offset other production declines.) If these trends were to continue after a tax was imposed, the share of production from wells started during the year following the tax and after would grow as shown in Table 8.1.

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[5]It is tempting to believe that, while tax-induced cancellations clearly impose socially relevant costs, tax-induced delays simply put off production and can even be seen as saving oil production for future generations. Hence, tax-induced delays may actually have socially relevant benefits. Two points are important.

First, while we may be consuming too much oil today instead of saving it for future generations, if we are, we are probably consuming too much of *everything*. Singling out oil is hard to justify; we should be encouraging saving of all kinds. Even if we wanted to save oil, a tax on California production is an odd way to do it. Recall that such a tax affects production, not consumption; it simply induces us to exhaust oil sources outside California *relatively* faster than those within the state. Since California cannot isolate itself from the rest of the country, legally or economically, future generations of California consumers are not much affected by such a policy choice.

Second, if we set aside special concern for future generations, delay imposes real, socially relevant net costs. To understand them, recall that a severance tax has only minor effects on final consumers; it affects only producers, refiners, and the governments whose revenue is influenced by a severance tax. It is relatively easy to show that a tax-induced delay in production causes the market value of refining assets used to process heavy oil and of production properties themselves to fall by more than the amount by which net tax revenues rise. That is, refiners and producers lose more than governments gain as a result of the tax. The greater the delay, the larger this net loss will be. Hence, delay that affects not total production of oil but only its timing can have significant costs for those with rights to produce and process oil and, hence, uncompensated costs to society as a whole.

Table 8.1

SHARE OF PRODUCTION FROM WELLS STARTED AFTER A NEW TAX

Years After New Tax Starts	Share of Production from Post-Tax Wells (percent)
1	7.4
2	14.4
3	20.7
4	26.7
5	32.2
6	37.5
7	42.2
8	46.6
9	50.8
10	54.7

The share of new wells grows steadily, but even after nine years new wells account for barely one-half of statewide production. Any tax effect on new investment will have little effect in the short run. It will grow over time, but only slowly.

For example, suppose that the Permian Basin's cumulative supply elasticity applied, and that we could ignore the effects of production delays, in translating tax effects on cumulative production into effects on current production. If we expect real oil prices to remain constant, a 6 percent tax would cut oil production by .5 percent through its effect on new investment in the first year after the tax; it would cut production nine years from now by 3.7 percent. If real oil prices were rising at 4 percent a year, the 6 percent tax would cut production by .5 percent in the first year and by 1 percent in the ninth. These numbers are strictly illustrative, but the effect of a similar tax in California would probably be of the same order of magnitude.

In sum, to understand how a new severance tax might cut oil production through its effect on new oil production, we need to understand three factors: how the tax affects the total cumulative production available from new wells, how it affects the time at which this production occurs, and how the tax effects on production from new wells relate to the total level of production in the state. While these effects are extremely difficult to quantify with any precision, we expect the total effect on production from this source to be small in the short run and to grow slowly through time. We expect this primarily because new wells account for little production in the short term and for only a slowly growing share over time; hence, even a large tax effect on new production translates into a small effect on total production.

EMPIRICAL EVIDENCE ON NEW INVESTMENT IN CALIFORNIA

The price controls that prevailed on most types of crude oil in the 1970s make it extremely difficult to estimate formal investment models that we might use to predict the effects of a severance tax on new investments. This is especially true of California, where special entitlement programs, required to cope with the preponderance of heavy oil in the state, complicate the controls. Hence, we did not attempt any formal econometric analysis of the determinants of new investment, and we doubt that any is likely to be successful in the near future.

We took an alternative approach. We hypothesized that rising prices allow production to expand along a number of dimensions. As we noted in the discussion of Fig. 8.1, higher prices allow development of oil from deeper wells, lower gravity oil, oil further offshore, and so on. Even under price controls, real prices did rise, though slowly; all heavy oil was decontrolled in 1979. We used statistical models to seek the characteristics of oil production most sensitive to these price changes. Although such models cannot yield reliable price elasticities, they can provide information on the *relative* sensitivity of different factors to price increases. As explained above, such information should be useful in predicting the relative sensitivity of these same factors to a tax that lowered the price which producers receive.

Our schedule and budget allowed us to examine one annual cross-section of new production activity. Across a near-complete sample of operators' activities in individual pools in 1981, we sought correlations between a wide variety of pool characteristics and the rate of investment in new production wells in those pools. The pool characteristics included:

- Gravity, in degrees API
- Depth

- Pay thickness[6]
- Remaining oil in place
- Steam injection
- Associated gas production
- Location
- Type of producer in the pool
- Share of producer's production in California

We examined these characteristics in a wide variety of ways, looking for robust relationships. Appendix E provides details on this work; the remainder of this section uses simple summary statistics to report our principal results.

Surprisingly, few of these pool characteristics make any difference in producers' decisions to expand production. Many play a significant role in individual models, but only three factors have any consistent predictive value. We shall discuss them in a moment. First, let us review two examples that are representative of the majority of our results.

The first is a characteristic often used as a proxy for cost, and hence a variable that we would expect to affect production as prices rise: the depth of a pool.[7] Table 8.2 illustrates our results. It breaks the state into four production areas and seeks differences in depth between properties with and without new investment. Because costs rise with depth, we should expect that rising prices would open the best *new* investment opportunities in properties producing from deeper pools. If anything, however, the opposite occurs; depth is consistently shallower in properties with new investment. It is significantly shallower only in Los Angeles and Orange Counties.[8] Heavy oil is located in the shallower pools, and if anything these relationships appear to be an artifact of the growing production of heavy oil in the state. We discuss this below.

The second result illustrating a factor's lack of effect on new investment is reported here because of its intrinsic interest to policymakers. It is the size of the producing *firm*. Table 8.3 illustrates our results. We had no prior expectations about which producers would expand production faster. Table 8.3 shows that only in the state tidelands does any significant difference exist between the investment behavior of the top 22 producers and other producers in the state; smaller pro-

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[6]Pay thickness is the economically recoverable thickness of a reservoir from top to bottom.

[7]For example, Lewin and Associates, 1981, uses depth as the principal variable with which to predict a wide variety of production-related costs.

[8]The t-value of 2.36, using a Welch's t in a two-sided test, indicates that the probability of a significant difference is greater than 99 percent.

Table 8.2

AVERAGE DEPTH FOR PROPERTIES WITH AND WITHOUT NEW INVESTMENTS IN 1981[a]

Location	Difference of Mean t-value	Average Depth (feet) With Investment	Without Investment
State Tidelands[b]	.36	5061 (1328)[c] n=34	5335 (1456) n=4
Kern County[d]	.74	2971 (2816) n=318	5071 (3556) n=94
Los Angeles[e] and Orange Counties	2.36	3507 (1834) n=186	5330 (2739) n=13
Other	.98	4398 (2351) n=252	4879 (2704) n=33

SOURCE: Data base compiled at Rand from California Oil and Gas Division well-data files, CCCOP, 1980 and R. Nehring and E. R. VanDriest, The Discovery of Significant Oil and Gas Fields in the United States. Appendixes, R-2654/2-USGS/DOE, January 1981.

[a]Long Beach Tidelands, federal offshore leases, and Elk Hills were excluded because these areas are unlikely to be taxed. Also, investment decisions in these areas are likely to be made differently because royalties paid in Wilmington are unusually high, and production decisions for the Elk Hills are made by Congress.

[b]Excludes Long Beach Tidelands and federal offshore leases.

[c]Parentheses denote standard deviations.

[d]Excludes Elk Hills.

[e]Excludes Long Beach Tidelands.

Table 8.3

1981 NEW INVESTMENT RATES BY TYPE OF OPERATOR[a]

Location	Largest 22 Operators	Other Operators
State Tidelands[b]	.0173	.0000
Kern County[c]	.0476	.0428
Los Angeles[d] and Orange Counties	.0058	.0056
Other	.0241	.0170

[a]Investments in 1981 do not include confidential wells, which tend to be exploratory rather than being development wells. In comparing investment rates between Table 1 and Table 3, this fact should be considered. Although actual investment rates are underrepresented in this table, there is no reason to believe that inclusion of confidential wells would have changed the general trends.

[b]Excludes Long Beach Tidelands and federal offshore leases.

[c]Excludes Elk Hills.

[d]Excludes Long Beach Tidelands.

ducers are apparently excluded from the tidelands by the costs and risk of development there. Elsewhere, larger firms *appear* to expand production faster than smaller firms, but the difference is marginal; our formal tests find no significant and robust difference outside the tidelands.

Our analyses of pay thickness, remaining oil in place, steam injection, associated gas production, and share of production in California yielded similar results. Either their levels have no effect on new investment or apparent relationships can better be explained by collinearity with one of the factors that does affect investment. Let us now turn to these factors.

The most important is a bit surprising; it is effectively the level of past investment. The number of wells existing in a field is the single most important determinant of the number started in 1981. Further, as Table 8.4 indicates, the *rate* of expansion is very close to being constant across a wide variety of *property* sizes; properties simply expand over time at an exponential rate.

Table 8.4

PROPENSITY TO INVEST BY SIZE OF PROPERTY[a] IN 1981

	Total Number of Producing Wells January 1981 (A)	Total Number of New Production Wells in 1981 (B)	A/B
Properties with:			
0-50 production wells	10,434	203	.020
51-250 production wells	12,911	344	.027
251-1000 production wells	15,526	479	.031
1000+ production wells[b]	7,343	167	.028

SOURCE: Data base compiled at Rand from California Oil and Gas Division well-data files, CCCOP, 1980 and R. Nehring and E. R. VanDriest, The Discovery of Significant Oil and Gas Fields in the United States, Appendixes, R-2654/2-USGS/DOE, January 1981.

[a]Wells owned by a single operator in a specified pool are assumed to be in the same property for the purposes of this study.

[b]The figures in this row exclude operations of Kernridge, formely a subsidiary of Shell Oil Company, which was operating in the Belridge field. The operation in this field was expanding at a very high rate of 437/3377 = .1259 in 1981.

Second, the gravity of oil on a property is important. All other things being equal, we should expect rising prices to favor the development of heavier oil. Hence, properties with new investment should on average produce heavier oil than those without. Table 8.5 confirms our expectation. The t-values for difference-of-means tests tell us that, onshore, properties with new investments produce heavier oil than those without throughout the state. The variation in gravity offshore is smaller than that onshore, and costs associated with the gravity of oil are a far smaller consideration than they are onshore; hence, the absence of any importance here is not troubling.

Table 8.5

AVERAGE API FOR PROPERTIES WITH AND WITHOUT NEW INVESTMENT IN 1981[a]

Location	Difference of Mean t-value	Average API Gravity: With Investment	Average API Gravity: Without Investment
State Tidelands[b]	.27	21.9 (4.3)[c] n=35	21.0 (6.4) n=4
Kern County[d]	7.50	17.7 (6.7) n=318	25.2 (9.1) n=96
Los Angeles[e] and Orange Counties	2.97	18.7 (5.4) n=187	24.1 (6.4) n=13
Other	2.56	18.5 (8.0) n=235	22.8 (9.2) n=33

SOURCE: Data base compiled at Rand from California Oil and Gas Division well-data files, CCCOP, 1980 and R. Nehring and E. R. VanDriest, The Discovery of Significant Oil and Gas Fields in the United States, Appendixes, R-2654/2-USGS/DOE, January 1981.

[a]State tidelands, federal offshore leases, and Elk Hills were excluded because these areas are unlikely to be taxed. Also, investment decisions in these areas are likely to be made differently because royalties paid in Wilmington are unusually high, and production decisions for the Elk Hills are made by Congress.

[b]Excludes Long Beach Tidelands and federal offshore leases.

[c]Parentheses denote standard deviations.

[d]Excludes Elk Hills.

[e]Excludes Long Beach Tidelands.

Why gravity is so important when other effects are not is a bit of a puzzle. Even when effects show up for other variables, they appear to be spurious reflections of this one effect.[9] The decontrol of heavy oil in mid- to late 1979 may have led to an unusually high level of investment in new heavy oil production by 1981. But recall from Sec. II that the trend toward heavy oil production in California has been steady and long lived. On the basis of the evidence at hand, we cannot claim that the strong interest in heavy oil in 1981 is based *solely* on price and hence that significant new taxes could significantly dampen that interest.

The final determinant of new investment is location within the state. Given the severe environmental problems in Kern County and the Southern California air basin, we expected problems in expanding production in those areas. As Table 8.6 indicates, production is in fact growing slowly in the Los Angeles area, but the San Joaquin Valley—dominated by production in Kern County—consistently leads the state in its rate of expansion. Table 8.6 verifies that these trends continue in 1981. Discussions with oil firms confirm that, while some firms suffer from a shortage of permits to allow expanded production in Kern, others do not and expansion should continue despite environmental concerns.

These consistent patterns over time have led to systematic differences in the amount of oil produced from new wells in different parts of the state. Table 8.7 shows the importance of production from wells developed during the four years preceding 1981 to total production in 1981. While the total state proportion is roughly consistent with our illustrative figures in Table 8.1, the proportions in different parts of the state differ markedly. If the experience of the past four years continues, tax effects on new investment can potentially have a greater effect on total production in Kern County than elsewhere.[10]

In sum, our empirical analysis of investment behavior in 1981 suggests what factors currently affect the number of new production wells that we should expect to see on a property. The most basic is the number of wells already on the property; properties of different mixes tend to expand at the same exponential rate. Second, properties with heavy oil expand faster than those with light. How much of this is due

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[9]The best example is depth. It shows a slight negative correlation with new investment, but this results from its negative correlation with heavy oil production. Similarly, occasional negative correlations between associated gas production and new investment probably flow from the negative correlation between gas and heavy oil production. Steam injection also shows similar traits. While we expect all of these to have effects *independent* of gravity, our models are not subtle enough to capture these.

[10]Of course, the high rate of expansion in Kern suggests a level of profitability that a new tax might not seriously impair.

Table 8.6

RATIO OF NEW PRODUCTION WELLS TO EXISTING PRODUCTION WELLS

	Year			
Location	1977	1978	1979	1980
San Joaquin Valley	.053	.047	.040	.053
Coastal Region	.050	.026	.037	.045
Los Angeles	.012	.008	.009	.014
State total	.045	.036	.034	.044

SOURCE: Compiled from CCCOP Annual Reports, 1976, 1977, 1978, 1979, and 1980.

to the decontrol of heavy oil prices in 1979 is unclear. Finally, expansion is most sluggish in southern California. Nothing else matters, at least at the level of analysis we were able to apply. While property-by-property analyses will obviously identify a wide variety of other factors in each case, analyses of other generic property characteristics are not likely to give policymakers additional assistance in predicting where new investment is likely and how new taxes might affect such investments.

SUMMARY

Predicting the effects of any policy on long-term investment is always a tricky business. Uncertainty about future oil prices and the absence of readily usable data on the development costs of oil yet to be exploited in California make predictions of the effects of a severance tax especially tricky. We offer the following basic observations.

First, no matter how a new tax affects production from new invest-

Table 8.7

CONTRIBUTION OF 1977-80 WELLS TO TOTAL 1981 PRODUCTION[a]

Area	Production (%)
State Tidelands[b]	9.69
Kern County[c]	27.06
Los Angeles[d] and Orange Counties	4.40
State Total	22.07

SOURCE: Data base compiled at Rand from California Oil and Gas Division well-data files, CCCOP, 1980 and R. Nehring and E. R. VanDriest, The Discovery of Significant Oil and Gas Fields in the United States, Appendixes, R-2654/2-USGS/DOE, January 1981.

[a]Production from 1980 confidential wells is not included.

[b]Long Beach Tidelands and outer continental shelf are excluded.

[c]Elk Hills is excluded.

[d]Long Beach Tidelands excluded.

ment, its effect on total production must start small and grow only slowly. That is because relatively little oil comes from new wells. Statewide, only one in five barrels currently comes from wells developed in the past four years. This share differs across the state. It is slightly higher—one in four—in Kern County and much lower elsewhere. Hence, the effect of any uncertainty about tax effects on new investment is bounded by the thing of most importance to us: tax effects on total production.

Second, when real oil prices are rising, tax effects on new investments are more likely to be construction delays than cancellations. But regardless of how fast real oil prices rise, a new tax will tend to cut the total amount of production from new wells over any reasonable planning horizon. The size of the cut will grow only *slightly* as the rate of growth in real oil prices falls. As a result, longer-term tax-induced production cuts used in Secs. IV and V need not be very sensitive to assumptions about the rate of real price increase.

Finally, a tax increase will limit the range of economically viable options available on any date for oil production. It will limit how deep wells can go, how far offshore they can be drilled, how heavy oil can be, and so on. But it is extremely difficult to determine the relative importance of these factors. If their relative effects could be successfully parsed, they could improve tax design by allowing policymakers to tax at higher rates properties whose characteristics suggest that they are less likely to cut production in response to a tax (see App. B). We have been unable to parse these effects with simple models. Time will be needed before adequate models are available to exploit such effects in tax design.

IX. EFFECTS OF EXEMPTIONS ON OIL PRODUCTION AND TAX REVENUES

From a *tax* point of view, production of oil in California is highly concentrated; 30 producers account for 95 percent of the production. This naturally raises the question of whether the advantage of taxing smaller producers—primarily additional revenue—offsets (a) the administrative cost of collecting taxes from these producers and (b) the costs to policymakers associated with the high level of opposition to the tax that this large number of smaller operators can generate.[1]

This section examines the effects of two particular exemption arrangements. It begins with a total "tax eligible" quantity of oil produced in the state equal to 264 million barrels per year, about three-quarters of the state's production. It then looks at how various exemption arrangements affect the level and composition of this quantity. The two exemption levels examined are those proposed in legislation recently before the California State Assembly. One, from a bill by Assemblyman Tom Bates, would exempt the first 36,500 barrels produced by each operator annually.[2] The other, from a bill by Assemblyman Michael Roos, would exempt the first 100,000 barrels a year.[3]

These exemption levels are offered to illustrate the effect on tax revenues and production of a range of possible exemptions, and do not imply any judgment that either, or any, level is better than another. Comparing the effects of these exemptions with the alternative of no exemption at all, we offer insights into how well any system of production allowances would meet its intended goals.

We have chosen to focus on the types and quantities of oil affected by these exemption allowances, rather than on the tax revenues that may result. These revenues are readily estimated by simply multiplying the production volume by an appropriate average selling price ($25-27 per barrel) and applying a severance tax rate to the quantity. This revenue estimate should then be reduced by the expected losses on other state and local tax bases, as discussed in Sec. IV, to arrive at

[1]Since a nominal severance tax is currently levied on all production in the state, administrative procedures for collecting severance tax revenues are already in place. However, a new tax set at a much higher level than the existing one will substantially increase the incentives to avoid paying it. Higher tax administration and collection costs may therefore result. One way to minimize these costs is to reduce the number of individuals and companies liable for the tax.

[2]Assembly Bill 2947.

[3]Assembly Bill 3756.

a net revenue total. We have also excluded all production from the Naval Petroleum Reserve at Elk Hills because we believe that most or all of it would not be taxed by the state. And because the net yield of new revenues would be so low, we have also excluded Long Beach Tidelands production.

BASIC RESULTS

Exemption Effects on Production Volume and Number of Operators

Figure 9.1 illustrates the small effect that either exemption has on the total volume of oil subject to tax (and therefore the total revenues realized). At the same time, it shows the dramatic effect that both exemptions have on the number of operators subject to the tax. Exempting the first 36,500 barrels of annual production excludes less than eight million barrels, leaving nearly 255 million barrels subject to the tax. Exempting the first 100,000 barrels per year leaves almost 250 million barrels subject to taxation, or about 95 percent of the total eligible. Both exemptions exclude the overwhelming majority of operators from the tax.[4] Out of 651 operators,[5] 531, or 82 percent, have no taxable production under the first allowance, and 581, or 89 percent, have none under the second. To the extent that the tax is intended to reach most oil production in the state, while excluding most operators from tax liability, it appears that either system, *or any allowance in this range*, would work quite well.

Exemption Effects on the Number of Producing Properties and Wells

The amount of revenue generated by a severance tax levied as a percentage of production value is determined only by the price of the

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[4]Exemption allowances such as these obviously create substantial incentives for larger companies to divide their operations into smaller units, or subsidiaries. A large producer could avoid between $50,000 and $150,000 in new severance tax liability for each artificial subdivision created for this purpose. Special provisions in the tax act may be necessary to prevent this from happening.

[5]Unit operations are included and in many cases a large share of that type of production—where several operators maximize efficient production according to standard conservation guidelines by pooling their operations—would not be exempted, since it belongs to a major operator whose own production from nonunit operations is counted elsewhere. We have counted unit operations as distinct operators, nonetheless, because of the difficulty in assigning production shares to separate companies. This probably results in a very small underestimation of the taxable production totals.

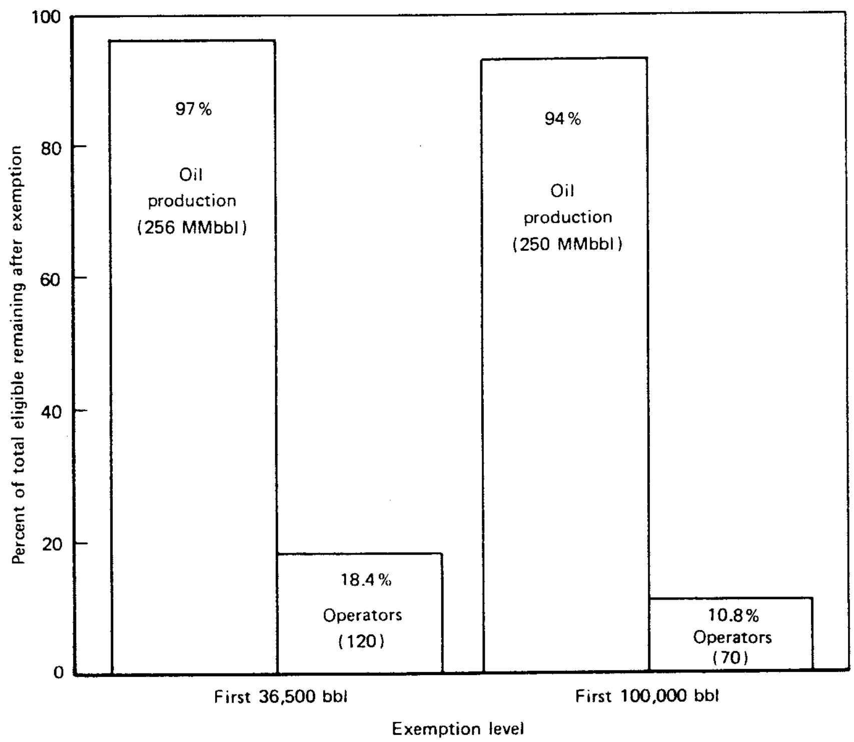

Fig. 9.1—Effect of exemption level on taxable oil and operators

oil and the amount produced. The administrative and political costs of a tax may bear little relationship to these factors, however. To a large extent, of course, tax administration costs are a function of the number of operators subject to the tax, rather than of production volume. Depending on the way the tax is designed, these costs may also be closely tied to the number of producing wells or properties; if the tax is targeted to the level of production per well, or to certain types of producing properties, then the number of wells and properties becomes an important administrative concern. Therefore, another important way to study the effects of different exemption levels is to examine how each arrangement affects the total number of producing properties and wells that would be subject to taxation.

In Fig. 9.2, the proportion of taxable producing properties and oil-producing wells out of the total eligible is shown for each exemption level. If an operator would have no tax liability under a given allowance system, all of his properties and wells are excluded. If an operator's production exceeds the allowance, then all of his properties and wells are counted. This criterion produces the somewhat striking results shown in Fig. 9.2. Very few producing wells are excluded by either exemption; over 90 percent of all wells produce oil still subject to taxation. On the other hand, the number of producing properties exempted paints a very different picture. Nearly half of the state's oil properties would be exempted under either exemption arrangement. Either exemption level would focus the tax on the larger producing properties and would exempt a significant share of the others.

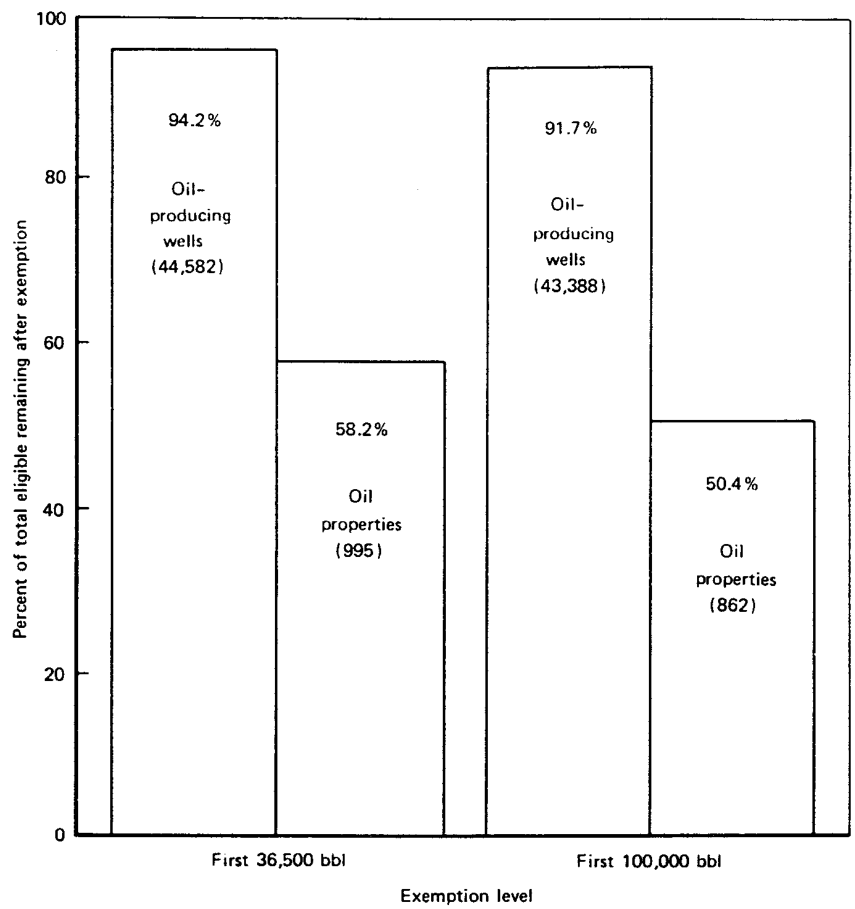

Fig. 9.2—Effect of exemption level on number of production properties and wells

Exemption Effects on Gravity of Production

From Fig. 9.3, it appears that the exemption level bears very little relation to the gravity of the oil produced. Only for very light oil (greater than 34 degrees API) does either curve jag significantly. This very light oil contributes only 2.7 million barrels, or 1 percent, to the state total, in any event. Moreover, this category is dominated by the

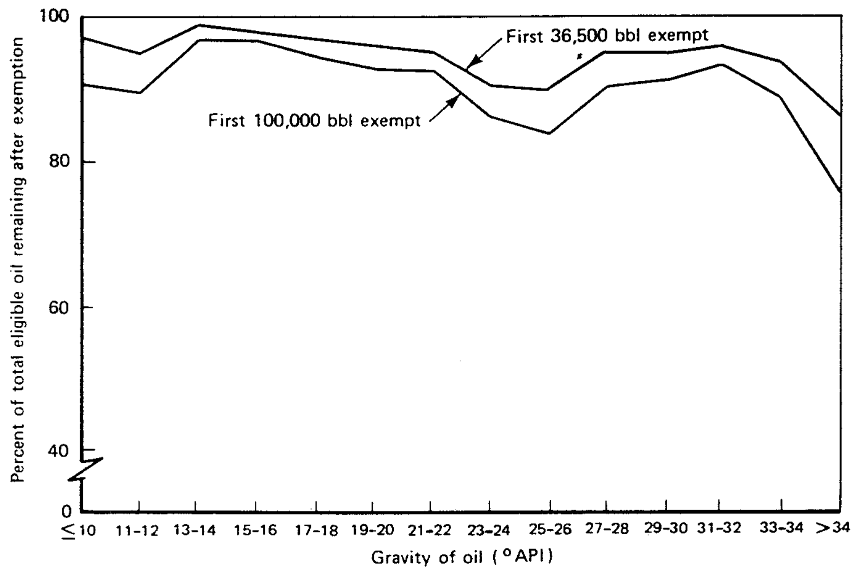

Fig. 9.3—Effect of exemption level on gravity of taxable oil

smaller operators, who account for over two-fifths of all the oil produced over 34 degress API. With this minor exception, it therefore appears that any attempt to give greater allowances to heavier oil will not succeed using either of the two exemption levels examined. If anything, there is a slight bias toward taxing heavy oil. A slightly larger share of the eligible light oil is exempted under both allowances than is heavy oil.[6]

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[6]NOTE: The data presented in this section aggregate oil production by operators, applying the portion of the operator's total taxable production to each producing property equally. A tax would have to be designed with specific allowances for certain types of oil by properties, such as by gravity or stripper exemptions, to be certain that the tax excluded oil produced from these properties. The numbers presented are those resulting from an even application of each operator's exemption to *all* oil produced by that operator.

Exemption Effects on Major and Smaller Operators

One of the primary concerns in designing appropriate tax exemption levels, mentioned earlier, was that for the smaller operators. Dividing operators as before into two groups, one consisting of the top 25 operators, the other of the remaining 626 (including unit operations), permits us to look at least at how the *relatively* smaller operators fare under each level of exemption. Figure 9.4 shows both the portion of eligible oil and the portion of operators subjected to a tax under the two exemption levels.

The smaller operators contribute 8.3 percent to the total eligible production, but only 5.7 percent to the total after the first 36,500 barrels are exempted, and barely 4 percent after the first 100,000 barrels are excluded. Thus, both exemption systems shift to some degree the tax burden onto production by the largest operators. Both systems also significantly shift the burden on the major operators themselves by exempting most of the smaller producers completely. Specifically, the 36,500 exclusion exempts all but 95 smaller operators, and a third of the smaller operator production, while the 100,000 allowance leaves less than half of their production and only 46 smaller operators subject to the tax. On the other hand, neither level has any appreciable effect on the major operators or their production. Only one to two million barrels of annual production by the top two dozen or so producers is exempted under the two methods.

Any nontaxable production allowance would also succeed in exempting most oil properties and wells operated by smaller producers. As shown in Fig. 9.5, only about a third to a quarter of the oil properties operated by the smaller producers would be taxed under either system, with very little effect on properties operated by the major producers. Similarly, while almost all wells operated by the major producers would be subject to taxation, the first 36,500 barrel exclusion would reach only about two-thirds of the smaller operators' wells; and the first 100,000 barrel exemption would exclude almost half of the smaller operators' wells.

The pattern observed for the exemption level effects on the gravity of the oil produced and taxed holds here for smaller operators as well. Because the total amount of oil produced by these 626 operators accounts for such a small portion of the total eligible oil produced, minor changes in the amount produced in any gravity category can result in substantial percentage shifts. Thus, the curves in Fig. 9.6 gyrate across the gravity categories. Nonetheless, a somewhat larger than expected percentage of heavy oil remains subject to tax under both exemption levels. As Fig. 9.4 showed, about three-fifths to one-third of the oil produced by smaller operators is taxable under the 36,500 and 100,000 barrel allowances, respectively; yet 64 percent and 42 percent

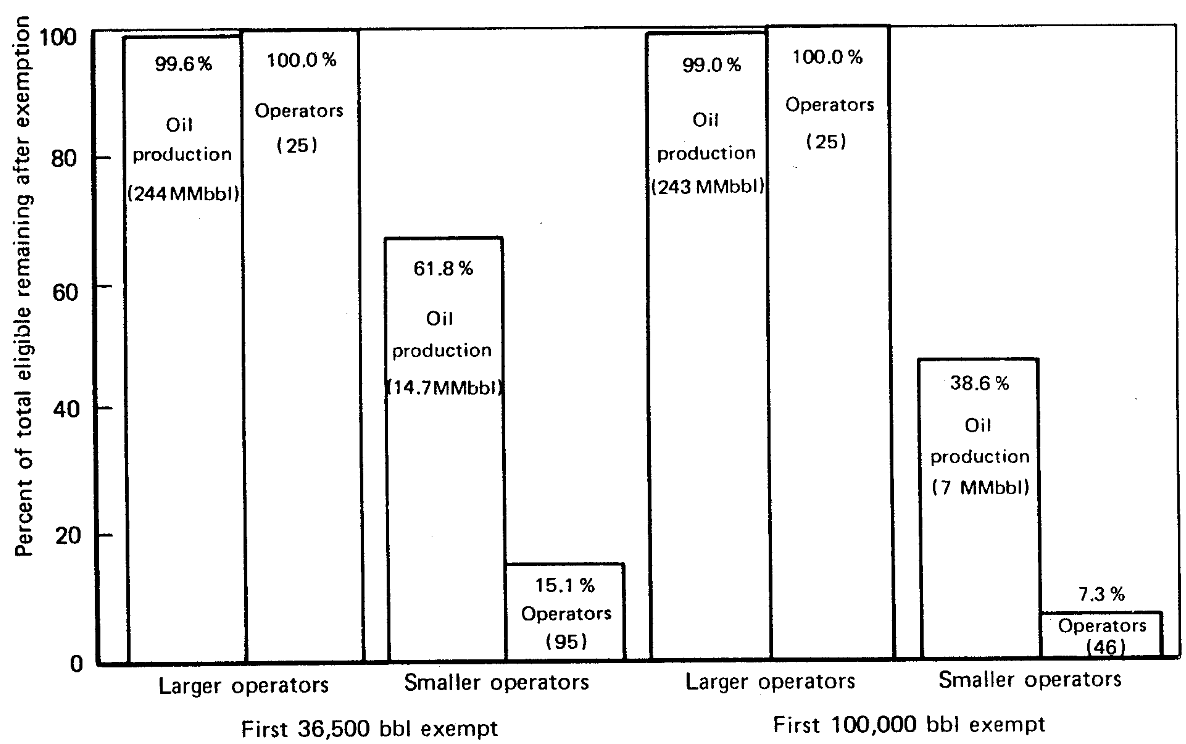

Fig. 9.4—Effect of exemption level on taxable oil and operators for major and smaller operators

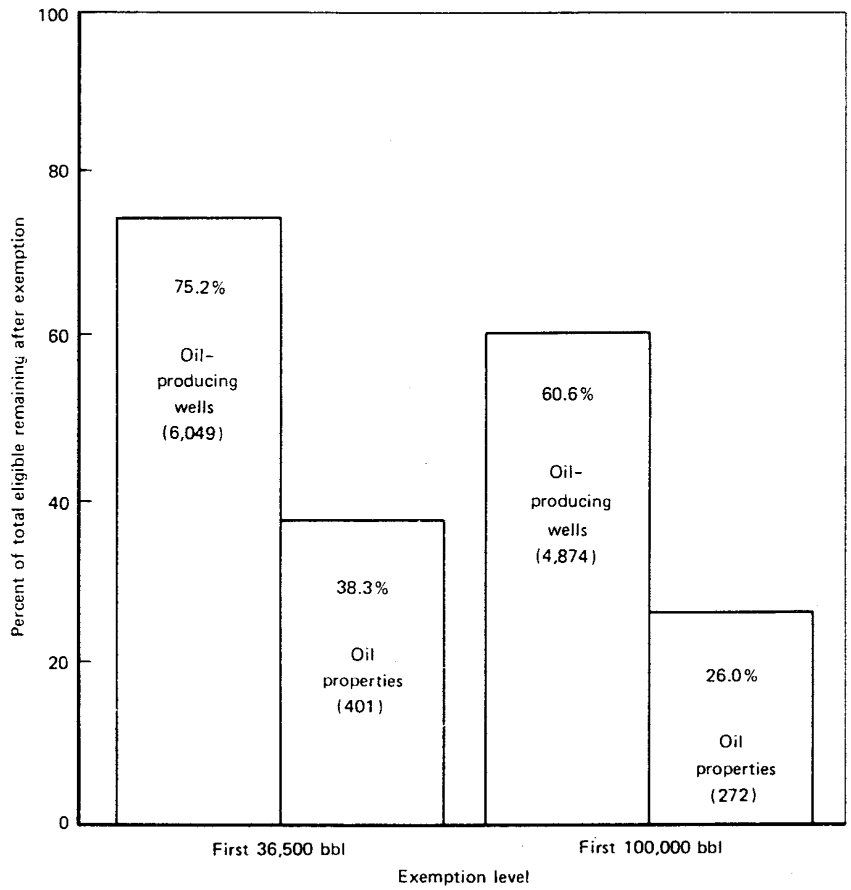

Fig. 9.5—Effect of exemption level on smaller operators' properties and wells

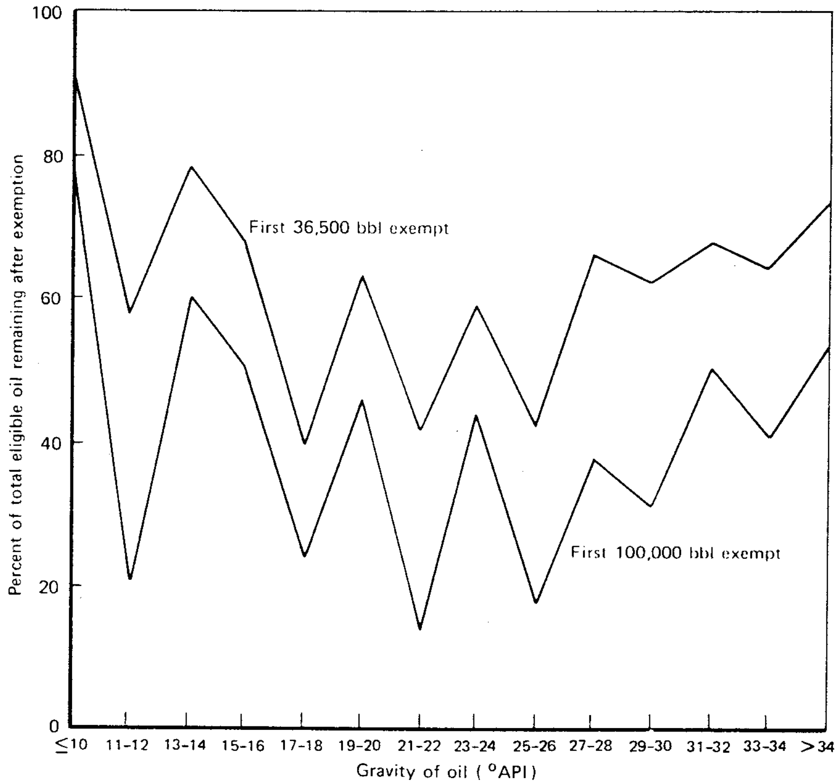

Fig. 9.6—Effect of exemption level on gravity of taxable oil for smaller producers only

of their respective heavy oil production remains taxable. Both exemptions free a larger share of light oil than heavy oil produced by the smaller operators.

Exemption Effects and Stripper Oil

Although about three-quarters of the oil properties in the state produce stripper oil, such oil accounts for only 13 percent of the state's total eligible oil. Nonetheless, both exemption levels exclude sizable portions of this oil from taxation, while they have little effect on nonstripper oil, as seen in Fig. 9.7. While a maximum of 6.4 million barrels of nonstripper oil is exempted under the 100,000 barrel annual exclusion, 7.3 million barrels of stripper oil are thus exempted. These 7.3 million barrels of stripper oil represent a much larger share of the total 35.3 million barrels of stripper oil produced than do the 6.4 million barrels of the 228 million barrels total nonstripper oil produced.

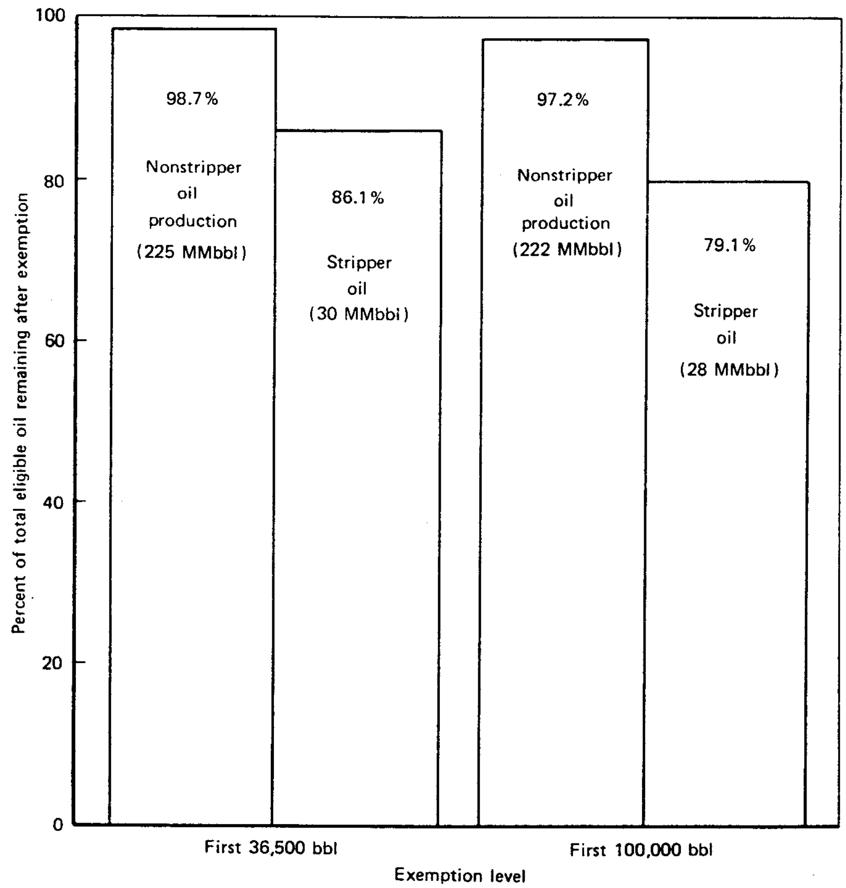

Fig. 9.7—Effect of exemption level on stripper oil production

Exemption Effects on Stripper Oil for Major and Smaller Operators

A majority of the oil produced by the smaller operators is stripper oil, and, as we have seen, smaller producers gain the greatest individual advantages of both exemption levels. As a result, Fig. 9.8 should not be surprising. A large share of smaller producers' stripper oil is exempted by both allowances. It is interesting to note, however, that the exemptions lean more heavily toward their stripper oil than toward their nonstripper oil production. Between 44 and 65 percent of the stripper oil produced by the smaller producers is exempted. Almost none of the stripper oil produced by the larger operators is exempt, however.

CONCLUSION: DESIGNING TAX EXEMPTIONS

As we have seen, providing tax allowances gives policymakers considerable latitude in designing a severance tax for specific effects. If one goal is to reduce the number of operators subject to the tax while maximizing the state's tax receipts, a relatively small allowance of several thousand barrels a year would work quite well (based on 1981 production). And if another goal is to reduce the tax's burden on smaller, presumably higher cost producers, the exemption levels examined in this section indicate a degree of success: stripper oil production by the smaller producers is disproportionately excluded from taxation under both allowance systems.

Neither system appears, however, to impose a higher portion of the tax burden on lighter oil. Nor does either system very completely exempt stripper oil, especially that produced by the state's largest operators. Specific allowances for either type of oil would be necessary to shift the effect of the tax completely away from such production and onto other types of production. Many states have such provisions in their severances taxes. Perhaps the simplest method would be to set the tax at a lower rate for certain categories of oil production—with or without the broader exemptions. In any event, tax designers have great leeway. Because a small number of operators dominate state oil production, major exemptions are likely to result in *relatively* minor losses of revenue.

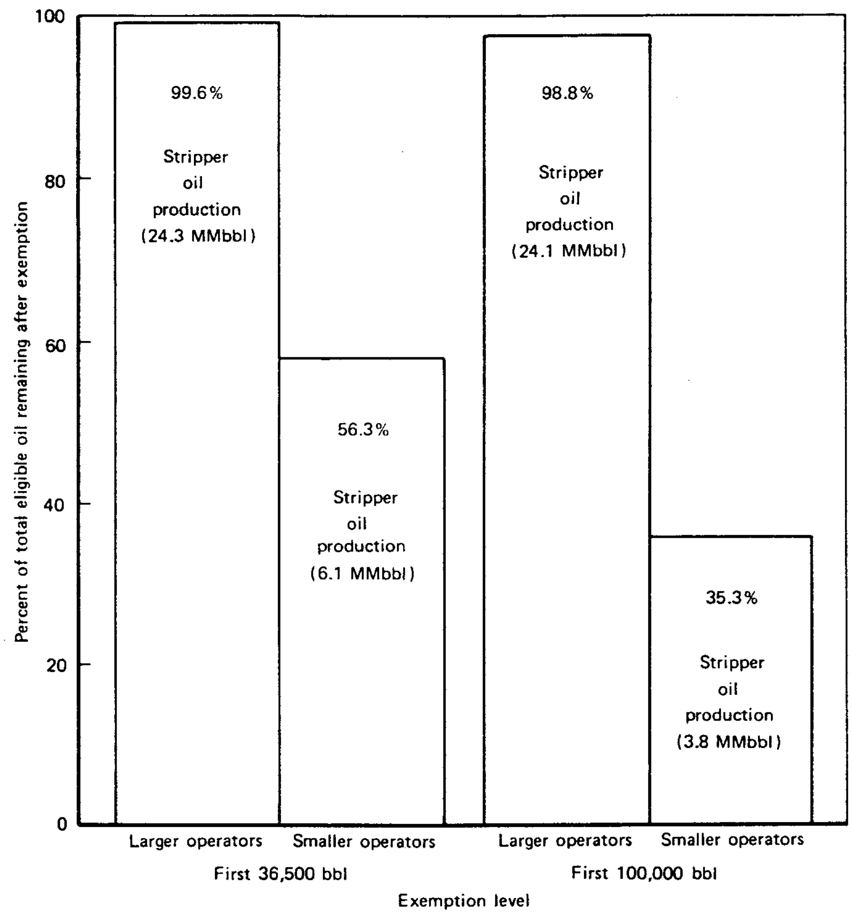

Fig. 9.8—Effect of exemption level on stripper production by major and smaller operators

X. CONCLUSIONS

Where do we stand? Is a new severance tax on oil produced in California a good idea or not? If it is, what should it look like? These are the questions that the policymaker must ultimately answer to his own satisfaction. In this final section, we bring together the results of our analysis into two basic points that should help the policymaker answer these questions:

- Viewed as one potential instrument of state fiscal policy, a new severance tax on oil production in California appears to be an effective source of new revenue.
- Policymakers could derive additional benefits from a severance tax that pays close attention to the characteristics of individual oil producers and oil-producing properties.

While laying these two points out in more detail, this section also provides the policymaker and his staff with a practical guide to the integration of material from different parts of this report.

ONE EFFECTIVE NEW REVENUE SOURCE

Because we have examined only the effects of a severance tax, we have no information to suggest that a severance tax is the best possible source of revenue for the state or that the state has any need of new revenue in the near future. If new revenue is required, however, California policymakers are likely to view a new severance tax on oil production as an effective new source of revenue.

Imposition of such a tax is likely to have relatively little effect on production. It will inevitably induce some producers to shut in production earlier than they would have otherwise. Producers will also delay, downsize, and even cancel some new investments. Nonetheless, none of these decisions poses a serious threat to total production in the state, at least for the levels of severance taxes now being considered.

In the first few years after a new tax, the only effect on production will come from early shut-ins. As Table 7.4 indicates, a 6 percent statutory tax is likely to cut *state-wide* production by less than 1 percent. Lower tax rates will have an even smaller effect.

Beyond the first few years, early shut-ins will continue and be joined by effects on new investment. We have no detailed information on the conjectured size of this effect. But, as the discussion in Sec. VIII suggests, a *very* rough estimate indicates that the effect will be very small in the beginning and could grow to a level of 1 to 4 percent of total production after about a decade. The level of this longer-term effect depends on the actual rate at which real oil prices climb over the next decade. If they in fact climb at 4 percent a year, we will find ourselves at the low end of this suggested range; if they remain constant, we will be at the upper end.

Putting all of this information together, we come to the following conclusion: A 6 percent tax will cut *state-wide* production by up to one-half a percent in the first year after the tax and by about 1 to 4 percent after ten years. Note that these cuts are *not* from the level in the year before the tax is imposed, but from the level that would have prevailed in each year if no tax had been introduced.

Given these expectations about production effects, we expect the tax to generate substantial new net revenue for California. If we exempt from the tax production the Long Beach Tidelands, Elk Hills, and the federal offshore area (see below), almost all "tax-eligible" production occurs on private lands. A substantial portion of this is produced by major national and multinational firms with only a portion of their production in California. Table 4.8 tells us that a new tax on such oil will yield 92 to 98 percent in new net revenue. We expect this high level to be fairly characteristic for the state as a whole and to be relatively insensitive to levels of production cuts or effective federal windfall profit tax rates. The new severance tax will cut state income tax receipts by about a penny for every dollar of severance tax revenue collected. It will cut local property taxes by up to seven cents on the dollar. Hence, the state can easily compensate local governments for any losses. Effects on royalty income from individual properties on state land will be significant; but, taken as a whole, such production accounts for a small portion of tax-eligible production.

The probable share of the tax borne within the state is harder to pin down, but it appears to be relatively low. Given the character of most tax-eligible oil in the state, Table 5.2 tells us that only about 35 to 50 percent will fall on firms in California in the first years following the introduction of a 6 percent tax. The high end of this range assumes the effective windfall profit tax rate to be low for most firms in California; the low end assumes that it is high. As time passes, production cuts will grow and the windfall profit tax will phase out, so that after about ten years firms in California will bear some 55 to 80 percent of the tax. The low end of this range assumes that real oil prices rise at 4 percent a year; the high end assumes that they remain constant. These results are only slightly sensitive to the actual level of the severance tax chosen for the range of tax rates typically discussed. Hence, while the severance tax falls more and more on firms in California over time, these firms will still be able to export a substantial portion of the tax over this ten-year period.

Firms within California are able to pay only a portion of the new tax because someone else is paying the rest—the federal government and other state governments. States with unitary arrangements for their corporation income taxes collect taxes on profits earned in California. As severance taxes cut these profits, such taxes will fall, thereby offsetting part of the severance tax. This effect is small; Table 4.9 tells us that such states will lose perhaps one to two cents for every dollar of severance tax collected. Less directly, all states with personal income taxes and stockholders of firms with oil business in California will lose some revenue as a severance tax reduces the profits of these firms. At most, these states will lose four cents per dollar of severance tax revenue. The federal government suffers the most. An extra dollar of severance tax will cut its revenues by 30 to 50 cents in corporation income tax, up to 30 cents in personal income tax, and as much as 50 cents in windfall profit tax. The total loss will fall as the windfall profit tax phases out, but not by much. In sum, a tax that may look good to California policymakers will draw a very different reaction from policymakers elsewhere. It is conceivable that they could react in ways that would raise the costs of the severance tax to Californians. California policymakers should at least be aware of this possibility.

The pattern of the tax's incidence within California is likely to have two features that many California policymakers will find attractive. First, as Sec. VI indicates, final consumers within California are unlikely to feel much of the effect of the tax. Theory tells us that, to the extent that refined products are traded across California's borders, the prices of those products must reflect circumstances outside California. Hence, a tax within California can affect these prices only by affecting prices in the world market. We expect such effects to be small. California engages in active interstate trade in all major products, and actual wholesale price trends in California and Texas, coupled with California's share of the world market, strongly suggest that California taxes cannot affect these prices by much. Hence, we agree with the prevailing opinion that final consumers will not bear much of the tax. To the extent that California policymakers give these consumers special consideration, they will find attractive the feature that oil producers and refiners pay the lion's share of the tax.

Second, as discussed in Sec. VI, a uniform severance tax is likely to fall more heavily on light oil producers than on heavy oil producers. We have established this result only theoretically. If it holds up empirically, it suggests that a uniform *statutory* tax structure has an attractive differentiated structure *in practice*. High-cost producers of heavy oil are less burdened by the tax than lower-cost producers of light oil. This may be considered appropriate strictly on the grounds of fairness. To the extent that a given effective tax rate cuts heavy oil production more than it cuts light oil production, such a structure also allows California to collect a given amount of revenue at a lower cost to private firms in California. Most California policymakers would find that attractive.

Taking all these effects together, we have a tax that

- Increases California's dependence on outside sources of crude oil only slightly
- Generates over 90 cents of new revenue for every dollar of severance tax revenue collected
- Exports a substantial portion of its tax burden outside the state
- To the extent that it falls on Californians, falls less heavily on Californians of special concern to many policymakers than on others

These features make the severance tax an effective new source of revenue for California policymakers.

OPPORTUNITIES IN A DIFFERENTIATED TAX

By definition, a differentiated tax gives policymakers more latitude to reach their goals than a uniform tax does. As a result, such a tax is likely to play an important role in attempts to reach legislative consensus on the need for and the design of a new tax. Our budget and schedule have not allowed us to explore the opportunities for differentiating a severance tax in detail. But our results should help those interested in exploring such opportunities to get started. In particular, they offer important information on tax designs that exempt certain types of production from taxation or that charge different rates to different types of oil producers or production.

We assume from the beginning that production on federal lands will be exempt from the tax. Although California can legally tax operators on such land, they have traditionally been exempted and we expect no change in the near future. This factor exempts production from Elk Hills and the federal offshore areas.

Beyond federal lands, the most obvious area to exempt is the Long Beach Tidelands. The state's royalty arrangements in this area make it difficult to generate significant new revenue from these properties with a severance tax; at best, if severance tax revenues rise by a dollar, state royalty revenues fall by almost 90 cents. As the windfall profit tax phases out, net tax yield from the Tidelands will fall to a few cents on the dollar. Under these circumstances, we expect many policymakers to believe that the Long Beach Tidelands should be exempted from the tax. Note that we do not include production from *other* tideland properties in this assessment.

Of more general interest are exemptions of different types of production and producers. Recent tax proposals, for example, have suggested exempting either the first 36,500 or the first 100,000 barrels of each producer's annual production. Such exemptions are designed to reduce administrative costs associated with producers who do not contribute much tax revenue. They can also substantially reduce the number of producers injured by a tax without reducing by much the revenue collected. Whether such exemptions are worthwhile depends on how much revenue is given up to pursue these other goals. As Fig. 9.1 shows, neither cuts the amount of otherwise eligible oil production that is taxed by more than 5 or 6 percent; both exempt more than 80 percent of all producers. Because neither changes the mix of oil produced by selling price, their effects on revenues are about the same as their effects on production subject to the tax. Whether 5 or 6 percent of total revenue is too high a price to pay for eliminating the administrative costs and opposition associated with taxing 80 percent of the producers in the state obviously requires a political judgment. That judgment would be even better informed if it were to consider the incremental effects of moving from one exemption level to another: moving from 36,000 to 100,000 barrels cuts revenues by about 2 percentage points and cuts the number of producers taxed by about 8 percentage points. More detailed information on incremental effects could be generated (for example, see Fig. 2.4) to help policymakers decide whether either of these, or some other exemption rule, is the most appropriate.

It is worth noting that one possible justification for exemptions like those above is that they reduce the tax burden on stripper production and other high-cost production that smaller producers as a group tend to pursue. The exemptions above do not do this particularly well; such high-cost production should be targeted directly if policymakers want to exempt it for whatever reason. Exemptions of this kind are common in other states.

Ideally, it would be appropriate to scale the tax rate to the tax's effect on various kinds of production—for example, production of heavy crude or stripper oil, production from deep pools or offshore, and the like. Unfortunately, we do not have the empirical information to do this in a systematic way. For example, we cannot say how a severance tax's effect on investment decisions changes as the depth of a well changes from 11,000 to 12,000 feet. In part, this is because our empirical analysis in this area was only exploratory. Nonetheless, even our more detailed models showed little promise in identifying such effects. We suspect that, given the difficulty of identifying the structure underlying investment behavior with data from the period of price controls during the 1970s, the high degree of uncertainty about future world oil prices, and the relatively scanty information about California's cumulative future investment opportunities as a function of after-tax price, policymakers should not hope for good empirical information on a tax's effect on investment in specific types of oil properties any time soon. Hence, we surmise that attempting to key tax rates or even exemptions to specific production characteristics in any way that systematically considers probable production responses to the tax is not feasible in the near future.

We were more successful, however, in identifying how a property's tax status affects its probable response to a new severance tax. Appendix B shows how to differentiate a tax in a way that cuts the cost to the oil companies in California—who pay most of the tax—which is imposed in raising any given amount of revenue by means of a severance tax. It depends on the existence of differences in *marginal* shares of the tax burden across properties within California. Section V shows that differences in *average* shares are substantial under a uniform tax and that they are systematically related to the tax status of different properties. This is likely to be true of marginal shares as well, suggesting that a severance tax keyed to tax status could raise more revenue at no *net* costs to private citizens. We believe that this point suggests a promising direction for future work on tax design. It should proceed, however, in full understanding of the restrictions placed by the federal government on the deductibility of certain types of differentiated taxes from the windfall profit tax.

In the end, we cannot answer the questions posed at the beginning of this section. We can only provide information that policymakers can use to reach their own answers. Our results suggest that even the simplest severance tax—a uniform tax—has many features that California policymakers may find attractive. If they see a need for a severance tax, we suspect that California policymakers will want to exempt oil from federal lands and the Long Beach Tidelands. There will be less agreement on other ways of tailoring the tax. Some careful attention to the options available, however, could well speed consensus. In any event, we hope that California policymakers find the work begun here to be useful in their deliberations.

Appendix A

THE TAX MODEL

Appendix A explains the tax model used to derive tax results in Secs. IV and V. It lays out the simple model in two steps, considers and resolves three difficulties in the first step, shows briefly how information from the model can be used to calculate changes in profits and in deadweight loss, presents the formulas for the measures of net yield and Californians' tax share presented in Secs. IV and V, and shows how to interpret those results in a net present value context.

THE MODEL

As noted in Sec. V, we are concerned about major taxes on oil. Each tax is a function of its tax base. In our simple model, we proceed in two steps. We first examine all the taxes relevant to understanding the effects of a new severance tax on corporation profits, net of taxes. We then examine how personal income taxes affect the income ultimately realized by corporation stockholders. In the discussion that follows, let:

- p = selling price of oil
- Q = quantity of oil sold
- $C(Q)$ = cost of oil production
- σ = 1 for state land, 0 for private land
- I_F = federal corporation income tax payments
- I_{SC} = California state corporation income tax payments
- I_{SO} = other state corporation income tax payments
- W = federal windfall profit tax payments
- S = severance tax payments

P = property tax payments

R = royalty payments

I_{FP} = federal personal income tax

I_{CP} = California personal income tax

I_{OP} = other state personal income taxes

α_C = share of corporation income taxed by California

α_O = share of corporation income taxed by other states

α_S = share of stockholders in California

α_E = share of stockholders elsewhere

t_W = marginal windfall profit tax rate

p_B = base price under windfall profit tax

ω = operator's economic interest as a share

t_S = severance tax rate

t_P = property tax rate

V = assessed value of property for tax purposes

r = royalty rate

Π = corporation income after taxes

Y = stockholder income after taxes

$I_F(.)$, $I_{SC}(.)$, $I_{SO}(.)$, $I_{FP}(.)$, $I_{CP}(.)$, $I_{OP}(.)$, $V(.)$, and $C(.)$ are functions and I_F', I_{SC}', I_{SO}', I_{FP}', I_{CP}', I_{OP}', V', and C' are their first derivatives with respect to their tax base.

Step 1

We start by considering all taxes and fees relevant to corporation income, net of taxes. Seven taxes are important; each can be represented by an equation. Consider first equations for properties outside the Long Beach Tidelands; we consider the Tidelands later.

$$I_F = I_F(pQ - C - I_{SC} - I_{SO} - W - S - P - \sigma R) \qquad \text{(A.1a)}$$

$$I_{SC} = I_{SC}[\alpha_C(pQ - C - W - S - P - \sigma R)] \qquad \text{(A.1b)}$$

$$I_{SO} = I_{SO}[\alpha_O(pQ - C - W - S - P - \sigma R)] \tag{A.1c}$$

$$W = t_W(1 - p_B/p)(1 - t_S)(1 - \sigma r)pQ \tag{A.1d}$$

$$S = t_S pQ \tag{A.1e}$$

$$P = t_p V(pQ - C - W - S - P - R) \tag{A.1f}$$

$$R = rpQ \tag{A.1g}$$

Note that, while we are positing a simple model, it is nonetheless relatively general. Only equations (1d), (1e), and (1g) are specifically linear; the others can accept any functional relationship between tax base and taxes deemed app-opriate.

The use of σ deserves some elaboration. In (1a), R is effectively deductible on state land, but not on private land. This is because a royalty paid by one private party to another remains taxable while one paid to the state escapes federal taxation. Hence, I_F represents <u>all</u> federal taxes paid on a property. Note that it implies equal marginal federal tax rates for the owner and payor of the royalty. While these rates may well differ, we expect the owner's rate to remain in the low to mid .40s--that is, close to the corporate rate of .46. Because we have no special interest in the royalty holder as opposed to the operator per se, we see no reason to complicate the model to make this distinction. Similar arguments apply with regard to (1b) and (1c). For (1d) we assume that state royalties are not taxable under the windfall profit tax. While this is currently at issue, it should be resolved as shown in (1d).

It is worth noting that, while (1f) takes a relatively general form, it is still quite simplified. It is based on the following simplified view of a net present value calculation:

$$V = \sum_{t=1}^{n} (pQ - C - W - S - P - R)(1 + i - \pi + \delta)^{-t}$$

$$= (pQ - C - W - S - P - R) \sum_{t=1}^{n} (1 + i - \pi + \delta)^{-t} \qquad \text{(A.2)}$$

where t is a time index, n is the horizon for the calculation, i is the real cost of capital, π is the real rate of change in oil prices, and δ is the decline rate for oil production from the property. The cost of capital is adjusted by the rate of change in prices and oil production to allow the net cash flow from the property change over time. Using relatively representative values used elsewhere in this report of i = .075, π = .02, δ = .10, and n = ∞,

$$\sum_{t=1}^{\infty} (1 + i - \pi + \delta)^{-t} \equiv V' = 6.45 \approx 6.5 \qquad \text{(A.3)}$$

Other values of V' are obviously possible. Because this lies in the middle range of values we might consider, we use V' = 6.5 throughout the report.

Actual county formulas are quite detailed. There is some evidence, however, that their application differs from one country to the next. The amount of complexity that would be required to reflect both the formulas and their effective variations seems out of proportion with that reflected in the other equations. Hence, we continue with this simple form and keep the simplification reflected in it carefully in mind.

Equations for the Long Beach Tidelands differ from these in two respects. First, the net income limitation on the windfall profit tax is important to most properties in the Tidelands. Hence, we must change (1d) to

$$Q = \omega t_W(.9)(pQ - C - I_{SC} - I_{SO} - P - S) \qquad \text{(A.1d')}$$

Eq. (1.d') reflects the fact that when the net income limitation applies, the relevant tax base is .9 times gross income net of certain taxes and costs. The portion of tax that can be collected from the property is equal to the operator's share of the total economic interest in the property. The second change we must make for the Long Beach Tidelands is to reflect the net income basis for royalties in the area:

$$R = r(pQ - C - W - S - P) \qquad \text{(A.1g')}$$

Eq. (1.g') shows that costs and excise taxes are deductible from the tax base for these royalties.

The system of equations (1a) to (1g), or that altered to reflect the Long Beach Tidelands, allows us to define the seven major tax levels as functions of oil price (p), production level (Q), and a series of tax parameters. For our purposes, the most important tax parameter is t_S, the marginal severance tax rate. We wish to know how these seven taxes change when severance taxes change. We can determine this by totally differentiating the system in (1) with respect to tax levels, production level, and the severance tax rate. We show the results of this differentiation below in matrix form; changes in taxes are normalized by the initial level of gross revenues, p_0Q_0:

$$\begin{bmatrix} 1 & I'_F & I'_F & I'_F & I'_F & I'_F & \sigma I'_F \\ 0 & 1 & 0 & \alpha_C I'_{SC} & \alpha_C I'_{SC} & \alpha_C I'_{SC} & \sigma\alpha_C I'_{SC} \\ 0 & 0 & 1 & \alpha_C I'_{SO} & \alpha_C I'_{SO} & \alpha_C I'_{SO} & \sigma\alpha_C I'_{SO} \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & t_P V' & t_P V' & 1+t_P V' & t_P V' \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \frac{dI_F}{P_0Q_0} \\ \frac{dI_{SC}}{P_0Q_0} \\ \frac{dI_{SO}}{P_0Q_o} \\ \frac{dW}{P_0Q_0} \\ \frac{dS}{P_0Q_0} \\ \frac{dP}{P_0Q_o} \\ \frac{dR}{P_0Q_0} \end{bmatrix}$$

$$= \begin{bmatrix} I'_F\left(1 - \frac{C'}{P_0}\right)\frac{dQ}{Q_0} \\ \alpha_c I'_{SC}\left(1 - \frac{C'}{P_0}\right)\frac{dQ}{Q_0} \\ \alpha_o I'_{SO}\left(1 - \frac{C'}{P_0}\right)\frac{dQ}{Q_0} \\ t_W\left(1 - \frac{P_B}{P_0}\right)(1 - \sigma r)\left[\left(1 - t_S\right)\frac{dQ}{Q_0} - dt_S\right] \\ t_S\frac{dQ}{Q_0} + dt_S \\ t_P V'\left(1 - \frac{C'}{P_0}\right)\frac{dQ}{Q_0} \\ r\frac{dQ}{Q_0} \end{bmatrix} \qquad (A.4)$$

The matrix for the Long Beach Tidelands is the same if we substitute for the fourth row in this matrix equation,

$$\frac{dW}{P_0Q_0} + .9\omega t_W\left(\frac{dI_{SC}}{P_0Q_0} + \frac{dI_{SO}}{P_0Q_0} + \frac{dS}{P_0Q_0} + \frac{dP}{P_0Q_0}\right) = .9\omega t_W\left(1 - \frac{C'}{P_0}\right)\frac{dQ}{Q_0}$$

and for the seventh row,

$$r\left(\frac{dW}{p_0Q_0} + \frac{dS}{p_0Q_0} + \frac{dP}{p_0Q_0}\right) + \frac{dR}{p_0Q_0} = r\left(1 - \frac{C'}{p_0}\right)\frac{dQ}{Q_0}$$

Expressed in simple matrix notation, this system becomes

$$AdT = B \tag{A.5}$$

We can express the effect of changes in the severance tax on changes in levels of all taxes as

$$dT = A^{-1}B \tag{A.6}$$

That is, with complete information on A, B, and dQ/Q, we can estimate the complete effects of any change in severance tax. For simplicity, we assume that A and B are fixed over the path of any change in the severance tax. We also parameterize dQ/Q as a direct function of dt_S, $dQ/Q = \beta dt_S$, and vary β to achieve changes in dQ/Q. For fixed β, these assumptions allow us to treat $(dT_i/p_0Q_0)/dt_S$ as constant, for T_i the i^{th} tax (I_F, I_{SC}, I_{SO}, and so on). That is, any result reported in the form $(dT_i/p_0Q_0)/dts$ or as a ratio of effects, dT_i/dT_j, is independent of the level of severance tax chosen and can be used as a basis for calculating the effects of any level of t_S. Under these circumstances, finite changes in t_S and Q can be correctly substituted for the infinitesimals in (4) and their finite effects simply calculated from (6).

So long as the marginal tax rates are fixed, A is in fact fixed over the path of any change in the severance tax. But C'/p_0 in B is not. We discuss why below. A more extensive analysis could use this approach in a piecewise manner by continually adjusting B for changes in C'/p_0. In our analysis, C'/p_0 is implicitly assumed to remain constant.

Some Complications in Step 1

With a few exceptions, the information in A and B involves only marginal, tax information and is relatively easy to get. But a number of the parameters important to the analysis present problems.

The first is C'/p_0, the ratio of marginal cost to price. To understand C'/p_0, consider the decision an oil producer makes in choosing its level of output and hence C'. It maximizes its profits:

$$\Pi = pQ - C - I_F - I_{SC} - I_{SO} - W - S - P - R \tag{A.7}$$

That is, it chooses Q, and hence C', for which $dT/dQ = 0$ and hence

$$\frac{C'}{p_0} = 1 - \sum_i \frac{dT_i/p_0Q_0}{dQ/Q_0} \tag{A.8}$$

We can solve for the finite analog of $(dT_i/p_0Q_0)/(dQ/Q_0)$ in (4) by setting $dt_S = 0$ and $dQ/Q_0 = 1$ and solving the system. Substituting these values into (8) yields an equation in C'/p_0 which we can readily solve for C'/p_0. We then substitute the value for C'/p_0 back into (4), effectively eliminating the need to use exogenous assumptions about C'/p_0.

Second, which value of t_S should we use: the initial value of 0, the after-tax value of, say, 6 percent, or some value in between? The simplest way to solve this is to examine the effect of changing t_S finitely in (1e):

$$\Delta S = p_0(Q_0 \Delta t_S + t_S^0 \Delta Q + \Delta t_S \Delta Q)$$
$$= p_0 \Delta t_S (Q_0 + \Delta Q)$$

for $t_S = 0$. Normalized for initial gross revenue, this becomes

$$\frac{\Delta S}{p_0 Q_0} = \Delta t_S + \frac{\Delta Q}{Q_0} \Delta t_S, \tag{A.9}$$

a direct finite analog for the relevant differential equation in (4) if $dt_S = t_S$. Hence we use the after-tax value of t_S throughout the tax analysis.

Finally, what values of dQ/Q are appropriate? We can determine how output should respond to a tax change by examining the comparative statics of the first order condition for profit maximization. Let $T_i = T_i(t_i, Q)$ where t_i is the marginal rate for the i^{th} tax. Then:

$$p_0 - C' = \sum_i \frac{\partial T_i}{\partial Q} = \sum_i t_i$$

and

$$-\frac{dC'}{dQ} = \sum_i \frac{dt_i}{dQ} \tag{A.10}$$

Note that

$$\frac{dT_i}{dQ} = \sum_i \left(\frac{\partial T_i}{\partial t_i} \frac{dt_i}{dQ} + \frac{\partial T_i}{\partial Q} \right)$$

$\partial T_i/\partial t$ is the effect on the i^{th} tax of a change in its marginal rate. It is the portion of production affected by a change in the rate. Assume that all production relevant to the tax offset created by a change in t is involved. Hence, $\partial T_i/\partial t = Q$. Then the first term on the right of (8) becomes $Q\Sigma\, dt_i/dQ = -Q\, dC'/dQ$. $\Sigma \partial T_i/\partial Q$, of course, is simply $p_0 - C'$. Hence, (10) can be rewritten, in a form appropriate to (4),

$$\frac{(dT/P_0Q_0)/dt_S}{(dQ/Q_0/dt_S} = -\frac{C'}{P_0}\left(\frac{dC'/C'}{dQ/Q}\right) + 1 - \frac{C'}{P_0}$$

or

$$\frac{dQ/Q_0}{dt_S} = \frac{dT/p_0Q_0}{dt_S}\left[1 - \frac{C'}{P_0}\left(\frac{1}{\varepsilon_S} + 1\right)\right]^{-1} \quad (A.11)$$

where $\varepsilon_S \equiv (dQ/Q)/(dC'/C')$ is the property's elasticity of supply. If we have information on ε_S, we can combine it with other information generated by the model above to determine relevant levels of $(dQ/Q)/dt_S$. Note that all differentials are total differentials. $(dT/p_0Q_0)/(dt_S)$ includes the effect of a production cutback and hence an assumed value of $(dQ/Q_0)/dt_S$. This value must be consistent with that on the left. We have taken a slightly different course by assuming a value for $(dQ/Q_0)/dt_S$ and calculating the implied value of ε_S:

$$\varepsilon_S = \left\{\frac{P_0}{C'}\left[1 - \frac{(dT/p_0Q_0)/dts}{(dQ/Q)/dts}\right] - 1\right\}^{-1} \quad (A.12)$$

If our assumed value of $(dQ/Q_0)/dt_S$ yields a reasonable value of ε_S, then we judge it to be reasonable itself.

Step 2

When Step 1 is complete, we know the effects on corporations and all taxes relevant to corporations. Next, we must calculate the effects on the stockholders of these corporations. The following set of four equations describes their situation

$$I_{FP} = I_{FP}(\Pi - I_{CP} - I_{OP}) \tag{A.13a}$$

$$I_{CP} = I_{CP}(\alpha_S \Pi) \tag{A.13b}$$

$$I_{OP} = I_{OP}(\alpha_E \Pi) \tag{A.13c}$$

$$Y = \Pi - I_{FP} - I_{CP} - I_{OP} \tag{A.13d}$$

These equations have the same character as those in (1). They assume that all profits are directly distributed and taxed as dividend income. This provides an upper bound on I_{FP}, I_{CP}, and I_{OP}, and a lower bound on Y. They reflect the deductibility of state taxes from the base for federal taxes and the inclusion in each state's tax base of only the income of stockholders living in that state. The aggregation of I_{CP} and I_{OP} in (13a) assumes that stockholders in different states pay the same federal marginal tax rate on average. Totally differentiating, normalizing to p_0Q_0, and solving this system yields:

$$\begin{aligned}
\frac{dI_{FP}}{p_0Q_0} &= I'_{FP}\left(1 - \alpha_S I'_{CP} - \alpha_E I'_{OP}\right)\frac{d\Pi}{p_0Q_0} \\
\frac{dI_{CP}}{p_0Q_0} &= \alpha_S I'_{CP}\frac{d\Pi}{p_0Q_0} \\
\frac{dI_{OP}}{p_0Q_0} &= \alpha_E I'_{OP}\frac{d\Pi}{p_0Q_0} \\
\frac{dY}{p_0Q_0} &= (1 - I'_{FP})(1 - \alpha_S I'_{CP} - \alpha_E I'_{OP})\frac{d\Pi}{p_0Q_0}
\end{aligned} \tag{A.14}$$

Since we know $d\Pi$ from Step 1, we can easily calculate all effects relevant to stockholders using (14).

Changes in Profits and Deadweight Loss

The implied value of ε_S makes it simple to calculate measures of the effects of severance taxes on profits and deadweight loss. The change in profits, assuming a locally linear marginal cost schedule and normalizing for initial revenues, is

$$\frac{\Delta\Pi}{P_0Q_0} \equiv \Delta C' \left(Q_0 + \frac{1}{2}\Delta Q\right)/P_0Q_0$$
$$= \frac{1}{\varepsilon_S}\frac{C'}{P_0}\frac{\Delta Q}{Q_0}\left(1 + \frac{1}{2}\frac{\Delta Q}{Q_0}\right) \quad (A.15)$$

We can easily calculate this quantity with the information above. The change in deadweight loss, viewed analogously, is

$$\frac{\Delta\Lambda}{P_0Q_0} \equiv \Delta Q \left(P_0 - C' + \frac{1}{2}\Delta \quad (P_0 - C')\right)/P_0Q_0$$
$$= \frac{\Delta Q}{Q}\left(1 - \frac{C'}{P_0} - \frac{1}{2}\frac{C'}{P_0}\frac{\Delta Q}{Q}\frac{1}{\varepsilon_S}\right) \quad (A.16)$$

Again, this is easily calculated with the information above.

Tax Effects Presented in Section V

The numerical results in Sec. V represent simple combinations of the individual effects on profits and taxes calculated above. Net yield is calculated as

$$\frac{\dfrac{dI_{SC}}{P_0Q_0} + \dfrac{dS}{P_0Q_0} + \dfrac{dP}{P_0Q_0} + \sigma\dfrac{dR}{P_0Q_0}}{\dfrac{dS}{P_0Q_0}} \quad (A.17)$$

Californians' tax share is

$$= \frac{\frac{d\Pi}{P_0Q_0} + (1 - \sigma)\frac{dR}{P_0Q_0}}{\frac{dI_{SC}}{P_0Q_0} + \frac{dS}{P_0Q_0} + \frac{dP}{P_0Q_0} + \sigma\frac{dR}{P_0Q_0}} \qquad (A.18)$$

Under our assumptions, the numerators and denominators of (17) and (18) are proportional to dt_S. As a result, each ratio is independent of the magnitude of the change in severance tax.

INTERPRETATION OF RESULTS IN A NET PRESENT VALUE CONTEXT

No horizon is specified in the analysis; hence, we could potentially apply the model to any horizon--from three months to three decades--with equal success. Presumably, however, the net present value of tax effects concerns us. Hence, results in the near term are more important than those in the long term, and as the horizon becomes longer, it becomes less and less obvious how to interpret the results in a net present value context.

To see how this is done, assume the analysis is applied to an infinitesimal sliver of time and that we are interested in aggregating across time to measure the net present values of each effect reported. Note that, under the assumptions above, we can represent each tax effect as a linear function:

$$\frac{dT_i/P_0Q_0}{dt_S} = \gamma_{0i} + \gamma_{1i}\frac{dQ/Q_0}{dt_S} \qquad (A.19)$$

where γ_{0i} and γ_{1i} are constants and $(dQ/Q_0)/dt_S$ is a function of time. The present value of the i^{th} tax effect over any interval τ_1 to τ_2 is then

$$\int_{\tau_1}^{\tau_2} \frac{dT_i/p_0Q_0}{dt_S} e^{-\rho t} dt = \gamma_{0i} \int_{\tau_1}^{\tau_2} e^{-\rho t} dt + \gamma_{1i} \int_{\tau_1}^{\tau_2} \frac{dQ/Q_0}{dt_S} e^{-\rho t} dt$$

so that

$$\frac{\int_{\tau_1}^{\tau_2} \frac{dT_i/p_0Q_0}{dt_S} e^{-\rho t} dt}{\int_{\tau_1}^{\tau_2} e^{-\rho t} dt} = \gamma_{0i} + \gamma_{1i} \frac{\int_{\tau_1}^{\tau_2} \frac{dQ/Q_0}{dt_S} e^{-\rho t} dt}{\int_{\tau_1}^{\tau_2} e^{-\rho t} dt} \tag{A.20}$$

ρ is the discount rate appropriate to the decisionmaker. The expression on the left is the weighted average of the i^{th} tax effect over the interval τ_1 to τ_2; the ratio in the second term on the right is a similar weighted average for $(dQ/Q)/dt_S$ over the same period. Note that (A.19) fully captures the structure of (A.20). Hence, though our analysis has no explicit time frame, its results for tax effects--shown in (A.17)--can be interpreted in any specific time frame of interest to the policymaker. Each tax effect is an average; ratios of tax effects are ratios of these averages.

Things are not quite so simple for effects on profits. If we consider the net present value of the effects of an infinitesimal severance tax, we start with

$$\frac{d\Pi/p_0Q_0}{dt_S} = Q\,\frac{dC'/p_0Q_0}{dt_S}$$

$$= -\,Q\sum_i \frac{dt_i/p_0Q_0}{dt_S}$$

$$= -\sum_i \frac{dT_i/p_0Q_0}{dt_S} + \frac{dQ/Q_0}{dt_S}\sum_i \frac{t_i}{p_0} \qquad (A.21)$$

(These results are drawn from Eq. (10) and the associated discussion.) The first term on the right is simply a sum of expressions like those in (A.19). Because $\Sigma\, t_i/p_0$ is a constant (for an infinitesimal severance tax) the second term can also be expressed as a linear form like (A.19). That is, (A.21) is linear in $(dQ/Q_0)/dt_S$. Hence, a net present value calculation for (A.21), like that in (A.20), will preserve the structure of (A.21) and allow us to use our expression to speak of the net present value of the effects on profits of a very small change in severance tax. As the tax rises, however, note that $\Sigma\, t_i/p_0$ changes, eliminating linearity in any expression like (A.21) for a discrete change in taxes. Whether a 3-7 percent tax is small enough for us to exploit the linearity in (A.21) in moving to net present value measures is problematical. We have not examined this problem empirically, but suspect that it bears attention in any more detailed analysis. For now, we assume that we can interpret our estimates of profit changes just as we do those of tax effects. An appropriate definition of tax-induced changes in production allows us to use our estimates to examine the net present value of profit changes over any time period.

Appendix B

CALIFORNIANS' TAX SHARE AND TAX DESIGN

One of the most interesting aspects of the severance tax is its ability to export a portion of its tax burden from California. Given any level of net revenue collected through the severance tax, California policymakers designing the tax would presumably like to maximize the portion of that tax exported or, equivalently, minimize the portion of the tax paid in California. We can use such a criterion to guide policy choices which charge different tax rates for different kinds of oil properties. This appendix explains this notion formally and provides a graphical explanation of how it works.

FORMAL MODEL

Let Π^j be the level of after-tax corporate profits associated with the j^{th} oil property, T^j the net tax revenue collected from that property through the revenue taxes and t_S^j the severance tax rate on the j^{th} property. Then the policymaker's problem can be characterized by the following Lagrangean:

$$\max_{t_s^j} L = \sum_j \Pi^j - \lambda\left(\sum_j T^j - \bar{T}\right) \quad .$$

First order conditions require that[1]

[1]So long as the j^{th} tax rate affects only profits and revenues from the j^{th} property, a reasonable assumption, the second order conditions for a maximum are satisfied when

$$\frac{\partial L}{\partial t_S^j} = \partial \Pi^j/\partial t_S^j - \lambda \partial T^j/\partial t_S^j = 0$$

or

$$\frac{\dfrac{\partial \Pi^j/P_0^j Q_0^j}{\partial t_S^j}}{\dfrac{\partial T^j/P_0^j Q_0^j}{\partial t_S^j}} = \lambda \quad . \tag{B.1}$$

The expression on the left of (B.1) is simply the infinitesimal analog of (A.14), our measure of the tax share borne by the j^{th} property. Eq. (B.1) states that we should set the tax rate for the j^{th} property so that every property in the state has the same marginal tax share.

A GRAPHICAL EXAMPLE

To see the implications of this result, consider two properties that supply net revenues to Californian governments of $T^1 + T^2$ when both face the same severance tax rate. Let us change the tax rates they face in a way that holds $T^1 + T^2$ constant. Figure B.1 will assist us in this discussion. The area of the box in Fig. B.1 is $T^1 + T^2$. The area to the left of aT_S^a is the starting value of T^1; to the right is the starting value of T^2. Distances along the

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$$\partial^2\Pi^j/\partial t_S^{j2} - \lambda\partial^2 T^j/\partial t_S^{j2} < 0 \ \forall j \quad .$$

The second expression on the left is zero in our model, as explained in Appendix A. Hence, the second order condition requires that marginal tax effects on profits fall as taxes rise. Because the marginal tax effect on profit is negative, this is equivalent to requiring that the magnitude of tax effects on losses grow as the tax rate grows.

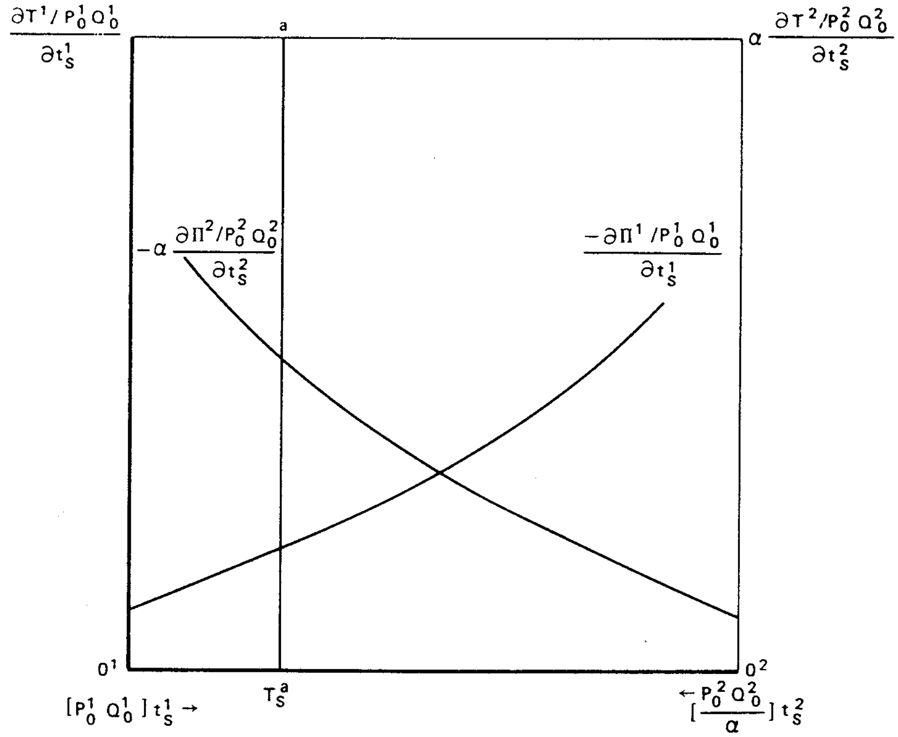

Fig. B.1—Effects on the marginal tax shares of two properties under differential severance taxes

abscissa measure payments of severance taxes. For example, $p_0^1Q_0^1t_S^1$, measured from the left, is the severance tax paid by the first property. At the start, it pays $0^1T_S^a$. We can alter this only by changing t_S^1. On the ordinate is the constant rate at which net revenues change as t_S^1 changes. Because this rate is constant in our model,

$$T^1 = \left(p_0^1Q_0^1t_S^1\right)\left(\frac{\partial T^1/p_0^1Q_0^1}{\partial t_S^1}\right)$$

for any level of t_S^1. Similarly,

$$T^2 = \left(\frac{p_0^2 Q_0^2}{\alpha} t_S^2\right)\left(\alpha \frac{\partial T^2/p_0^2 Q_0^2}{\partial t_S^2}\right) .$$

α is a scaling factor that allows us to present the taxes garnered from these two properties in a common box. Note that the severance tax paid on the second property, $p_0^2 Q_0^2 t_S^2$, is equal to the distance, measured from the right, $\alpha\ 0^2 T_S^a$. That is, changes in the two severance tax rates must always obey the condition that

$$\alpha dt_S^1 = - dt_S^2$$

in order to hold total revenues, $T^1 + T^2$, constant. This is the fundamental interpretation of the scaling factor α. It reflects both the relative sizes of the two properties and the relative sensitivities of net revenues to changes in the severance tax on the two properties.

The final features of Fig. B.1 requiring explanation are the two curves within the box. That rising from the left is the tax induced marginal loss in profits from the first property associated with any change in severance taxes. Its analog for the second property rises from the right. Hence the ratio $a_j T_S^a / a T_S^a$ is the marginal tax share for the j^{th} property.

Equation (B.1) suggests that the difference in these tax shares means that a change in the tax rates charged on the two properties can make the two property owners *jointly* better off. To demonstrate this result, increase t_S^1 and reduce t_S^2 just enough to hold $T^1 + T^2$ constant. T_S^a will move to the right. Losses to the first property rise by $a_1T_S^a$. But profits rise even more on the second property, $a_2T_S^a$. Such a tax change makes the property owners *jointly* better off by an amount a_2a_1. Such a tax change will always have such potential so long as severance tax rates are such that T_S^a differs from T_S^* in Fig. B.2. (Figure B.2 simply replicates Fig. B.1 without all the notation.) T_S^* defines the pair of tax rates, t_S^1 and t_S^2, for which $T^1 + T^2$ is maintained constant and the marginal tax shares for the two property owners reach equality (at a^*). As (1) implies, we cannot improve on this position. In fact, the shaded area represents the joint gain to the property owners of moving from T_S^a to T_S^*; it is effectively the *additional* tax burdens exported via finer tax design.

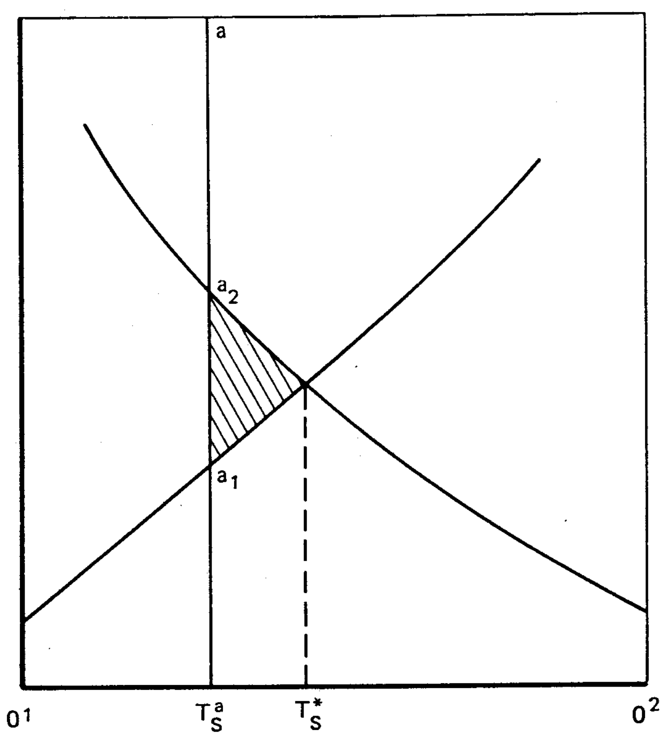

Fig. B.2—Gains to Californians of moving to a set of differential severance taxes

Appendix C

CRUDE OIL PRICING IN CALIFORNIA

If new severance taxes are introduced in California, they will most likely take the form of an ad valorem tax on crude oil prices. Because oil quality varies substantially in California and individual prices are quoted for oil from individual fields, the pattern of crude oil prices to which severance taxes would be applied could be extraordinarily complex. This appendix provides some basic information on crude oil prices that proved useful in our analysis; it may also prove useful to those who use our results.

The starting point for any analysis of crude oil prices in California must be the posted price bulletins of the three principal refiners in the state: Chevron, Mobil, and Union. Other firms like ARCO and TOSCO also post prices, but the first three clearly provide the broadest coverage in the state. Each company posts a base price for each of a series of fields in the state. That price applies to a base gravity for the field; purchases of oil at different levels of gravity from a field call for an adjustment in the price to reflect departures from this base gravity. Each firm uses its own adjustment rate, but that rate is the same in all fields where it posts prices. These postings were made monthly during volatile periods like 1979, but are generally revised and posted at longer intervals. During the period of the price controls, separate price schedules were posted for each legal classification of oil.

These prices serve as the basic vehicle for transactions between refiners and producers. Though "bonuses" are sometimes used to adjust these prices in bilateral negotiations, they can generally be said to reflect actual transaction prices. For that reason, the State Lands Commission uses, not actual transaction prices, but these posted prices to track royalties due from state (and federal) lands. They could presumably be used in a similar way to track severance taxes, though the opportunity for systematic abuse should be kept in mind.

We would expect the prices different refiners offer for similar oil to be similar in any field. In fact, at any point in time, considerable variation can exist in both base price and base gravity in a particular field. Even prices adjusted to the same gravity differ. Over time, however, prices move together, suggesting that variations at any point in time represent some small amount of inertia or just random variation. Differences may also be worked out by bilaterally negotiated bonuses.

We observe similar behavior in the adjusted factors used by the major posting refiners. Fig. C.1 shows the adjustment rates for oil not subject to price control posted by ARCO, Chevron, Mobil, and Union over the last five years.[1] Chevron, Mobil, and Union have used identical rates except for a short period during 1978 and 1979 and two months during early 1982. ARCO, oddly, has gone its own way for several years.[2]

This general congruence of prices should not be taken as evidence of collusion; in fact, we expect such a pattern in a completely competitive or a completely cartelized market. It is also important not to conclude that, because the major refiners post these prices, they

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[1]The adjustment factors are slightly more complex than those shown here. Mobil used several rates during 1978 and the beginning of 1979: 10 cents for 10-16 degrees API, 6 cents for 16-20 degrees API (as shown), and 4 cents for 20-40 degrees API. All the firms used a similar structure in 1982: 40 cents for oil of less than 20 degrees API (as shown), 20 cents for 20-34 degrees API, and 10 cents for 34-40 degrees API.

[2]One independent producer told us that ARCO's posted prices are not a good reflection of its true bid price. Its strong posted adjustment rates may reflect this.

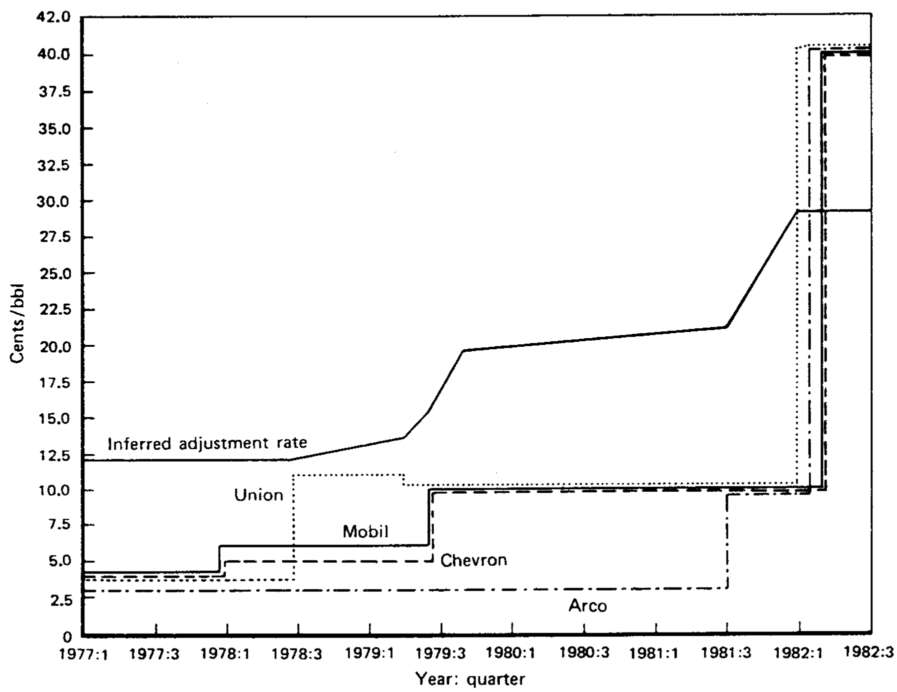

Fig. C.1—Posted and inferred adjustment rates in California

also <u>control</u> them. Their posted prices could just as easily reflect their estimates of competitive prices. A major antitrust suit is now under way to determine whether collusion has in fact occurred in California. Reaching a definitive conclusion about the extent of collusion in the market would carry us beyond the scope of this study. Successful collusion not sanctioned by the state is extremely unusual over any significant period of time, particularly during a period of turbulence like that we have observed recently in the California oil market. Because of this and because our data are broadly consistent with competitive market behavior, we have assumed that competition characterizes the California market for crude oil.

If these prices do reflect a competitive market, the adjustment rates should reflect the marginal cost of upgrading oil to be a substitute for oil one degree API higher. This is the explanation refiners usually gave us for adjustment rates, properly interpreted. In fact, the posted adjustment rates may not be the appropriate rates.

The "inferred" rates can be derived by regressing price on posted base gravity and the average sulfur content for a field in a cross-section of prices quoted in any bulletin. Table C.1 presents the results for several such regressions.[3]

Table C.1

PRICE ADJUSTMENT
(Cents per degree of gravity)

Year	May 1979	June 1979	June 1981	March 1982		
Gravity	All	All	All	<20	20-33	>34
Posted adjustment rate	5	10	10	40	20	10
Estimated adjusted rate (mean)	12	15.3	19.7	54	21	14
95 percent confidence interval	11.6-12.4	14.7-15.9	19.4-20	37-71	17-25	2-26
R-square	0.98	0.97	0.996	0.70	0.72	0.43

SOURCE: Price data are from Chevron Posted Price Bulletins.

For example, in June 1981, the posted adjustment rate for all levels of gravity was 10 cents per degree API. The "inferred" rate, estimated in the regression, was 19.7 cents, with a t-value of 20. The confidence interval for the estimated rate does not come close to

[3]Posted price and gravity are from Chevron's posted price bulletins; sulfur content (not shown) is based on Sohio data quoted in Bonner and Moore, 1980.

containing the posted rate.[4] Note that gravity and sulfur content explain virtually all the variation in posted prices. This is a general characteristic of regressions during periods when a single posted adjustment rate applied for all gravity levels. Only in March 1982 do the posted rates fall into the 95 percent confidence interval for the "inferred" rate and that only because the degrees of freedom in the regressions required to cover these posted rates were so few.

Fig. C.1 charts the "inferred" rate estimated from a series of regressions. It consistently lies above the posted rates except in 1982. To the extent that this rate represents the appropriate rate with which to compare the prices for different gravities of oil, note that the crude oil market for California becomes remarkably simplified; essentially one price schedule applies to the entire state. Several refiners have suggested to us that this is an appropriate way to view these prices. That is, schedules for individual fields simply become a veil for this more fundamental state-wide schedule.[5] Such a state-wide schedule offers a promising way to examine the magnitude of shortages of capacity to process heavier crudes; we did not have time to pursue this. Additional analysis should give the divergence of field-specific and state-wide schedules more attention.

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[4]Posted price falls 44 cents per percentage point of sulfur (t-value, -7.8).

[5]Note that this suggests that, if the major refiners are colluding, they have decided to forego one major benefit of collusion. Monopsonistic exploitation should be far easier in isolated fields than in the state as a whole. By tying the entire state together, such a schedule--if we have interpreted it properly--allows the refiners to exploit only those opportunities available at the state level.

Appendix D

PRODUCTION PLANNING AND TAX-INDUCED SHUT-IN OF WELLS

This appendix provides background material to help elucidate our analysis of shut-ins in Sec. VII. It first explains the basic factors producers consider when scheduling production over time. It then presents a simple mathematical model of production over time. The model allows us to choose profit maximizing decline rates and well lives and show how they depend on a producer's expectations about oil prices and production costs. Its results assist us in choosing cases for our shut-in analysis. Finally, the appendix explains the mathematics underlying the abandonment analysis itself.

OIL PRODUCTION OVER TIME

Production from an oil well or reservoir follows a fairly predictable path over time. In the beginning production rapidly rises to maximum capacity. It then gradually falls off until too little oil is produced each year to justify annual operating costs. The well is shut in and production ceases. If oil prices justify it, enhanced recovery can be used to "renew" production from a well. When this is used, primary recovery techniques are used first. Production declines under primary recovery until enhanced recovery begins. Production rises rapidly as cyclic steam processes are applied. Production is then generally switched to a steam drive process and gradually declines again unless additional enhanced recovery techniques are applied. A producer must decide how much capacity to give a well (under primary or enhanced recovery), how fast to allow production to decline (again, under either type of recovery), when and if to switch from primary to enhanced recovery, and when to terminate production. These decisions are obviously interrelated.

Our analysis treats primary and enhanced recovery separately. It essentially posits a fixed quantity of oil available through primary recovery and examines a producer's decision with regard to how to produce that oil over time. If a producer uses enhanced recovery, the analysis proceeds in precisely the same way. It posits a fixed quantity of oil available through any enhanced recovery technique and examines production over time. While this deemphasizes relationships between decisions about primary and enhanced recovery, it allows a simplicity that elucidates the important effects of a severance tax on production over time.

To understand how producers schedule production over time, it is important to understand first why production typically declines over time. Two reasons are important. The first is physical. Pressure within a reservoir of given volume is proportional to the amount of oil trapped within that volume. Hence, this pressure will drop as oil is removed. To the extent that production relies solely on internal pressure within a reservoir to lift oil to the surface, production will gradually fall over time as both the amount of oil in the ground and the pressure this oil provides fall. To the extent that pumping or enhanced techniques are used to free and lift oil, this effect is less important, but it does affect the cost of extracting oil; that cost will rise over the life of the well. This leads to less and less production over time.[1]

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[1] Specifically, given the capacity of wells in a reservoir, the per barrel variable cost of producing oil from the reservoir in any year rises as production increases. Production occurs where marginal profit--

The second reason is strictly economic. Given the fixed quantity of oil in the reservoir, the producer wants to assure that the present value of the marginal profit associated with its production is equal in all periods in which it was produced.[2] For present values of marginal profits to be equal, however, marginal profits in current dollars must increase over time. Hence, the gap between price and variable costs must rise over the life of the reservoir. Even if production costs were the same every year, then, production would fall over time to assure a growing marginal profit level in current dollars. In fact, as we discussed earlier, production costs rise over time in response to physical depletion. This complicates the economic effect, but does not change its basic character: it forces rising marginal profits over time that lead to falling production over time.[3]

Both physical and economic forces, then, encourage producers to allow production to decline over time from a peak level. The physical effect depends on geophysical characteristics of the reservoir and of the oil in it; similarly, the economic effect depends on the structure of costs and expectations about prices over time. Historically, these two effects together have tended to yield a constant percentage rate of

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the difference between price and cost--reaches the appropriate level. We will discuss what that level is in a moment. The important point here is that the level of production at which that marginal profit is reached falls over time as the general cost of lifting oil from the reservoir rises through time.

[2] If this were not true--if, for example, the present value of marginal profit were higher in period A than in period B--the producer could increase profits by rescheduling production so that more production occurred in period A and less in period B. Such rescheduling would continue until the present value of marginal profits were equal all around and profit could not be raised any higher by rescheduling.

[3] The complication arises from the fact that production in an early period causes the depletion that raises costs in later periods. This change in costs must be considered a part of the cost of producing oil early in the life of the reservoir. For a survey of studies that characterize the cost associated with such intertemporal dependencies, see Peterson and Fisher (1977). The important point here is that the presence of these complications does not change our qualitative conclusion that economic forces encourage decline in production over time.

decline. The historical prevalence of this pattern leads us to adopt it as a reasonable approximation of reality.

Note that both effects ultimately draw their power from the finiteness of the resource. Whether it is most useful to think of a reservoir or individual well in that reservoir as the most reasonable focus in any discussion of finiteness depends on how much "communication" occurs between wells in a reservoir--how easily oil flows in the rock structures between wells. If oil flows easily, production from any well is not finite in the same sense that the reservoir as a whole is. If oil does not flow easily, the oil accessible to each well is relatively finite and our attention can easily focus on the individual well. Communication is not typically good in the heavy oil reservoirs that characterize much California oil production. Hence, our analysis will usually concentrate on a typical well in a field. But similar analysis could just as easily consider a reservoir as a whole where communication is good.

Perhaps an even more basic issue is whether in fact fixed quantities of oil can be posited with regard to a well or a reservoir. Even if the quantity associated with a well or reservoir were known with certainty--and it is not--the amount that could be recovered could vary with the rate at which oil is extracted. A great deal of controversy exists about the effects of the rate of decline on the ultimate quantity of oil recoverable. Though techniques are available to predict these effects in specific cases, little empirical information is available to help predict these effects in a more general context. Sometimes an increase in the rate of decline increases the size of the recoverable resource; sometimes it reduces it.[4] In general, we will assume that

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[4] For an excellent overview of these effects and the empirical data available on them, see Lohrenz, 1981.

changes in decline rates have no effect on the total size of the rèsource.

In sum, the producer has a given quantity of oil to extract and he must choose a maximum initial capacity, a constant rate of decline from that capacity, and a termination date.[5] The simplest way to choose these values is to examine the well in a life cycle context and maximize the net present value of oil produced over the well's life. Net present value depends on production costs, net revenues, and a rate of discount. Three types of production costs are important: (a) the initial capital investment in capacity, (b) operating costs associated with each barrel of oil produced (for example, steam costs in a steam-drive system), and (c) operating costs independent of the production rate (for example, the cost of maintenance scheduled on a calendar basis). Revenues are simply the product of price and quantity over time, less taxes. In this context, the rate of discount is a producer's cost of capital net of taxes. Given these costs, prices, and taxes, the net present value of production from a well depends on its production profile over time. The producer chooses the production profile that maximizes net present value. The next subsection presents a simple model that allows us to do precisely that.

OPTIMAL DECLINE RATES AND WELL LIVES

This subsection presents a simple production planning model to illustrate the effect of several assumptions about oil price and production costs on profit-maximizing decline rates and well lives. Numerical results derived here provide one justification for the cases chosen for analysis in Fig. 7.4.

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[5] These parameters are closely related because any selection of them must just yield that quantity available in the reservoir. As shown below, once the producer has chosen the decline rate, the others follow immediately. That is, he need only optimize with regard to one parameter.

In this subsection, let

NPV = net present value

K = initial capacity

R = recoverable oil in the ground, assumed fixed in the face of alternative decline rates and known with certainty

p_o = real price of oil in the initial period, net of production-related costs and taxes

b_1 = real investment cost per barrel of initial capacity

b_o = annual real operating costs that are independent of production, per barrel of initial capacity

T = well life

r = real cost of capital, net of taxes

δ = production decline rate, assumed constant over time

π = real annual rate of escalation in oil prices, assumed constant over time.

A firm will plan production from a well or pool in order to maximize the net present value of that production:

$$NPV = -b_I K + p_o K \int_o^T e^{-(r + \delta - \pi)t} dt - b_o K \int_o^T e^{-rt} dt \qquad (D.1)$$

The first term is the investment cost, expressed as strictly proportional to initial capacity and summed to a single net present value figure for the initial period, t = 0. The second term is the net present value of revenues net of production related operating costs and taxes. It reflects an assumed exponential decline in production at a rate of δ per year, a rise in real price at a rate of π per year, and a real cost of capital net of taxes of r . The third term is the net present value of operating costs that are independent of the annual production rate. They are assumed to be strictly proportional to capacity and are discounted to the initial period at the cost of capital r .

T is endogenous in this maximization because net present value will be maximized if and only if production continues to the point where annual revenues net of production-related costs and taxes just equal annual operating costs independent of production:

$$b_o K = p_o e^{\pi T} K e^{-\delta T}$$

or

$$\frac{b_o}{p_o} = e^{(\pi - \delta)T} \qquad \text{(D.2)}$$

The firm will maximize (1) subject to (2) and a desire to recover a fixed quantity of recoverable oil in the ground (whose magnitude is known with certainty).

$$K \int_o^T e^{-\delta t}\, dt = \frac{K}{\delta}(1 - e^{-\delta T}) = R \qquad \text{(D.3)}$$

By manipulating (1) and substituting in (2) and (3), we derive the firm's profit function, which it maximizes by choosing a level for a single variable, δ :

$$\begin{aligned} NPV &= \left[-b_I + \frac{p_o}{r + \delta - \pi} \left(1 - e^{-(r+\delta-\pi)T} \right) - \frac{b_o}{r} (1 - e^{-rT}) \right] K \\ &= \left\{ -b_I + \frac{p_o}{r + \delta - \pi} \left[1 - \left(\frac{b_o}{p_o} \right)^{\frac{r+\delta-\pi}{\delta-\pi}} \right] - \frac{b_o}{r} \left[1 - \left(\frac{b_o}{p_o} \right)^{\frac{r}{\delta-\pi}} \right] \right\} K \\ &= \left\{ -b_I + \frac{p_o}{r + \delta - \pi} \left[1 - \left(\frac{b_o}{p_o} \right)^{\frac{r+\delta-\pi}{\delta-\pi}} \right] - \frac{b_o}{r} \left[1 - \left(\frac{b_o}{p_o} \right)^{\frac{r}{\delta-\pi}} \right] \right\} \left[1 - \left(\frac{b_o}{p_o} \right)^{\frac{\delta}{\delta-\pi}} \right]^{-1} \delta R \end{aligned}$$

(D.4)

As we would expect, (4) is homogenous of degree one in the three price-type parameters, b_I, b_o, and p_o . Hence, the optimal choice of δ will depend only on relative values of these.[6] We normalize on b_I. In the actual NPV function we maximize, then, 1 is substituted for b_I in (4), p_o/b_I for p_o, and b_o/b_I for b_o. NPV is also homogenous of degree one in R; we normalize its value to 1. We maximize (4) with a simple hill-climbing algorithm based on Newton's method.

We assume that a firm makes a calculation of this kind before it invests and then chooses a decline rate which will remain constant over the life of the well. The initial choices effectively define a path through time that is extremely costly to alter later. In fact, once capital is invested, a firm has an incentive to produce as much as possible in each period since production-dependent net marginal revenues are positive. It is constrained to the planned decline path by the initial choice of capacity. Hence, in trying to estimate optimal decline rates for wells now about to be abandoned, we must look back to the date when they were being planned. In doing so, we assume $r = .075$ to reflect a 15-percent real cost of capital and 50-percent marginal tax rate on capital, both long-standing planning figures. We assume $\pi = 0$ to reflect the situation before 1973. And we choose cost and price parameters to span the range of likely values:

p_o/b_I	.75, 1.00, 1.25, 1.50
b_o/b_I	.10, .15, .20, .25, .30, .35

p_o/b_I tends to rise with gravity; b_o/b_I tends to fall. Hence, extreme high values of p_o/b_I and b_o/b_I are unlikely together; low values of p_o/b_I and b_o/b_I are also unlikely together.

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[6] For example, doubling all of them will double the value of NPV at all values of δ; it will not change the value of δ as NPV reaches a maximum.

A firm responds to a change in anticipated real price escalation not by changing the decline rate, but by changing the life of a well. Recall that (2) defines the date of shut-in. If null-subscripted values of T and π represent the period before a change in π and unit-subscripted values represent the period afterward,

$$\frac{T_1}{T_0} = \frac{\pi_0 - \delta}{\pi_1 - \delta} \; \frac{\ell n(b_o/p_o)}{\ell n(b_o/p_o)} = \frac{\delta - \pi_0}{\delta - \pi_1} \qquad (D.5)$$

for a given value of δ .

Table D.1 presents values of δ and T_0 calculated from (4) under the assumptions above and of T_1 calculated from (5) for $\pi = .04$ on the basis of the previously calculated δ and T_0 . $\pi = .04$ represents the upper bound on recent forecasts of real oil price escalation. Hence, T_1 represents the maximum well life we should associate with each decline rate.

Note that T_1 will be defined only for values of δ greater than .04. If δ is smaller, annual net revenues no longer fall over time; production will go on indefinitely under our assumptions. Of course, it is unreasonable to expect a constant decline rate to continue indefinitely. Ultimately, decline must accelerate enough for annual net revenues to begin to fall. This is likely to occur any time the life of a well lengthens substantially.

Note further that where new anticipations about price escalation dramatically increase well life, the wells are unlikely candidates for current shut-in. For example, suppose a well life of 305 years were in fact appropriate for $b_o/b_I = .30$, $p_o/b_I = .75$. A 15-percent tax would cut the life of that well to about 260 years, still well into the future. On this basis alone, none of the cases with longer lives in Table D.1 should be relevant to us.

Table D.1

Optimal Decline Rates and Well Lives for Various Oil Prices and Production Costs[a]

		p_o/b_I			
b_o/b_I		.75	1.00	1.25	1.50
	δ	.100	.135	.166	.190
.10	T_0	20.2	17.1	15.2	14.3
	T_1	33.6	24.2	20.0	18.0
	δ	.081	.115	.146	.174
.15	T_0	19.9	16.5	14.5	13.2
	T_1	39.3	25.3	20.0	17.2
	δ	.066	.099	.129	.157
.20	T_0	20.0	16.3	14.2	12.8
	T_1	50.8	27.3	20.6	17.2
	δ	.054	.085	.114	.142
.25	T_0	20.3	16.3	14.1	12.7
	T_1	78.5	30.8	21.7	17.6
	δ	.043	.073	.101	.128
.30	T_0	21.3	16.5	14.1	12.6
	T_1	305.4	36.7	23.3	18.3
	δ	.032	.062	.090	.116
.35	T_0	23.1	16.9	14.2	12.6
	T_1	b	47.7	25.7	19.2

[a] b_o = operating costs, b_I = investment costs, p_o = initial oil price, δ = decline rate, T_o = well life for constant real oil prices, T_1 = well life for real oil prices rising 4 percent annually.

[b] Undefined because $\delta < \pi = .04$. See text.

Given these considerations and others that resulted from discussions with experts knowledgeable about California, we decided not to examine in detail wells with an estimated life longer than 35 years. While such wells clearly exist, we believe wells with shorter lives are far more likely to be important to our analysis of abandonments. This limit, combined with the results in Table D.1 were inputs to our decisions about the cases for analysis shown in Fig. 7.4.

BASIC SHUT-IN MODEL

To calculate the effects of shut-in on production, we make the following assumptions.

(a) In any particular field, one decline rate is appropriate for any well in that field. It is not sensitive to tax-induced price changes.

(b) A portion of operating costs for a well is tied to the capacity of that well and not to its actual production in any year.

(c) Production from a well continues so long as revenues net of taxes can cover annual operating costs.

(d) Production in the field responds to price only by responding to the balance of operating cost and revenue in point (c).

Under these assumptions, we can model the response of oil production to taxes in the following way. First, specify production in t_c, the "current period," from wells begun in t_o as

$$K(t_o)e^{-\delta(t_c-t_o)} \qquad (D.6)$$

where δ is the predetermined decline rate and $K(t_o)$ is the product of the number of wells and the capacity of a representative well begun in t_o. Second, assume that $K(t_o)$ is an exponential function of time:

$$K(t_o) = K^* e^{\theta(t_o - t^*)} = \bar{K} e^{\theta t_o} \tag{D.7}$$

where K^* is capacity at some arbitrary date t^*, $\bar{K} \equiv K^* e^{-t^*}$. θ can represent a growth of rate for capacity or a more general measure of the mix of old and new wells on a property, and can be negative or positive. We discuss this in the text. Third, revenue net of production-related operating costs and taxes from wells begun in t_o during t_c is

$$p\ K(t_o) e^{-\delta(t_c - t_o)} \tag{D.8}$$

while costs are $b_o\ K(t_o)$. Production from wells begun in t_o continues until

$$(p\ e^{-\delta(t_c - t_o)} - b_o)\ K(t_o) = 0 \tag{D.9}$$

For given p, δ, and b_o , this defines a value $T = t_c - t_o$ for which the equality in (9) holds.

This information is sufficient to tell us how much production will occur in t_c from all wells producing profitably in t_c . Bringing (6) and (7) together tells us how much oil is produced from each vintage of wells.

$$\bar{K} e^{\theta t_o} e^{-\delta(t_c - t_o)} = \bar{K} e^{-\delta t_c} e^{(\theta + \delta) t_o} \tag{D.10}$$

Integrating (10) over the range of vintages that can profitably produce in t_c yields:

$$\bar{K} e^{-\delta t_c} \int_{t_c - T}^{t_c} e^{(\theta + \delta) t_o}\, dt_o$$

$$= \bar{K}e^{-\delta t_c} \left(\frac{1}{\theta+\delta}\right) \left[e^{(\theta+\delta)t_c} - e^{(\theta+\delta)(t_c-T)}\right]$$

$$= \frac{1}{\theta+\delta} \bar{K}e^{-\delta t_c} e^{(\theta+\delta)t_c} \left(1 - e^{-(\theta+\delta)T}\right)$$

$$= \frac{1}{\theta+\delta} \bar{K}e^{\theta t_c} \left(1 - e^{-(\theta+\delta)T}\right) \tag{D.11}$$

Note that $\bar{K}e^{\theta t_c}$ is simply the capacity added in t_c (from (7)). Eq. (11) simply relates total production to this figure.

We assume that in the short term, δ is fixed. Under these circumstances, if p changes, it changes T by changing the equilibrium in (9). For example, (9) tells us that, if net revenue changes from p^o to p^1

$$T^1 - T^0 = \frac{1}{\delta} \ln (p^1/p^0) \tag{D.12}$$

Note that a percentage change in price leads to the same <u>absolute</u> change in T, no matter how large the absolute change in price is. This results from the exponential form of the relationship in (9).

Eqs. (11) and (12) give us the basis for estimating how much a particular price change affects the life of a representative well. From (11), for example, we know that for T_i, production in t_c is

$$\frac{1}{\theta + \delta} \bar{K}e^{\theta t_c} \left(1 - e^{-(\theta+\delta)T_i}\right)$$

Hence, the <u>change</u> in production when T_i changes from T_0 to T_1 is

$$\frac{1}{\theta + \delta} \bar{K}e^{\theta t_c} \left(e^{-(\theta+\delta)T_0} - e^{-(\theta+\delta)T_1}\right) \tag{D.13}$$

Taken as a percentage of production before the change, we get

$$\frac{e^{-(\theta+\delta)T_0} - e^{-(\theta+\delta)T_1}}{1 - e^{-(\theta+\delta)T_0}} \qquad \text{(D.14)}$$

This is the basic expression we will use to characterize percentage effects of shut-in on production.

Appendix E

TAX EFFECTS ON NEW INVESTMENTS

As discussed in Sec. V, a major part of the burden of a severance tax will be borne by producers. Undoubtedly, imposition of a tax will cause delay and/or cancellation of new investments by reducing profitability. In particular, a new tax lowers the oil price received by producers in any given year and hence restricts the types of new investments that firms might undertake. We undertook a variety of statistical analyses to explain what types of investments a new tax would discourage.[1]

As explained in Sec. VIII, we found a change in price (or tax) level was unlikely to affect one generic type of oil production more than another, at least at the levels of aggregation that are appropriate for statistical analysis. No analyst is happy with such a "negative" finding, particularly when it contradicts his priors going into the analysis. Nonetheless, though we cannot characterize our analysis as being more than exploratory, we would now not expect to find qualitative results much different from these if we continued the statistical analysis in more detail. This appendix explains the basis for that conclusion. In particular, it explains the types of statistical analysis we pursued and the reason why, though individual models showed many significant affects, the work as a whole leads to negative findings in general. We see no point in presenting the specific empirical findings themselves, beyond those offered in the text.

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[1] Data used were compiled from California Oil and Gas Division well-data files, CCCOP 1980, R-2654/2, and price lists of oil companies. Unit of observation was defined by properties, where all the wells operated by a single operator in a specified pool were assumed to make a property. For details see Arguden (1982).

THEORETICAL BASIS FOR THE CHOSEN VARIABLES

As noted in Sec. VIII, rising prices steadily expand the depth to which wells can be drilled, the range of gravities and sulfur contents that can be exploited, the range offshore, and so on. Hence, to the extent that rising prices make new investment possible, we expect (somewhat paradoxically) that among producing properties in a particular year, properties with new investment in that particular year will have relatively higher production and refining costs. Despite price controls, oil prices rose steadily (though slowly) through the 1970s. They rose markedly for heavy oil when it was decontrolled in 1979. As a result, looking across properties with producing wells in 1981, we would expect ceteris paribus new investment to be positively related to the following variables:

- construction, capital, and operating and maintenance costs (higher prices justify higher costs)
- low gravity (heavier oil is harder both to produce and to refine)
- small pay thickness (higher prices justify the fixed costs required to reach pools of smaller size)
- little remaining oil in place[2] (for the same reason as that for pay thickness)
- steam injection per barrel of oil (holding gravity constant, higher prices justify greater steam injection to exploit higher viscosity reservoirs)

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[2] Obtained from R-2654/2 and a separate heavy oil data-base compiled at Rand for DOE by Richard Nehring.

- low gas production per barrel of oil (less revenue from gas is required to cover costs).

We could test these hypotheses in a model of the form:

$$N_i = f(X_i \cdot \beta) + \varepsilon_i \qquad \text{(E.1)}$$

where

N_i = number of new production wells in 1981 for the i^{th} property[3]

X_i = vector of independent variables for the i^{th} property

β = vector of parameters, to be estimated, showing the effect of the respective variables on new production wells.

ε_i = error term for the i^{th} property

The relative size of the parameters, β, could also give us information on the relative effects of price increases on the characteristics of properties for which production was profitable. Such information could prove useful in tax design if the relative effects were well enough defined to suggest that properties of different kinds would respond in systematically different ways to the effective price cut a tax would effect.

In addition to these variables, we considered a number of others. Number of producing wells on a property acted as a scale proxy; it might also indicate how much field-specific technical knowledge an operator has about a property. We expected it to be positively correlated with

[3]Because the ultimate goal of investment is oil production, the dependent variable chosen was new production wells rather than total new wells, which include service wells and injection wells. This choice of a variable to represent investment decisions is justified by a very high, above 96 percent, success rate in developmental wells, which consist of 95.2 percent (= 2091/2196) of all new oil production wells. The rest is accounted for by successful exploratory wells, which have a different underlying investment structure. (SOURCE: American Petroleum Institute Monthly Drilling Reports for 1981.)

number of new wells. Size of operator and the share of an operator's total production that occurs in California could affect a property operator's willingness to invest; we had no prior expectation about the direction of these effects. Location in areas with serious environmental problems could impede new development. We expect this to be an especially serious problem in Kern and Los Angeles counties. Finally, depth of wells on a property provided an especially attractive proxy for a wide variety of costs. In particular, drilling and completion, producing equipment, other lease equipment, new injections equipment, well workover and operating and maintenance costs were computed from depth figures by using cost-estimating relationships developed by Lewin and Associates (1981). Here, we would expect greater depth to lead to more new production wells.

How any of these variables would be related to new production wells would depend on geophysical characteristics, on investment decision processes, and other factors that do not immediately suggest a functional form for (E.1). Hence, we expected results on the effect of any one of these variables to be interesting and useful only to the extent that it remained robust across several functional forms.

FUNCTIONAL FORMS

We used ordinary least squares, two-part probit, and negative binomial models to examine investment decisions.

Ordinary Least Squares Model

We started by using the variables above individually and simultaneously, in ordinary least squares regressions with linear and logarithmic functional specifications for the function f (.) in (E.1).

An untransformed dependent variable and the logarithm of it were used. The logarithm of the dependent variable was the preferred specification because the impossibility of negative investments and the low rate of new additions made it impossible for the untransformed data to be normal.

Two-Part Model

One of the problems with the multiple regression models which were used to estimate function of f (.) in (E.1), was that a large number of properties did not have new additions in 1981, making the distribution of our dependent variable highly skewed. In other words, the existence of a large number of properties with no investment made it impossible for the data to be normal or lognormal. Furthermore, we expected the decision to invest or not to be related to the same independent variables. Therefore, errors would be correlated with independent variables and the estimates would be statistically inconsistent. We used a two-part model to correct this problem. For this purpose, we analyzed investment decisions in two stages. The first stage consisted of a probit model, which attempted to explain a dichotomized decision to invest or not. The second stage tried to explain the number of new production wells conditioned on a decision to invest. Formally, our model had two equations:

$$D_i = X_i\beta + \varepsilon_i \qquad \varepsilon_i \sim N(0,\ 1) \qquad \text{(E.2)}$$

Where

D_i = zero-one variable indicating an investment decision for the i^{th} property

X_i = vector of independent variables for the i^{th} property

β = vector of coefficients for equation (E.2)

ε_i = error term for the i^{th} property

and $\log (N_i \mid D_i = 1) = X_i \gamma + U_i \quad U_i \sim N(0,\sigma^2)$ (E.3)

where

N_i = number of new production wells

γ = vector of coefficients for equation (E.3)

U_i = error term for the i^{th} propety.

The expected number of new additions in a property with characteristics X_i can be calculated by substituting appropriate estimates of β, γ, and σ^2 into[4]

$$E(N_i \mid X_i) = P_i \cdot E(N_i \mid O_i = 1, X_i) \tag{E.4}$$

$$= P_i \exp (X_i\gamma + \sigma^2/2)$$

where

$$P_i = Pr(D_i = 1) = Pr(N_i > 0) = \Phi(X_i\beta)$$

and Φ denotes normal cumulative distribution.

The estimate obtained from equation (E.4) can be statistically inconsistent if U_i is not normally distributed. However, our normal plots for the second stage of this model indicated that normal distribution was a close approximation for the distribution of U_i.[5]

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[4] Failure to multiply by the exp $(\sigma^2/2)$ term in equation (E.4) will result in predicting median number of new additions rather than expected number of new wells.

[5]For further technical discussions of the two-part model, see N. Duan, W.G. Manning, Jr., C.N. Morris, J.P. Newhouse, Comparison of Alternative Models for the Demand for Medical Care, The Rand Corporation, R-2754/HHS, January 1982.

Negative Binomial Model

The fact that new additions can only take integer values suggests that we should use a discrete probability function to model new well additions. The negative binomial function offers an attractive basis for such a model. It allows us to explain the number of new wells added to the i^{th} property in one year, n_i, in the following way:

$$P(N=n_i) = \frac{\hat{\lambda}_i \exp(-\lambda_i)}{n!} \tag{E.5}$$

where

$$\lambda_i = A_i \exp(X_i\delta) \tag{E.6}$$

$$A_i \sim \Gamma(\theta) \tag{E.7}$$

for

λ_i = rate at which wells are added on the i^{th} property

N = random variable

$\Gamma(\theta)$ = gamma distribution with parameter, θ.

The model uses information on n_i and X_i to estimate δ and θ, which in turn allow us to explain how elements of X_i affect the level of n_i.

The negative binomial model works in the following way. If A_i were not distributed gamma with parameter θ, but were instead a constant and equal for all i, (E.5) and (E.6) together would define a Poisson model. We would have to make two important assumptions to use this simplified version of the negative binomial model. First, additions would be assumed independent of each other. Although investments for enhanced recovery, in particular for steam flooding, are made in 5-, 7- or 9-spot patterns where one injection well is surrounded by production wells, our data did not indicate clustering of investments. In fact, there were 74 properties with only one new production well (see Table E.1). Therefore, the assumption of independence of new wells is not a bad approximation. Second, the mean and variance of the distribution of new wells should both be equal to λ for the Poisson to be a good approximation of reality. This assumption is too strict, and we did not expect it to hold. Therefore, instead of assuming A_i are all equal to a common constant, we assume they are distributed according to a gamma distribution, turning our model back into a negative binomial model.

Table E.1

DISTRIBUTION OF NUMBER OF PROPERTIES[a] BY NUMBER OF NEW PRODUCTION WELLS

Number of Properties	Number of New Production Wells	Number of Properties	Number of New Production Wells
2157	0	2	16
74	1	2	18
27	2	1	21
20	3	2	22
12	4	2	23
9	5	2	24
6	6	1	30
2	7	1	37
9	8	1	42
3	9	1	43
7	10	1	45
4	11	1	47
3	12	1	58
1	13	1	105
1	14	1	437
1	15		

SOURCE: Data base compiled at Rand from California's Division of Oil and Gas well-data files, CCOP 1980 and R-2654/2.

[a]All wells operated by a single operator in a specified pool are assumed to make a property.

A gamma distribution can represent a wide range of functions, depending on the value of Θ, which is to be estimated. Hence, it allows a great degree of flexibility. We can interpret A_i as follows: For every property, we have a set of observable factors, X_i, which affect investment decisions in that property. But for every property, there are other factors we could not observe, and these factors, too, have an effect on the investment decisions. Therefore, we may have two observations with identical values of independent variables but with different levels of investment. Different realizations, A_i and A_j, from the gamma distributions, $\Gamma(\Theta)$, may be assumed to be the reason of this unexplained difference in investment levels of these observations. In making inferences, we will not be able to make different predictions for these two observations, but our inferences will indicate the general tendency of the investment rate, given a set of values for the independent variables. Individual properties will have different realizations of investment rates around this general tendency according to a gamma distribution. In short, this formulation incorporates our ignorance about the investment decisions in individual properties but enables us to make inferences about the general tendency to invest.

RESULTS

The models described in the previous subsection were applied to the full sample of properties and subsections of the sample when there were enough observations to make reasonable estimations. In particular, models were fit to subsamples consisting of Kern County, offshore, and Los Angeles and Orange County properties. In addition, to be able to capture simple general trends, the variables were dichotomized.

The only significant effect that was robust with regard to model specification was the effect of existing production wells. That is, new additions increase as the number of existing production wells becomes larger. However, the proportion of new additions to existing wells did not differ with property size. The rest of the independent variables were not robust with regard to model specification and usually they were insignificant. Where they reached significance levels, it was clear that they represented the general tendency of the producers to invest in heavy oil pools especially in onshore fields. In particular, API degrees and depth had negative coefficients and steam injection had positive coefficients for onshore fields. The coefficient of depth, which was intended to be a proxy for costs, did not have the expected sign. Because heavy oil pools are usually in shallow geological formations and require enhancement, apparently this proxy was indicative of a tendency to invest in heavy oil pools. (See Sec. VIII for a discussion of the reasons for this tendency.)

Furthermore, we found no statistical evidence for differential investment rates by operator characteristics like scale of operations and percentage of California production to world production. Therefore, we conclude that simple measurable factors like gravity, depth, production from recent wells, steam-to-oil ratio for enhanced recovery projects, associated gas production or producer characteristics do not have well enough defined effects on new investment to use them to differentiate tax rates on different types of properties.

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