EFFECTS OF A SEVERANCE TAX ON OIL PRODUCED IN CALIFORNIA: REJOINDER

Frank Camm, Christopher W. Myers

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PREFACE

In September 1982, The Rand Corporation published a study of how a new severance tax on California oil production would affect, among other things, government tax revenues, profits, and oil production (F. Camm et al., Effects of a Severance Tax on Oil Produced in California, R-2940-CSA, September 1982). Funded by the California State Assembly, the study provided a framework for discussion of several severance tax alternatives under consideration. Shortly thereafter, eleven oil companies jointly funded a study by The Economics Group, Inc., which reviewed the Rand analysis and attempted to extend parts of it (R. T. Deacon et al., The Proposed California Crude Oil Severance Tax: An Economic Analysis, The Economics Group, Inc., RFD-83038-CC, February 1983). This Note is a rejoinder to that study.
SUMMARY

Rand's 1982 study of the effects of a new severance tax on California oil production provided a framework for discussion of several severance tax alternatives under consideration in the state legislature (see Preface). Shortly thereafter, eleven oil companies jointly funded a study by The Economics Group, Inc. (hereafter TEGI), which reviewed the Rand analysis and attempted to extend parts of it. This note is a rejoinder to TEGI's comments on our earlier report.

TEGI'S CRITIQUE OF THE RAND ANALYSIS

TEGI's analysis makes one important addition to the Rand analysis. By implicitly assuming that income taxes are a relevant cost to oil producers who are thinking about shutting in their wells, Rand argued that a portion of the cost of a severance tax relevant to this decision is tax deductible. TEGI correctly pointed out that income taxes are not relevant and hence none of the severance tax is deductible. A 6 percent statutory tax rate is also a 6 percent effective tax rate for the purposes of this one part of Rand's analysis. As a result, production from existing wells responds more than Rand had predicted--about 1.2 percent instead of 0.6 percent for a 6 percent tax. This change also raises Rand's estimate of the portion of the tax paid by California oil companies: The 35 to 50 percent portion paid after about a year, and the 55 to 80 percent portion paid after 10 years, rise by about 3 percentage points, or about 4 to 9 percent.

These are the only changes that TEGI's criticism, carefully examined, dictates. The great majority of Rand's findings remain valid. Little of TEGI's criticism of Rand's results and methods stands up to close scrutiny.

This is true in part because TEGI so often misstates material from the Rand report. For example, TEGI claims (p. 36):
Rand (p. 88) concludes that "to the extent that refiners bear a portion of the tax, integrated producers will be more heavily affected than nonintegrated producers." This non sequitur is offered by Rand (p. 140) as another reason why the "pattern of the tax's incidence within California is likely to have . . . features that many California policymakers will find attractive."

Despite heavy quotation from the Rand study, this statement is simply false. What Rand actually said is the following (p. 140):

The pattern of the tax's incidence within California is likely to have two features that many California policymakers will find attractive. . . . First, . . . final consumers within California are unlikely to feel much of the effect of the tax. . . . Second, . . . a uniform severance tax is likely to fall more heavily on light oil producers than on heavy oil producers.

TEGI is often careless in its statements about the Rand work. As a result, we can deal with many of TEGI's concerns by simply restating what Rand actually said.

TEGI also applies inappropriate data to Rand's analysis in their critique.

For example, TEGI argues that the literature on production response strongly suggests that an effective 6 percent tax would cut production 6 percent. The tax effect on production is important in itself and because it affects how much revenue California can collect and ultimately who pays the tax. Rand expects a production cut of no more than 4 percent from such a tax during the decade after it is imposed. Ironically, TEGI's own analysis of California predicts a production cut of about 3.4 percent during the decade following introduction of a tax, the only period Rand considers. This value is fully consistent with values of production cuts that Rand considers.

Similarly, TEGI uses state-wide average parameter values to examine Rand's analysis of tax-induced production response from existing wells. But Rand's analysis is not designed to use state-wide averages. The use of state-wide averages yields a lower-bound estimate of how much production from existing wells falls after a tax; it cannot predict the
actual level of production cut. Viewed in this way, an application of state-wide averages verifies that Rand's estimate of response from existing wells--about a 1.2 percent production cut for a 6 percent effective tax--is quite reasonable.

**TEGI's Extensions of the Rand Analysis**

Rand estimated tax-induced effects on production by looking at production from existing and new wells separately. TEGI continues this approach and attempts to move beyond Rand's analysis in both areas. TEGI's analyses in both areas suffer similar problems. TEGI starts with widely accepted economic models. But the models used in both areas do not properly capture vital information about oil production in California. And TEGI offers little information on the extent of uncertainty or the effects of small changes in the scenarios it uses in both areas.

For example, TEGI's analysis of production from existing wells requires accurate measures of oil remaining to be produced by existing wells and the decline rate of individual wells in a field. TEGI assumes that currently reported proven reserves will all be produced from existing wells. They will not; significant portions will be developed with new wells. TEGI also assumes that the rate at which average production per well in a field changes over time reflects the decline rate relevant to tax analysis. It does not; in Sec. IV below, we construct a simple example in which the rate that TEGI measures is unrelated to the decline rate their analysis requires. Apparently as a result of this misspecification, TEGI has a great deal of difficulty measuring decline rates and must resort to *ad hoc* methods to assign decline rates to fields where over half of TEGI's predicted production response occurs. Though TEGI does not report it, we demonstrate that its production response estimates are extremely sensitive to small errors in the decline rate estimate. Hence, the misspecification and these *ad hoc* methods raise serious doubts about TEGI's results. Taken together, these problems leave us with little faith in any of the production response estimates TEGI develops for existing wells.
TEGI's analysis of production from new wells joins a standard econometric investment model with a simple scenario in which future real oil prices remain constant.

The investment model is unlikely to be stable over the period of estimation, 1947 to 1981, or the period of prediction, 1982 to 2011. This is true because (a) price controls during the 1970s distorted TEGI's price variable, (b) price expectations are likely to be sensitive to changes in price controls and OPEC pricing not reflected in the model, (c) TEGI's method for incorporating the effects of changes in the geological, engineering, and technological factors relevant to new investment requires that information on these factors from beyond 1981 is irrelevant, and (d) TEGI misspecifies the influence of the windfall profit tax on new investment. If the model is unstable, we simply cannot believe its predictions.

Even if it is stable, however, the future remains highly uncertain. We can expect the thirty years of TEGI's period of prediction to offer the same variety of surprises we have experienced in the last thirty. TEGI says little about uncertainty, either through the use of confidence intervals calculated from its econometric model or through sensitivity analysis around its "baseline" scenario. For example, a one percent increase in the rate at which real oil prices rise beyond TEGI's assumed zero rate of change eliminates any tax effects on cumulative production beyond about the sixth year after the tax is imposed. TEGI does not report the results of this type of sensitivity analysis.

Because we doubt that TEGI's model is stable and cannot use TEGI's reported results to determine what range of outcomes is reasonable even if the model is stable, we do not believe TEGI's results on production from new wells will be useful to policymakers.

The Rand Corporation takes no position on whether California should adopt a severance tax. Our work for the Assembly has been aimed at clarifying the principal issues associated with such a tax and providing defensible, objective information that Assembly members can use to decide whether California should adopt a severance tax. We believe that additional analysis can help legislators make an informed decision.
ACKNOWLEDGMENTS

We wish to thank Yılmaz Argüden, David Lyon, Edward Merrow, Richard Nehring, Charles Phelps, and Daniel Relles of Rand, and James Campion of the Division of Oil and Gas, for their help in preparing this Note. We, of course, remain responsible for any errors of fact or interpretation.
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1. INTRODUCTION

In September 1982, The Rand Corporation published a study of how a new severance tax on California oil production would affect, among other things, government tax revenues, profits, and oil production. This work was funded by the California State Assembly. It was designed to provide an analytic framework for discussion of several severance tax alternatives that the Assembly was considering at the time. In February 1983, The Economics Group, Inc. (hereafter, TEGI), published a study of the effects of a severance tax that covered many of the issues considered in the Rand study. This work was prepared for and funded by eleven oil companies, who together produce about two-thirds of the oil produced in California. A significant portion of the TEGI study provides a critique and extension of the analyses offered in the Rand study. This Note is a rejoinder to TEGI’s comments on the Rand study.

When we first received the TEGI study from the Assembly for review, we were naturally curious to see how well our analysis had held up under a second round of close scrutiny. (The first round came during Rand’s formal review process preceding publication.)

Throughout the body of the Rand report, answers to the questions addressed were presented as ranges of numbers. Using guidelines offered in the text, readers who wished to could narrow these ranges to reflect their own assumptions and circumstances. We presented and explained more specific results in our conclusions. The TEGI authors had some difficulty reconciling these sets of numbers. This problem seemed to stem from two difficulties. First, TEGI did not understand Rand’s basic approach. Rand’s principal goal in pursuing quantitative analyses was to "provide a defensible framework for thinking about tax effects in the debate." The analyses presented [in the Rand report] should

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1 F. Camm et al., Effects of a Severance Tax on Oil Produced in California, The Rand Corporation, R-2940-CSA, September 1982, (hereafter referred to as "Rand").

provide not only answers to present questions but also several paths to answers to questions that will arise in the future" (Rand, p. 34). We offered a set of tools that people whose views on severance taxes differ could use to determine how important their differences were. In our conclusions, we narrowed the range of answers so as to present results that were consistent with assumptions that appeared most reasonable to us. This raised TEGI's second problem: They disagreed with our choice of assumptions. Because results derived with our assumptions differed from theirs, they argued that it was possible to use our tools to get answers very different from those we offered in our conclusions. Allowing this opportunity, of course, was precisely the point of our quantitative analysis. The work was meant to help frame a debate in which we could expect the participants to hold many different assumptions about California oil production. TEGI's critique demonstrates how easy it is to use the framework we built. Properly viewed, then, our analysis held up quite well.

We were also curious to see how much further along additional analysis could take the work we had started. On this point, we were disappointed. Despite extensive empirical work, TEGI brings little new light to bear on the key questions we had addressed:

How much new revenue does the state receive?
How are final consumers affected?
How are oil company profits affected?
How is total oil production affected?

What we found was straightforward application of basic economic tools, but only superficial understanding of the basic policy issues and important institutional structures examined with those tools. Hence, the applications were often inappropriate. We also found a basic unwillingness to characterize uncertainty or the effects of departing even slightly from the simple baseline scenarios that TEGI used in its analysis. These weaknesses will make it extremely difficult for policymakers to draw new and useful insights from TEGI's extensions of work in the Rand study.

This Note concentrates on Secs. 2 and 4 and Apps. A and C of the TEGI study. We do not comment on other parts of the study; they are not relevant to Rand's analysis. On the basis of this limited review, we
find that TEGI has made one useful addition to the Rand analysis. We discuss this in Sec. II below. Unfortunately, we find that most of the material we reviewed is less helpful. Section 2 of the TEGI study in particular seriously misrepresents our reported findings. As a result, a great deal of energy is expended without yielding much progress toward a better understanding of what a severance tax would do. We clarify our original results in Sec. III below to assure that TEGI's analysis does not create any confusion about them. In their Sec. 4, the TEGI authors attempt to move beyond the Rand findings to improve our understanding of how a severance tax would affect oil production. In this effort, they use several models and techniques that we explicitly considered and rejected as inappropriate. We do not attempt a definitive critique of TEGI's use of these models, but in Sec. IV below, we explain why we rejected them and argue that findings based on them should be viewed with extreme caution. We suggest a simple way to test the validity of the findings. Section V recaps our principal conclusions.

The Rand Corporation takes no position on whether California should adopt a severance tax. Our work for the Assembly has been aimed at clarifying the principal issues associated with such a tax and providing defensible, objective information that Assembly members can use to decide whether California should adopt a severance tax. We believe that additional analysis can help Assembly members make an informed decision. We look forward to seeing more serious analysis directed toward that purpose.
II. TEGI'S ADDITION TO THE RAND ANALYSIS

TEGI's analysis makes one useful addition to the Rand analysis. It corrects Rand's treatment of income taxes in the analysis of production response from existing wells. The correction increases the relevant production response slightly over one half percentage point and thereby increases the share of a severance tax that California companies would pay by about 4 to 9 percent. All of the 156a necessary to make these changes are present in the Rand report.

Rand's analysis of how a severance tax would affect production from existing wells implicitly includes income-based taxes as a cost relevant to the operator in determining the minimum level of annual production he can tolerate before shutting in production. TEGI correctly argues that income-based taxes are not relevant to that decision. Their theoretical argument is quite clear and well presented (see TEGI, pp. 156-161).¹ It has the following implications for Rand's empirical results.

First, the effective tax rate relevant to our analysis of production from existing wells is now approximately equal to the statutory rate. For a 6 percent severance tax, Table 7.3 (Rand, p. 105; reproduced below on p. 11 as Table 2) replaces Table 7.4 (Rand, p. 108) in Rand's analysis. The median production response to such a tax rises from 0.59 percent to 1.21 percent, or by about 0.6 percentage points.² That is, a six percent tax will cut back production from existing wells roughly 1.2 percent.

Second, this change alters the implicit short-run supply elasticities underlying Rand's analysis of net tax revenue for the state and the percentage of the tax borne by California companies. In particular, it raises |(ΔQ/Q)/Δt| from 0.1 to 0.2 (see, for example, Rand, pp. 54, 58).³ This change has a trivial effect on net revenue for

¹ Their empirical analysis, presented in TEGI, pp. 24-29, is flawed. We explain why in the next section. Problems in that presentation, however, do not alter the theoretical point underlying their example. The theoretical point is valid.
² TEGI challenges Rand's use of median production response as a useful summary statistic; we still believe it is appropriate and explain why in the next section.
³ (ΔQ/Q)/Δt is the percentage change in production induced by a change in the severance tax rate.
California from the types of properties most important in the state—properties which are owned by multinational firms and whose assessed value for tax purposes is unaffected by the severance tax. It reduces net revenues by less than a percentage point on most other property types (see Rand, pp. 54, 58). This change is minor in comparison with the 92 to 98 percent net revenue predicted in the Rand conclusion (p. 139). The change raises the share of the tax borne by California companies on the type of properties most important in the state (see above) by about 3 percentage points. Tax share can rise slightly more than 4 percentage points on some other property types (see Rand, pp. 71, 72). These changes represent less than a 10 percent change in the 35-to-50 and 55-to-80-percentage-point ranges reported in the Rand conclusion (p. 139).
III. MISUNDERSTANDINGS ABOUT RAND'S ANALYSIS AND CONCLUSIONS

The lion's share of TEGI's critique of the Rand study appears to be based on misrepresentations of Rand's analytic approach and conclusions. TEGI frequently reproduces statements from the Rand study inaccurately and then uses their misstatement of Rand's work as a straw man. A more reasonable and careful reading of Rand's analysis and conclusions would have saved TEGI a great deal of unnecessary thrashing about. Unfortunately, we fear that TEGI's discussion may confuse many readers of both studies about the true intent, content, and reliability of the Rand work. In this section, we review five major criticisms raised by TEGI and explain why they are misinformed or misdirected. We then consider two particularly important misunderstandings of the California oil market itself that come out in TEGI's discussion.

GENERAL PRODUCTION RESPONSE

How much a tax might reduce oil production in California is important in itself. It is also important to other issues, including questions of how much new tax revenue the tax can raise and how much of the tax is paid by California companies and the federal government. TEGI's discussion of production response to a tax has two problems. First, it misrepresents the conclusions reported in the Rand report. Second, in its critique of Rand's study, TEGI advocates the use of a unitary supply elasticity.¹ The value of the supply elasticity is important to policymakers because it summarizes the effect that tax changes have on production: the larger the elasticity, the larger the effect. TEGI's own analysis yields a supply elasticity much closer to that underlying the Rand conclusions which TEGI criticizes, than to unity. This suggests that the inconsistency TEGI sees in Rand's work in fact results from an inconsistency in TEGI's interpretation of Rand's work.

¹ A supply elasticity of unity states that production rises one percent for every one percent increase in the price producers receive net of taxes.
TEGI claims that Rand effectively assumes in its conclusions that a severance tax has no effect on production. For example: "Rand simply reported as a major conclusion the 30-55 percent burden figure, a range of estimates that assumes that the tax induces no production effect whatever" (TEGI, p. 8). Or: "Rand, in its conclusions, employed the assumption of no production cut" (TEGI, p. 12). These statements are simply false. The conclusion to the Rand report in fact states the following: "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" (Rand, p. 139). The conclusion then goes on immediately to discuss the implications of these production responses for the tax burden on California companies. We discuss this issue at greater length below.

TEGI's discussion of the appropriate level of supply response to use in Rand's analysis is also puzzling. Despite their insistence throughout the report that an elasticity of unity is appropriate, their own estimates support this value only in a very limited context. For example, it is easy to calculate the following average flow elasticities for the first, second, and third decades after the tax is imposed from TEGI's estimates of tax effects in Table 4.3 (TEGI, p. 103): 0.57, 1.3, and 2.2. Cumulative supply elasticities for these three decades are 0.57, 0.92, and 1.3. Whichever interpretation of supply response we choose--and both are represented in TEGI's references to the literature in Table 2.3 (TEGI, p. 13)--TEGI cannot justify an elasticity as high

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2 A flow elasticity is the percent change in production during any one period--for example, a year--induced by a one percent price change. Hence, the average annual flow for the second decade is \((7454 - 3646)/10 = 380.8\). The average fall in flow is \((412 - 123)/10 = 28.9\) or a 7.6 percent reduction. A 6 percent tax will induce such a reduction if the supply elasticity is \(7.6/6 = 1.3\).

3 A cumulative elasticity is the percent change in production from today through some future date--for example, over the next decade--induced by a one percent price change. The numbers in the text are simply calculated as follows: 3.4/6, 5.5/6, and 7.7/6.

4 It is also worth noting that each of the elasticities in TEGI's references is defined differently. There is no reason to believe that the elasticity in California would be the same as those in TEGI's table. For example, the "Rand" elasticity cited is for total U.S. production over an unspecified horizon. (This elasticity is from C. E. Phelps and R. T. Smith, Petroleum Regulation: The False Dilemma of Decontrol, The Rand Corporation, R-1951-KC, January 1979.)
as unity unless we speak of very-long-term elasticities associated with the second decade following imposition of a tax or beyond.

If TEGI were consistent in its analysis, it would use its elasticity value for the first decade after the tax—0.57—to discuss the Rand analysis. Rand makes no statements about results beyond the first decade following the tax. Such an elasticity implies a 3.4 percent drop in production in response to a 6 percent severance tax, which falls well within the range of production cuts of 1 to 4 percent discussed in Rand's conclusions. This should not be taken as an endorsement of TEGI's analysis of supply response. We discuss that below in Sec. IV. At this point we simply wish to demonstrate that applying TEGI's own assumptions to Rand's analysis yields answers consistent with the conclusions to the Rand study. TEGI's misrepresentation of Rand's work therefore suggests gross misunderstanding of the Rand analysis, the Rand conclusions, or both.

**TAX BURDEN ON CALIFORNIA COMPANIES**

The tax burden on California companies—the share of any new severance tax they pay—has become a central issue in discussion of the tax. TEGI's Fig. 2.1 and the discussion supporting it claim that Rand's estimates of the range of likely tax burden on California companies are systematically and substantially below reasonable estimates of this range. TEGI's claim suffers from two problems. TEGI misrepresents Rand's conclusions. And TEGI estimates a reasonable range of effects that is inconsistent with the results of their own analysis.

First, TEGI states that Rand reports only a range of 30 to 55 percent for the burden figure (TEGI, p. 8). This is simply not true. The Rand conclusion states: "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. . . . 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" (Rand, p. 139). The discussion then goes on to explain how to narrow these ranges further on the basis of additional assumptions.
Second, TEGI uses a supply elasticity of unity to calculate the reasonable range of tax burden in its Fig. 2.1. As noted above, not even TEGI's own analysis supports such a number in the period relevant to the Rand analysis—the first decade following the tax. If we use TEGI's own estimate of the supply elasticity during this period—0.57—the results they report in their Table 2.4 (TEGI, p. 15) change to those shown in Table 1 below.

An estimate of the most reasonable range of tax burden based on TEGI's own supply analysis, then, is perfectly consistent with the results reported in Rand's conclusions. This does not suggest that we endorse TEGI's supply analysis. It simply suggests that their estimate of supply response falls in the range explicitly considered both in our analysis and in our conclusions. TEGI's suggestion that Rand's conclusions are inconsistent with Rand's own analysis represents a gross misrepresentation of the Rand study.

Table 1

SHARE OF SEVERANCE TAX BORNE BY CALIFORNIANS:
MOST LIKELY CASES
(In percent)

<table>
<thead>
<tr>
<th>Tax-Relevant Property</th>
<th>Value Fixed</th>
<th>Value Sensitive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ownership</td>
<td>In-State</td>
<td>Interstate</td>
</tr>
<tr>
<td>Private land</td>
<td>66</td>
<td>63</td>
</tr>
<tr>
<td>State land</td>
<td>62</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>In-State</td>
<td>Interstate</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>62</td>
<td>60</td>
</tr>
</tbody>
</table>

SOURCE: See text.
NOTE: This is a revised version of TEGI's Table 2.4 (p. 15). This table assumes a crude oil supply elasticity of 0.57 and effective WPT rate of 15 percent. The value 0.57 is based on TEGI's analysis of supply response during the first decade following imposition of a tax. The term "property value sensitive" indicates that a property's assessed value is not effectively fixed by Proposition 13 guidelines.
PRODUCTION RESPONSE FROM EXISTING WELLS

Rand and TEGI agree that it is easiest to examine total production response to a tax by looking at response from existing and new wells separately. TEGI faults Rand's analysis of production response from existing wells on two points: first, that the effective tax rate that Rand associates with a 6 percent statutory rate is too low; and second, that Rand fails to take advantage of "the wealth of information that presently exists on oil production in California" (TEGI, p. 19) in order to narrow our estimate of statewide effects in a systematic way. As noted in Section II above, we agree with the first point. We reject the second.

TEGI's discussion of our production analysis focuses on results reported in Table 7.3 in the Rand study (pp. 105-6). It is reproduced here for convenience as Table 2. TEGI suggests first that, as a summary statistic, a mean of the response rates shown in Table 2 is at least as meaningful as a median. We disagree. As TEGI notes, a mean is appropriate if we assume we are equally likely to observe any one of these cases. We would not expect this to be true. Subjectively, we expect that cases with supply responses in the middle of the range presented are more likely than those with extremely large or small supply responses. This assumption makes the median more attractive as a summary statistic than it would be if cases were equally likely. In either case, however, we would emphasize that the measure of central tendency is a summary statistic and that attention should also be paid to the distribution as a whole.

TEGI is less patient with distributions. TEGI suggests that we should use statewide averages of the three parameters shown in Table 2 to pin down a more definitive summary figure. Such an approach would be appropriate only if supply response were linear in the three parameters shown in Table 2. It is not.

To see why TEGI's approach is inappropriate, consider an example. Suppose we have only two kinds of oil fields, A and B. In terms of the parameters in Table 2, let the average life of a well in years, T, equal 25 and the decline rate for individual wells, δ, equal 0.05 for both; the fields differ because the parameter characterizing the age
Table 2
CUT IN PRODUCTION CAUSED BY THE WELL SHUT-INS INDUCED
BY AN EFFECTIVE 6 PERCENT SEVERANCE TAX
( PERCENT )

<table>
<thead>
<tr>
<th>θ</th>
<th>T</th>
<th>-.10</th>
<th>-.05</th>
<th>0</th>
<th>+.05</th>
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</thead>
<tbody>
<tr>
<td>.05</td>
<td>20</td>
<td>9.49</td>
<td>6.19</td>
<td>3.71</td>
<td>2.06</td>
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<td>4.95</td>
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<td>30</td>
<td>7.72</td>
<td>4.13</td>
<td>1.83</td>
<td>.69</td>
</tr>
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<td>35</td>
<td>7.26</td>
<td>3.54</td>
<td>1.34</td>
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</tr>
<tr>
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<td>1.87</td>
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<td>25</td>
<td>.84</td>
<td>.38</td>
<td>.15</td>
<td>.06</td>
</tr>
</tbody>
</table>

δ = production decline rate
θ = parameter used to characterize age distribution of wells
T = well life in a field

SOURCE: Rand, p. 105.

distribution of wells in each field, θ, is -0.10 for A and 0 for B. We expect a 6 percent tax to induce a supply response of 8.41 percent for A and 2.56 percent for B. If the two field types produce equal amounts of oil, the average response is 5.49 percent. Now suppose we cannot observe the individual values of θ but only the average for θ of -0.05. If we use the average value of θ (and T and δ) to calculate the average production response, we find an average production response in Table 2 of 4.95 percent, 10 percent less than the actual production response.
The estimate is less because the function shown in Table 2 is "concave upward" in 0. Figure 1 illustrates this characteristic. The curve labeled I traces out the relationship between production response and 0 for T = 25, δ = .05. The four points highlighted on I are points reported in Table 2. II is a chord drawn from point A (-0.10, 8.41) representing field type A, to point B (0, 2.56) representing field type B. It can easily be shown that the average production response for field types A and B must lie on II. An average production response calculated from a statewide average value of 0 substituted into Table 2, on the other hand, must lie on I. Because II lies everywhere above I between A and B, the actual average must lie above the average calculated from a statewide average value of 0. When field types A and B produce the same amount of oil, we use points lying above 0 = -.05 to calculate these two averages. For the function represented in Table 2, II will always lie above I for any choice of field types. Hence the statewide average based on substituting an average value of 0 in Table 2 will always be too low. That is the meaning and consequence of a function being concave upward.

The function partially mapped in Table 2 is concave upward in all three parameters: 0, δ, and T. Hence, any attempt to substitute statewide averages into Table 2 to find statewide production response systematically underestimates that response. That is the reason we refrained from using the "wealth of information" TEGI contends could help narrow the range of relevant answers. The form of the function we display in Table 2 does not permit the use of TEGI's method.

It could be argued, though TEGI does not, that its approach effectively places a lower bound on the statewide production response. That is correct, and it is a possibility we did not consider in our analysis. Let us consider it now. TEGI's estimates for average age of well (26 years) and annual capacity growth rate (-3.8 percent) look reasonable (TEGI, p. 22). We dispute their choice of 6.0 to 7.5 percent for the average annual decline rate for wells. We do so because the only wells relevant to our analysis of production response in existing wells in the ten-year time frame we considered in our report are those approaching the end of their useful lives. In 1983, using TEGI's
Fig. 1 – Comparison of techniques for calculating statewide effects: an illustrative example
assumption of a 26-year average life, the wells in question are those initiated in the late 1950s. Under the production planning models used by both Rand and TEGI, decline rates are chosen and fixed when a well is initiated. Hence, the decline rate relevant to our production planning model is that for wells of late 1950s to early 1960s vintage, not the average for all wells in the 1970s. Our choice of an 11 percent decline rate as an important summary statistic in the Rand report (p. 100) is based on this reasoning; we need a decline rate from older wells to pursue this analysis. Using this decline rate, together with TEGI's \( T = 26 \) and \( \theta = -0.038 \) in Table 2, yields an estimated production response of 0.88 percent. This is a lower bound for the statewide response. The median value reported in the Rand report (p. 106) is 1.21 percent, about a third higher than this lower bound. We do not find this value to be unreasonable. We continue to emphasize, of course, that it is only a rough estimate of statewide effects. Information on statewide averages of key parameters cannot yield the precision that TEGI seeks.

**PROPERTY TAX REVENUES**

One significant concern about state severance taxes is that they will reduce local revenues from the property tax. Local officials want to assume that the state can compensate them for any losses from new revenues raised by a severance tax. TEGI argues that Rand's estimates of how much a severance tax would effect property tax revenues are too low and presents data from the Kern and Ventura County Assessors as evidence. As we emphasize in the original Rand study (pp. 147-148), our treatment of property tax revenues uses a simplified model of a very complex system. Because we are more concerned with state than with county effects, our basic intent is to estimate effects of the right magnitude. TEGI raises no specific objections about our methodology. We are satisfied that it is adequate for the goals we have in mind.

TEGI starts its critique by claiming that we expect "the property tax reductions . . . to be only $0.03 to $0.05 per dollar of severance tax revenue collected (Rand, Table 4.5)" (TEGI, p. 32). This is simply not true. Table 4.5 is not relevant to this issue.\(^5\) Tables 4.6 and 4.8

\(^5\) Table 4.5 (Rand, p. 53) displays "Effects on Tax Revenues in the
(Rand, pp. 54, 58) show clearly that we expect property taxes to fall by $0.040 to $0.073 per dollar of severance tax revenue collected. Since only about a third of all oil properties are potentially sensitive to the severance tax, the statewide average loss on property tax revenues would amount to between 1.5 and 2.4 percent of gross severance tax receipts.

TEGI then asserts that the statewide increase in assessed valuation of oil properties since 1978-79 "proves" their sensitivity to market conditions (TEGI, pp. 32-33). Again, this is simply incorrect. The increased aggregate value of assessments reflects changes in ownership (for example, Belridge), and reserve additions brought on by the large price increases of 1979-81 for individual properties. These rapid price increases are not likely to continue in the near future. The only other way in which a severance tax would affect property values would be if the tax reduced the values below their (adjusted) 1975 levels, an event our analysis demonstrates is not probable in the near future. TEGI's statement that "virtually all properties will eventually become subject to discounted flow valuation" (TEGI, p. 33), and hence sensitive to severance taxes, is correct if we consider a long enough horizon. But it fails to come to grips with our detailed numerical estimates. Even if production fell by as much as 9 percent in response to a 6 percent tax, property tax losses would amount to barely 7 percent of the revenue collected by a severance tax. We expect statewide production cuts at most only half this size over the next ten years.

TEGI concludes its discussion of our property tax results with data from the Assessors of Kern and Ventura Counties. These data involve potential tax-induced reductions in the assessed values of six oil properties in Kern and Ventura Counties. Neither the Assessors nor TEGI have made any claims about how representative these properties are. Given the way California assesses properties, the tax-induced reductions approximate reductions in the net values of these individual properties. Though Rand published no information on how severance taxes could affect

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Long Beach Tidelands When Production Does Not Fall." We assume these tidelands will not be taxed; hence, these effects are not relevant.

Members of the Assembly should be familiar with these data; they have been presented to the Assembly at least twice.
such net values, we made some preliminary calculations of this kind early in our analysis. All of the Kern and Ventura values fall within the range we presented with parameter values contained in the report. Hence, these specific values are consistent with our analysis. But until more comprehensive calculations of tax effects on local revenues are available, we will continue to prefer our estimates to those that might be inferred from six properties in Kern and Ventura Counties.

TAX EFFECTS ON REFINERS

We are very confused by TEGI’s critique of our treatment of refiners (Rand, pp. 78-88; TEGI, pp. 35-37). Rand’s theoretical analysis indicates that, at least in the short run, refiners of heavy oil will bear a portion of a severance tax while refiners of light oil will not. As a result, producers of heavy oil will bear a smaller portion of any uniformly imposed tax than producers of light oil. The TEGI authors take offense at these claims (TEGI, p. 35). We have difficulty responding because we have difficulty understanding TEGI’s objections. They state that "Rand’s definition of burden ignores . . . [the fact that] . . . lower existing taxes common on stripper and heavy crude production reflect a judgment that these sources are economically marginal." Lower tax rates reflect precisely such a judgment. That is precisely the point of our analysis. Because refiners of heavy oil bear part of the severance tax, the effective tax rate is lower for heavy than for light oil. A uniform tax in California would automatically favor (economically marginal) heavy crude production relative to light production in the same way that the taxes that TEGI mentions do.

We cannot say how much the effective tax rate falls. This raises TEGI’s second objection. We offer no empirical evidence. Unfortunately, within the resources available to us, we could not gather and analyze empirical data relevant to this issue. Nonetheless, we felt the theoretical result was important enough to report. We stated quite clearly that detailed empirical evidence was not available. One piece of evidence that was available is that Venezuela does not ship oil to California. We agree with TEGI (p. 36) that higher heavy oil prices could encourage such imports but their absence today suggests that the price of heavy oil must rise before they become important. A new
severance tax may or may not raise heavy crude prices high enough to allow Venezuelan imports. More detailed empirical evidence is needed on this point.

The most perplexing part of TEGI's critique of our refiner analysis is this claim (TEGI, p. 36):

Rand (p. 88) concludes that "to the extent that refiners bear a portion of the tax, integrated producers will be more heavily affected than nonintegrated producers." This non sequitur is offered by Rand (p. 140) as another reason why the "pattern of the tax's incidence within California is likely to have . . . features that many California policymakers will find attractive."

Despite heavy quotation from the Rand study, this statement is simply false. Neither do we place any value judgment on the tax's effect on integrated and nonintegrated producers, nor would we expect policymakers to do so in a systematic way. What we actually said is the following (Rand, p. 140):

The pattern of the tax's incidence within California is likely to have two features that many California policymakers will find attractive. . . . First, . . . final consumers within California are unlikely to feel much of the effect of the tax. . . . Second, . . . a uniform severance tax is likely to fall more heavily on light oil producers than on heavy oil producers.

We draw a distinction between light oil and heavy oil because many policymakers believe a severance tax should treat them differently; this distinction is not related to that between integrated and nonintegrated producers. Had the authors of the TEGI study read this passage carefully before starting their critique, they could have spared us the bizarre paragraph that follows their initial claim, quoted above.

Quite frankly, TEGI's comments on this issue baffle us. We can only conclude that they did not read the original Rand material carefully.
OTHER MISUNDERSTANDINGS

In their efforts to improve on Rand's analysis, the TEGI authors occasionally reveal basic misunderstandings about the California oil market. These misunderstandings may help explain some of their difficulty in using and extending the Rand analysis. We consider two related to TEGI's treatment of the windfall profit tax.

First, in an attempt to narrow our estimate of the effective windfall profit tax rate, TEGI states that "35 percent of all tax eligible oil is heavy (API gravity of 16 degrees or less)" (TEGI, p. 11). The number is actually more like 62 percent according to data compiled from the Division of Oil and Gas and the Conservation Committee of California Oil Producers. Even if one were concerned with all oil in the state, including the Naval Petroleum Reserve and Long Beach tidelands, heavy oil comprises nearly half (45 percent) of the state's 1981 production. This error would be less important if heavy oil did not play such a central role in the California oil market.

The desire to select a single average value of the effective windfall profit tax rate for the state raises a second and more fundamental issue. The effective rate for the windfall profit tax changes quarterly on any given property. Hence, we need to know how sensitive our results are to this change. TEGI is apparently unaware of this feature of the tax. It becomes even more important below when we discuss the treatment of this tax in their econometric model of production response from new wells.

TEGI also seems to be unaware of the net income limitation on the windfall profit tax. This becomes apparent in their Table 2.5 and its accompanying discussion (TEGI, p. 26). We show the correct form of this table below as Table 3. In this table, they attempt to show the

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7 TEGI wants this average figure in order to pin down the share of the tax borne by California oil companies. As we explicitly state (Rand, pp. 158-159), tax effects on estimated profit, which we use to calculate companies' tax burden, are not linear in the tax parameters we use. Hence, we have the same problem here with using state-wide averages that we had above with regard to the production response from existing wells. Further, the nature of this tax profit function is less clear, so we do not know whether the use of averages under- or overstates tax effects. This problem simply compounds problems discussed in the text.
### Table 3
**CORRECTED TEGI TABLE 2.5:**
**TAX LIABILITIES AND THE SHUT-IN DECISION**

<table>
<thead>
<tr>
<th></th>
<th>A. Baseline</th>
<th>B. 6% Severance Tax</th>
<th>C. 6% Price Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Revenue/bbl</td>
<td>$30.00</td>
<td>$30.00</td>
</tr>
<tr>
<td>2.</td>
<td>Severance tax</td>
<td>0.00</td>
<td>1.80</td>
</tr>
<tr>
<td>3.</td>
<td>WPT payment</td>
<td>4.20</td>
<td>3.95</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Net Income</th>
<th>WPT</th>
<th>Net Income</th>
<th>WPT</th>
<th>Net Income</th>
<th>WPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.</td>
<td>$22.00/bbl</td>
<td>$5.84</td>
<td>$2.16</td>
<td>$4.53</td>
<td>$1.67</td>
<td>$4.53</td>
</tr>
<tr>
<td>5.</td>
<td>$25.00/bbl</td>
<td>3.65</td>
<td>1.35</td>
<td>2.34</td>
<td>0.86</td>
<td>2.34</td>
</tr>
<tr>
<td>6.</td>
<td>$28.00/bbl</td>
<td>1.46</td>
<td>0.54</td>
<td>0.15</td>
<td>0.05</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Net income in absence of corporation income tax, *if* operating cost is:

<table>
<thead>
<tr>
<th></th>
<th>Net Income</th>
<th>WPT</th>
<th>Net Income</th>
<th>WPT</th>
<th>Net Income</th>
<th>WPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.</td>
<td>$22.00/bbl</td>
<td>2.92</td>
<td>2.16</td>
<td>2.265</td>
<td>1.67</td>
<td>2.265</td>
</tr>
<tr>
<td>8.</td>
<td>$25.00/bbl</td>
<td>1.825</td>
<td>1.35</td>
<td>1.17</td>
<td>0.86</td>
<td>1.17</td>
</tr>
<tr>
<td>9.</td>
<td>$28.00/bbl</td>
<td>0.73</td>
<td>0.54</td>
<td>0.075</td>
<td>0.05</td>
<td>0.075</td>
</tr>
</tbody>
</table>

Net income after 50% corporation income tax, *if* operating cost is:

Assumptions: WPT base price is $16.00/bbl and tax rate is 30%.
Severance tax and WPT are deductible from gross income.

SOURCE: TEGI, p. 26, with revisions.
interaction of the windfall profit tax, severance tax, and corporation income tax, under varying assumptions about operating costs. Their example involves heavy oil, taxed at 30 percent of the "windfall profit," and assumes a sales price of $30/bbl with operating costs of between $22 and $28/bbl. Under their assumptions, the net income cannot exceed $8 per barrel, even in the absence of the taxes. The "windfall profit" tax base is defined as the difference between the sale price ($30) and the assumed "base price" ($16), less a severance tax adjustment of 6 percent of the "windfall profit" ($0.84) where appropriate. This calculation yields a taxable "windfall" of either $12.20, $13.16 or $14.00. The minimum assumed operating cost of $22/bbl leaves a "profit" of $8 or less, however, thereby invoking the "Net Income Limitation" provisions of the Windfall Profit Tax Act of 1980.

This provides that the "windfall profit" from any barrel cannot exceed 90 percent of the net income realized from that barrel. Net income is defined, in general, as the gross revenue per barrel less all operating costs including state income and severance taxes and local taxes. Federal income and windfall profit taxes may not be deducted for this purpose. The WPT rate (in this case 30 percent) is applied to the lesser of the "windfall profit" (sales price - base price - severance tax adjustment) and 90 percent of the net income. In every example used in their Table 2.5, 90 percent of "net income limit" is the appropriate tax base, not the "windfall profit" tax base used by TEGI.

Applying the correct tax base results in the numbers shown in Table 3.\(^8\) Four points deserve mention. First, TEGI has substantially overestimated the windfall profit tax due in every case shown in lines 4-9, and significantly underestimated the producer's net income--by at least 100 percent and in some cases by more than 500 percent. Second,

\(^8\) It is worth noting in passing that the numbers chosen are unusually high, since such oil reached its highest sale price in early 1981 of about $25/bbl. There is reason to believe the operating costs chosen are also too high. See R. Nehring et al., The Heavy Oil Resources of the United States, R-2946-DOE, The Rand Corporation, forthcoming.

\(^9\) For simplicity neither we nor TEGI includes state income or property taxes in the examples shown in Table 3.
in every case, the producer's net income is positive, rather than negative, as TEGI claims in 10 of the 18 cases. Third, where the net income limit applies, it makes no difference to the producer's net income whether a 6 percent severance tax exists or the price is reduced by 6 percent instead. Cases B and C are identical. Fourth, the corporation income tax is irrelevant to the producer's shut-in decision— not because the shut-in point is the same with or without the tax (for example, at around $25/bbl operating costs; TEGI, p. 26) but because none of the cases is unprofitable. No shut-ins occur. While accepting their point about not including the corporation income tax in evaluating shut-in decisions, we must note that their example does not make the point they intended. On the contrary, it illustrates a fundamental misunderstanding of how one of the most important oil production taxes operates.
IV. TEGI'S NEW ANALYSIS OF PRODUCTION RESPONSE

TEGI attempts to build on the framework Rand set up for the analysis of production response with two extremely detailed numerical exercises. We have serious reservations about both. The purpose of this paper is to respond to TEGI's critique of the Rand study, not to offer a comprehensive critique of TEGI's analysis. Hence, we believe it is inappropriate for us to launch a detailed critique of TEGI's new analysis, at least in this setting. Nonetheless, we feel some obligation to explain why we believe the paths TEGI has taken to extend our analysis are inappropriate. In particular, we considered using some of the techniques they use and explicitly rejected them; TEGI's presentation of the techniques does nothing to change our judgment about their appropriateness. In this section, then, we raise questions about TEGI's new analysis of production response, but do not offer a point by point demonstration that our reservations are warranted. We do suggest a relatively simple exercise that could be used to test the validity of TEGI's approach and strongly recommend that anyone seriously planning to use the TEGI's results have this test conducted first. At the very least, anyone using TEGI's results should proceed with extreme caution.

PRODUCTION RESPONSE FROM EXISTING WELLS

The basic economic model underlying TEGI's analysis of production response from existing wells is the same as that in the Rand study. It is a standard production planning model that planners use when they wish to avoid the use of detailed geological data on a production site. It is best suited to the analysis of primary recovery, which suggests that studies attempting to extend the Rand analysis should consider more complex models. Nonetheless, it is probably adequate for current purposes. TEGI's analysis differs from Rand's in two fundamental ways. First, TEGI assumes that "the shut-in effect for a given field can be adequately captured by examining only a single average or 'representative' oil well in that field" (TEGI, pp. 88). This is valid only if all wells in a field start together, decline together at the
same rate, and end together. Rand uses the more reasonable assumption that wells within a field can differ and offers a simple parametric way to characterize these differences (see discussion of $\theta$ in Rand Appendix D). Second, TEGI attempts to use published data on individual fields to predict a tax's shut-in effect on each field. After careful thought Rand rejected this approach. While such an approach is possible with published data, the proper data differ from those TEGI used and were far too costly to gather in a form that would be analytically tractable.\(^1\) As a result, Rand pursued a less detailed parametric sensitivity analysis. These two differences point to severe problems about whether TEGI's formal economic models can tell us anything about what is actually happening in California's oil market. We believe this section of TEGI's analysis fails to capture enough realism about California oil production to be useful to policymakers.

Consider first TEGI's characterization of fields in terms of representative wells. This characterization is especially dangerous in an analysis of production response from existing wells for two reasons. First, it requires that any tax-induced shut-in effect occur at once for all wells in a field at the end of a field's lifetime. In fact, even the most extreme form of shut-in--abandonment--occurs routinely for various wells over the whole life of most fields. For example, consider the fields for which TEGI estimated production responses (TEGI, pp. 212-216). As Table 4 shows, wells were abandoned in over a quarter of these fields in 1981.\(^2\) But production will go on despite these

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\(^1\) Tapes publicly available from the Division of Oil and Gas contain monthly and annual operating data on every well in the state. These data make it possible to track individual wells over time. We initially considered aggregating wells into cohorts defined by similar characteristics and using these data to estimate decline rates by cohorts. Such estimation can abstract from the influence of capacity additions in a field and thereby allow one to estimate the decline rate relevant to tax analysis. We discuss below why this is important. We created such a cohort-based file for data from a single year to help us with some of our analysis of new wells. Unfortunately, given the resources available to us, we could not justify the cost of creating the multi-year data file required to estimate decline rates. Ultimately, such an approach could help resolve some of the issues that concern TEGI in their analysis.

\(^2\) This discussion draws on the Division of Oil and Gas Annual Report for 1981.
Table 4
CALIFORNIA FIELD DATA ON NEW DEVELOPMENT AND
NEWLY ABANDONED WELLS, 1981

<table>
<thead>
<tr>
<th>Item</th>
<th>Fields With No New Development Wells</th>
<th>Fields With Some New Development Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Fields With No Abandonments</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of fields</td>
<td>121</td>
<td>59</td>
</tr>
<tr>
<td>No. of new wells</td>
<td>0</td>
<td>289</td>
</tr>
<tr>
<td>No. of abandonsments</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>Fields With Some Abandonments</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of fields</td>
<td>18</td>
<td>47</td>
</tr>
<tr>
<td>No. of new wells</td>
<td>0</td>
<td>2366</td>
</tr>
<tr>
<td>No. of abandonsments</td>
<td>51</td>
<td>1101</td>
</tr>
</tbody>
</table>

SOURCE: Division of Oil and Gas, Annual Report, 1981.

abandonments; all fields with abandonments still have proven reserves to extract. Among fields with abandonments, almost three-quarters also added new development wells. In fact, most new well and abandonment activity occurred in fields with both abandonments and new wells. Furthermore, as Table 5 shows, levels of abandonments and new wells were positively related. This is because larger fields tend to have more of both. That is, wells are continually turning over--some being started, some ending--in fields that account for most new starts.

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<sup>1</sup> Fields in Table 5 are ranked by the combined number of oil and gas development wells and oil and gas well abandonments in 1981. Together, they represent almost 90 percent of all such wells in the state. Service and prospect wells are not included. Reserve rankings are based on estimated oil reserves as of December 31, 1981.
Table 5
CALIFORNIA FIELDS WITH MOST NEW DEVELOPMENT WELLS
AND ABANDONMENTS, 1981

<table>
<thead>
<tr>
<th>Field</th>
<th>Number of New Oil and Gas Development Wells</th>
<th>Number of Abandoned Wells</th>
<th>Reserve Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. South Belridge</td>
<td>714</td>
<td>488</td>
<td>4</td>
</tr>
<tr>
<td>2. Midway-Sunset</td>
<td>558</td>
<td>101</td>
<td>3</td>
</tr>
<tr>
<td>3. Kern River</td>
<td>199</td>
<td>99</td>
<td>1</td>
</tr>
<tr>
<td>4. Lost Hills</td>
<td>143</td>
<td>46</td>
<td>8</td>
</tr>
<tr>
<td>5. Goalinga</td>
<td>69</td>
<td>78</td>
<td>7</td>
</tr>
<tr>
<td>6. Mckittrick</td>
<td>60</td>
<td>57</td>
<td>20</td>
</tr>
<tr>
<td>7. Cat Canyon</td>
<td>84</td>
<td>24</td>
<td>12</td>
</tr>
<tr>
<td>8. San Ardo</td>
<td>65</td>
<td>24</td>
<td>6</td>
</tr>
<tr>
<td>9. Edison</td>
<td>64</td>
<td>7</td>
<td>19</td>
</tr>
<tr>
<td>10. Cymric</td>
<td>52</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>11. Poso Creek</td>
<td>38</td>
<td>21</td>
<td>34</td>
</tr>
<tr>
<td>12. Kern Front</td>
<td>38</td>
<td>17</td>
<td>23</td>
</tr>
<tr>
<td>13. Wilmington Onshore</td>
<td>46</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>14. Wilmington Offshore</td>
<td>44</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>15. Newport West Offshore</td>
<td>40</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>16. Elk Hills</td>
<td>33</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>17. Torrance Offshore</td>
<td>23</td>
<td>5</td>
<td>33</td>
</tr>
<tr>
<td>18. Mount Poso</td>
<td>15</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>20. Santa Maria Valley</td>
<td>18</td>
<td>6</td>
<td>13</td>
</tr>
</tbody>
</table>

Source: Division of Oil and Gas, Annual Report, 1981.

and endings." Under these circumstances, if a tax encourages premature shut-in of wells, as both Rand and TEGI agree it does, tax-reduced shut-ins will occur over the whole life of a field, not just at the end of its life. Hence, TEGI puts the effects of a tax on existing wells much too far in the future. Given TEGI's use of cumulative production

"This is true in part because many new development wells simply replace abandoned wells. If we treat such replacements as economically uninteresting events in the life of one extraction point in a field, the number of abandonments relevant to our analysis falls during the life of a field. But then not all new development wells are new wells relevant to our analysis. In this case, TEGI's count of relevant new development wells is overstated.
effects, this distortion will be most important to their estimates of effects in the first decade or so following the tax. This is of course the decade we believe is most important to policymakers.

Second, TEGI implies that the decline rate for the "average well" in a field—the rate at which production per well declines in the field—is equal to the decline rate for individual wells in the field. Rand (Appendix D) and TEGI (pp. 201-207) agree that the decline rate for individual wells is relevant to tax analysis because shut-in/abandonment decisions are made with regard to individual wells, not fields or average wells. Hence, TEGI's analysis of tax-induced shut-ins is valid only if the decline rate for an average well equals that for individual wells in the field. The rates are rarely equal.

To see why, consider a simple scenario. Let initial production per well in a field fall 3.6 percent annually (see TEGI, p. 223) and total initial production in the field fall 3.8 percent annually (TEGI, p. 22). Let each individual well decline 10 percent a year until they are shut in after 10 years. Suppose these conditions prevail over a long period of time so it is easy to observe these different rates in sufficiently detailed historical data. Finally, let us consider a year in which a field adds 200 wells, each producing 5000 barrels in its first year.

Table 6 compares production in this year (year 1) with production in the years that follow. Each column represents one year. Each row represents wells of a given age in any year. Note that the tenth row shows the number of imminent abandonments; abandonments occur over the life of the field. We calculate total production and total wells in any year by summing numbers in each column. The ratio of these sums gives us the production of TEGI's average well. TEGI uses this to calculate decline rates. In our example, the year-to-year decline rate is the same each year and equal to about 3.6 percent, the rate at which we assumed initial production per well fell. It is easy to show that, but for rounding effects, this calculated decline rate should be exactly 3.6 percent. (See the appendix to this section.) Further, we can show that this answer is independent of assumptions about the rate of change in

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5. This implies that well additions fall 100((1-.038)/(1-.036)-1) = -.207 percent annually.
Table 6
TEGI’S DECLINE RATE METHOD APPLIED TO A SIMPLE, HYPOTHETICAL FIELD

<table>
<thead>
<tr>
<th>Age of Wells</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>New wells</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of wells</td>
<td>200</td>
<td>200</td>
<td>199</td>
<td>199</td>
</tr>
<tr>
<td>Total production</td>
<td>1,000,000</td>
<td>962,000</td>
<td>925,444</td>
<td>890,277</td>
</tr>
<tr>
<td>Production/well</td>
<td>5,000</td>
<td>4,820</td>
<td>4,646</td>
<td>4,479</td>
</tr>
<tr>
<td>2 years old</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wells</td>
<td>200</td>
<td>200</td>
<td>199</td>
<td>199</td>
</tr>
<tr>
<td>Production</td>
<td>935,551</td>
<td>900,000</td>
<td>865,800</td>
<td>832,900</td>
</tr>
<tr>
<td>3 years old</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wells</td>
<td>201</td>
<td>200</td>
<td>200</td>
<td>199</td>
</tr>
<tr>
<td>Production</td>
<td>875,256</td>
<td>841,996</td>
<td>810,000</td>
<td>779,220</td>
</tr>
<tr>
<td>4 years old</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wells</td>
<td>201</td>
<td>201</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Production</td>
<td>818,846</td>
<td>787,730</td>
<td>757,796</td>
<td>729,000</td>
</tr>
<tr>
<td>5 years old</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wells</td>
<td>202</td>
<td>201</td>
<td>201</td>
<td>200</td>
</tr>
<tr>
<td>Production</td>
<td>766,072</td>
<td>736,962</td>
<td>708,957</td>
<td>682,017</td>
</tr>
<tr>
<td>6 years old</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wells</td>
<td>202</td>
<td>202</td>
<td>201</td>
<td>201</td>
</tr>
<tr>
<td>Production</td>
<td>716,700</td>
<td>689,465</td>
<td>663,265</td>
<td>638,061</td>
</tr>
<tr>
<td>7 years old</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wells</td>
<td>202</td>
<td>202</td>
<td>202</td>
<td>201</td>
</tr>
<tr>
<td>Production</td>
<td>670,509</td>
<td>645,030</td>
<td>620,519</td>
<td>596,939</td>
</tr>
<tr>
<td>8 years old</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wells</td>
<td>203</td>
<td>202</td>
<td>202</td>
<td>202</td>
</tr>
<tr>
<td>Production</td>
<td>627,295</td>
<td>603,458</td>
<td>580,527</td>
<td>558,467</td>
</tr>
<tr>
<td>9 years old</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wells</td>
<td>203</td>
<td>203</td>
<td>202</td>
<td>202</td>
</tr>
<tr>
<td>Production</td>
<td>586,866</td>
<td>564,566</td>
<td>543,112</td>
<td>522,474</td>
</tr>
<tr>
<td>10 years old</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wells</td>
<td>204</td>
<td>203</td>
<td>203</td>
<td>202</td>
</tr>
<tr>
<td>Production</td>
<td>549,043</td>
<td>528,179</td>
<td>508,109</td>
<td>488,800</td>
</tr>
<tr>
<td>Annual Totals</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of wells</td>
<td>2,018</td>
<td>2,014</td>
<td>2,010</td>
<td>2,006</td>
</tr>
<tr>
<td>Total production</td>
<td>7,546,138</td>
<td>7,259,386</td>
<td>6,983,529</td>
<td>6,718,155</td>
</tr>
<tr>
<td>Production/well</td>
<td>3,739</td>
<td>3,604</td>
<td>3,474</td>
<td>3,349</td>
</tr>
<tr>
<td>Est. decline rate</td>
<td>-.0361</td>
<td>-.0361</td>
<td>-.0361</td>
<td>-.0361</td>
</tr>
</tbody>
</table>
well additions, the length of time each well produces before being shut-in, and--most important--the decline rate for individual wells. That is, in this simple scenario, TEGI's method yields a decline rate unrelated to the decline rate relevant to analysis of tax-induced shut-ins. We cannot hope for more in more complicated--and realistic--scenarios.

To get the decline rate for individual wells that TEGI needs, one needs not the summary annual totals shown at the bottom of the table, but the data within the body of the table. Consider production from a cohort of wells over time. For example, production from wells begun in year 1 declines by 10 percent from 1,000,000 barrels in year 1 to 900,000 barrels in year 2. It declines by 10 percent to 810,000 barrels in year 3, and so on. (Number of wells, of course, does not change.) By tracking such cohorts of wells through time, one can use data like those in the body of the table to calculate the decline rate of individual wells. The information required to do this is simply not present in the data TEGI uses.

Let us now turn to TEGI's empirical implementation of the theoretical model. Problems arise in their use of reserve data and their estimation of decline rates.

Both the quality and the character of TEGI's reserve data raise questions. As they note, "these data constitute the most reliable published source of the information on California oil reserves presently available" (TEGI, pp 87-8). They neglect to note that these data are also the only comprehensive published source of such information. They do note that considerable uncertainty adheres to these data, but suggest that errors associated with individual fields will wash out as we move toward state-wide effects. That is true only if errors are independent of one another. Because the theory and models used to estimate reserves for fields in a particular region are often similar, errors in such estimation are often correlated. We have no idea how important this problem is; TEGI does not discuss this potential source of correlation.

A more serious problem is that TEGI's analysis assumes that existing wells will exhaust the reserves they use in their analysis. This assumption appears to stem from TEGI's assumption that existing
wells constitute the whole field; when they shut-in, the field's lifetime ends. We argue above that this assumption is not consistent with California experience. The source of TEGI's reserve data, the Division of Oil and Gas Annual Report, provides additional empirical corroboration for our point of view. Eighty percent (2114 of 2655) of the new development wells started in 1981 were unaccompanied by revisions in reserves for the fields in which they were placed.

Two-thirds of fields with new development wells experienced downward revisions or no additions to reserves. That is, a large fraction of the new wells in the state will be drawing on the reserves TEGI set aside for existing wells. TEGI has overestimated reserves for existing wells. To determine how much in error their estimate is would require more analysis than we can justify at this time.

TEGI's estimation of decline rates raises other problems. We have already noted that they estimate a decline rate that is inconsistent with the basic economic model underlying their analysis if fields cannot be characterized by a single representative well. But even if the parameter they sought were appropriate, their estimation technique raises questions. Their preferred method of estimating the decline rate is straightforward: "For most fields, the decline rate for existing wells was estimated as the average annual decline rate from the year of maximum production during the 1976-81 period to 1981, the most recent year for which data are available" (TEGI, p. 88; emphasis added).

Unfortunately, this straightforward approach does not yield reasonable decline rates for some fields. "Some California fields achieved maximum production per well in 1980, so there was no recent historical record of decline to use as a basis for estimation of a [the decline rate]. For a few cases, the average decline rate estimated over the 1976-81 period exceeded theoretical limits" (TEGI, p. 208; emphasis added).

Empirically, how important are these problems with TEGI's preferred

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6 This apparent "discrepancy" is a result of the way oil producers extract heavy oil in California and the way the Division of Oil and Gas records additions to reserves associated with new heavy oil production. New reserve additions are generally recorded when producers obtain permits to expand heavy oil development; the actual development can extend for a decade or more after reserve additions are made. Such concerns are especially important in California because such a high fraction of new development wells lies in heavy oil fields.
estimation technique to the policymaker? Two observations seem relevant.

First, TEGI reports results for 244 separate fields. Yet equations (C.24) and (C.25), which use data on fields that yielded reasonable results under TEGI's straightforward method to infer decline rates for fields that did not, are based on only 104 observations. Did only 104 of 244 fields have reasonable decline rates?

Second, we reviewed Division of Oil and Gas data on several of the state's largest fields to get a sense of how important the problem of maximum production rate per well in 1981 was. Four giant fields (South Belridge, Coalinga, Lost Hills, and Kern River) representing almost one-third of the state's tax-eligible oil production in 1981 had higher production per well in 1981 than in any year since 1976. Further, these fields account for more than half (56%) of the production response TEGI estimates from existing wells. That is, much of the oil in the state displays behavior inconsistent with TEGI's underlying model and hence their preferred method of estimating decline rates. We infer from this, though TEGI's documentation does not allow us to verify it easily, that equations (C.24) and (C.25) are based on data which exclude at least four of the state's largest fields. And most of the production response TEGI estimates occurs in these major fields.

A closer look at one of these fields, Kern River, raises additional doubts about TEGI's production response estimates. Almost half of TEGI's production response from existing wells occurs in this one field. The Kern River field is the state's largest, with estimated reserves of over one billion barrels. Discovered in 1899, it has been actively developed for many years, in spite of its relatively low gravity (12-14 deg. API). It was among the first major fields to use extensive enhanced recovery methods, beginning in the mid 1960s, well before the price jumps of the 1970s. Such early use of these methods was possible because the field is shallow and contains a thick reservoir; as a result development costs are relatively low compared to current oil prices. Is it reasonable to believe that a 6 percent tax could cut production from this type of field by 18 percent (TEGI, p. 213)?
We think not. Recall from the discussion above that TEGI's whole approach to estimating tax effects on existing wells is inappropriate. Even if it were not, recall that the decline rate for Kern River is inferred from data on other fields. We can infer from TEGI's Table C.1 (p. 213) that they assign a decline rate of 1.03 percent a year to Kern River field.\(^7\) TEGI's measure of lost production is extremely sensitive to the choice of decline rate. Raising the decline rate to 2 percent cuts the percentage of production lost to 6.0 percent; a 3 percent decline rate yields a percentage production loss of 1.8 percent, just a tenth the size TEGI reports for Kern River.\(^8\) Why the decline rate of 1.03 percent inferred for Kern River is meaningful in the context of this field itself is unclear. Unfortunately, getting the decline rate right is crucial to the robustness of TEGI's results. On the whole, TEGI's *ad hoc* results do not fit well with specific data available about the Kern River field.\(^9\)

In the end, we are not surprised that TEGI had difficulty using their approach to estimate decline rates. Their difficulty is perfectly consistent with the fact that fields cannot be characterized by representative wells when capacity is changing in a field. That is, TEGI's empirical difficulties with the decline rate take us directly back to a fundamental weakness in their underlying model and provide evidence that that weakness is empirically important.

If TEGI has used an inappropriate application of its economic model for their analysis, then systematically overestimated the level of reserves relevant to existing wells, and then used *ad hoc* techniques to estimate decline rates, their final results are probably suspect. We believe this is an accurate characterization of this part of TEGI's

\(^7\) From equation (C.3), the decline rate is \(\ln(1-s)/(T_1-T_0)\), where \(s\) is the tax rate. We simply substitute appropriate values from Table C.1.

\(^8\) One can infer from TEGI's discussion (pp. 201-207) that their measure of the tax-induced percentage reduction in production (PTF in Table C.1, p. 213) is \(((Q_{81}/R_{81})-1)/(s/(1-s))\), where \(Q_{81}\) is production in 1981, \(a\) is decline rate, and \(R_{81}\) is reserves remaining in 1981.

\(^9\) For more details in this field and other fields in TEGI's analysis, see R. Nehring et al., op. cit.
analysis. TEGI uses reasonable models to start. But it applies them inappropriately and attempts to use readily available data to do things that simply cannot be done. Policymakers should approach these particular results with extreme caution.

PRODUCTION RESPONSE FROM NEW WELLS

TEGI uses data on the period 1947-1981 to predict how a tax-induced once-and-for-all change in the real price of crude oil received by producers would affect oil production from new wells during the period 1982-2011. Two problems come up in TEGI's work. First, the projection simply offers a single set of point estimates and gives no indication of how reliable the projection is under TEGI's "baseline" assumptions or how sensitive it is to changes in the baseline. Second, the model used for projection does not appear stable even over the period 1947-81, much less over the full sixty-plus years of analysis; TEGI makes no effort to justify their choice of this specific model or to verify its stability.

Projection thirty years into the future is a daunting undertaking. Simple reflection on events affecting the California oil market over the last thirty years should provide some indication of what surprises are in store for us over the next thirty years. In fact, planners rarely take such future-studies seriously, especially when they offer only one scenario and do not even discuss the variation possible within that scenario. The Rand analysis attempted to look no farther than ten years into the future simply because we did not expect anyone to believe any results offered for a period longer than that. And even within that period, we examined a range of scenarios, based in part on discussions with planners from several oil companies producing in California. They uniformly emphasized the pervasive importance of uncertainty in the future of oil markets and the need for careful sensitivity analysis to assure that policies they propounded within their companies were robust. Recent experience bears them out, perhaps even more than they would like. For example, during our analysis, few oil firms expected real oil prices to fall in the future; since the Rand report was published, oil prices have in fact fallen and the lower bound planners now place on future oil price movements has shifted down significantly. The key point here is that TEGI gives no indication of such problems and
proceeds with an analysis that looks unrealistically far into the future and gives little indication of what confidence we should place in their results.

Two specific aspects of their analysis are particularly puzzling in this regard. First, TEGI suggests implicitly that their choice of a constant real oil price over the next thirty years as the basis for a "baseline projection" is rather innocuous. As the Rand study explains, however, tax effects with a constant oil price are qualitatively different from those with rising oil prices. With a rising price, a tax delays drilling dates, but does not eliminate drilling altogether on particular sites as it does with a constant price. This is particularly important to TEGI's approach, which emphasizes cumulative drilling losses over a thirty-year period. Cumulative effects of the tax could be significant in the early years following the tax, but would tend to level off rapidly later as drilling that the tax had discouraged early on became attractive again. For example, with only a one percent annual rise in real oil prices and a six percent tax, the tax effect on cumulative production would level off before the end of the first decade following the tax. At the very least, it is worth pointing out that an assumption of constant prices is not consistent with TEGI's claims throughout their report that they choose assumptions to assure lower bound estimates on the effects of the tax. But our key point here is not to argue that one percent is more appropriate than zero percent as a baseline estimate of real oil price escalation. It is to suggest that small changes in TEGI's assumptions dramatically alter their results. TEGI gives the reader--and the policymaker in particular--no indication of this sensitivity.

Second, TEGI does not exploit one of the most useful characteristics of the formal econometric models it uses; it offers none of the confidence intervals that can so easily be constructed around projections with the use of estimated parameters from the econometric models. While it appears that the long-run elasticity of drilling supply implied by their analysis \( a_1/(1-a_2) \) (at TEGI, p. 223) has a small variance far into the future, the absolute level of oil production and of oil lost because of the tax are highly uncertain. One especially visible example of this problem is the apparent new "lease on life" that
the end of the windfall profit tax brings in Figs. 4.4-4.6 (TEGI, pp. 97-99). This dramatic effect is based on coefficients whose presence in the drilling models cannot be justified by any commonly used statistical criteria. Proper representation of the variance around TEGI's projections would make this effect look less exciting and, more important, would improve the reader's understanding of it.

The use of econometric techniques to present confidence bounds around projections, of course, presumes that the underlying model TEGI has estimated and the scenario they have selected are correct. We have noted above how sensitive their analysis is to changes in scenario. Serious questions also arise about the model itself. This is where our most serious problems with the TEGI analysis of production from new wells arise. As noted above, Rand seriously considered pursuing an econometric approach much like that which TEGI presents. After careful consideration, however, we came to the following conclusion (Rand, p. 116):

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.

Nothing in TEGI's execution of such an analysis has led us to change that judgment.

TEGI estimates future production effects with an investment model that has been widely used within the economics profession. Some theoretical doubt has been raised recently about the method TEGI uses to model producers' expectations about future prices (it is not generally consistent with profit maximizing behavior), but the model as a whole is generally accepted by empirically oriented economists. That does not mean it is appropriate in all circumstances. A requirement that applies to all econometric models, and this is no exception, is that the model be stable both over the period of estimation (in this case 1947-1981)
and the period of forecast (1981-2011). That is, if a one percent price increase raises drilling by 1.3 percent in 1947, it must have precisely the same effect in 1967, 1987, and so on when all other variables remain constant. The same applies to every other variable in the model. There are very strong reasons to believe that this does not hold for the model TEGI proposes. Four in particular are important.

First, the American Petroleum Institute (API) annual average wellhead value per barrel of crude oil in California, which TEGI uses as its price variable, (TEGI, p. 218), is the price relevant to investment decisions in some periods, but not in others, during TEGI’s estimation period. From 1947 to 1970, all oil of the same kind sold for approximately the same price in California. During this period, the average price was probably close to the price a producer would expect to get for the marginal barrel from new investment.10 Price controls begun in 1971 end this automatic relationship. Because the price controls varied continuously during the 1970s, this systematic structural change in the California oil market cannot be easily captured. Price control ended in 1981, suggesting that the current API average price is once again a reasonable proxy for the variable we really want. The bottom line is that the decade of the 1970s represents a period during which we should expect the relationship between the price TEGI uses and that relevant to the analysis to differ systematically from the relationship between these prices during the periods before and after; TEGI’s price coefficient is not likely to be stable over this whole period. We could find no discussion of this potential problem in the sections of the TEGI report we reviewed.

10 This is complicated in California by the wide range of quality of oil produced in the state. Quality has systematically fallen over time, suggesting that even if real prices remained constant over time for every grade of oil in the state, thereby holding constant the incentive to invest in each type of oil, the API average would fall over time, suggesting a falling incentive to invest. TEGI apparently hopes its light-to-heavy-oil ratio will capture this effect, though they do not discuss it, and it seems to call for a term interacted with price (TEGI, p. 94). This type of consideration, however, is an order of magnitude less important than the key problems that concern us about TEGI’s model.
Second, TEGI's model requires that producers' expectations about future oil prices be based on a weighted average of past prices (TEGI, p. 217). Further, it requires that the weights used for this average be constant from 1947 to 2011. Such an assumption is often valid over shorter periods when markets are relatively stable and prices do not come under administrative controls for which economists have no good predictive models. Economists now generally recognize that administrative intervention in a market systematically increases uncertainty about prices in the market and changes the way individuals in that market view future prices. Two separate and important interventions in the oil market are likely to have affected the way price expectations are formed: the emergence and persistence of OPEC and the initiation and continual revision of U.S. price controls during the 1970s. We do not have time to document the importance of these effects here. What they suggest, however, is that the period relevant to TEGI can be divided roughly into a pre-OPEC, pre-controls segment (1947-1970), an OPEC and controls segment (1971-1981), and an OPEC post-controls segment (1982-2011). While the price expectations function may have been stable before 1971, it probably became quite chaotic during the 1970s, and differs now from its form during any of the periods of estimation. We could find no discussion of these problems in the sections of the TEGI report we reviewed.

Third, success from drilling exploratory or development wells and hence the incentive to drill at any given price depends on how much oil is left in the ground and how much it will cost to find and extract it. That is, the relationship between exploratory drilling and price will change over time if the geology of the oil remaining in the ground differs from that of the oil already removed. The relationship between development drilling and price will change over time as engineers' knowledge of existing fields improves and as drilling and operating technology improves. TEGI raises this issue and attempts to deal with it in two ways (TEGI, pp. 93-95). They include in their drilling models a trend variable to capture the falling productivity of new wells and a light-to-heavy-oil ratio to capture the effect of the growing importance of heavy-oil in the remaining oil resource. (The light-to-heavy-oil
ratio is then modeled in turn as a function of a simple trend variable.) And in their initial-production-from-new-wells model, they use a trend variable to capture the falling productivity of new wells. These are extremely ad hoc ways to incorporate information on the geological structure, engineering data, and technology that ultimately define the economically relevant oil resource in California. And they have a fascinating implication: They imply that we can infer everything we need to know about the geology and technology of oil that will be removed from the ground in the next thirty years from linear extrapolations of information on past production. New geological, engineering, and technological data are irrelevant. That is obviously an extreme assumption. It underlies a long-standing disagreement between economists, like the authors of the TEGI study, who prefer to use econometric models to estimate oil supply, and geologists, who are responsible for most of the major oil companies' reserve and resource estimation and view such simplified econometric investment models with great suspicion. A more systematic characterization of California's oil resource and the technology that will be available to exploit it would certainly give us more confidence that TEGI's model would remain stable over the sixty year period they analyze.\(^{11}\)

Finally, TEGI's treatment of the windfall profit tax illustrates a fundamental misunderstanding of how it works (TEGI, p. 95). If it phases out according to the existing legislative schedule, the effective rate of the tax will most likely continue to fall each year until 1991, when its termination officially begins. This is especially true for heavy oil in Tier 3. The base price for Tier 3 oil rises 2 percent faster than that for the other tiers, thereby accelerating the tax's phaseout if prices do not also rise. Moreover, the tax can actually subsidize the introduction of incremental tertiary recovery methods.\(^{12}\) A simple dummy variable cannot capture such change. Going beyond the legislation, the odds are good that the courts could halt the windfall

\(^{11}\) For information on new heavy oil technology expected during this period, see Nehring, et al., op. cit.

profit tax before 1991 or that the Congress could revise it to extend well beyond 1991. TEGI gives the reader no indication of these difficulties in the stability of its model.

Other arguments could be made about relevant changes in the tax law during the period of estimation (for example, the curtailment of the depreciation allowance) and other factors that raise serious questions about the stability of the model TEGI has estimated. But the basic point is clear: we cannot reasonably expect the type of model TEGI has estimated to remain stable over the proposed sixty-year period of analysis; it is not even stable over the period of estimation. We explicitly rejected the estimation of an econometric investment model for precisely these reasons. That is not to suggest that such a model could not be estimated. But the model that would be useful to policymakers would have to go well beyond the superficial treatment TEGI offers.

We have made many claims without demonstrating them empirically in TEGI's model. If our claims are correct, it should be possible to demonstrate the lack of stability in the model. One could split TEGI's sample and use one time series to estimate a model that would forecast the second time series. For example, one could forecast the period of price controls (1971-1981) or fading controls (1979-1981) with data from previous years. We predict that the model will not forecast well. Good performance of the model in these tests is obviously necessary before we take it seriously to forecast the future, but not necessarily sufficient: Our arguments above predict systematic changes in the model between the periods of estimation and forecast as well as within the estimation period. The serious user of TEGI's results should conduct this test before relying heavily on TEGI's results.
APPENDIX TO SECTION IV

THE MEANING OF THE DECLINE RATE FOR A REPRESENTATIVE WELL IN A SIMPLE SCENARIO

TEGI uses the decline rate of production from a "representative well"—total annual production per well—to estimate the decline rate relevant to tax analysis. This appendix uses a simple scenario to show that TEGI's measure can be totally unrelated to the measure they seek. Let \( W_t \) and \( q_t \) represent wells added and initial production per well in period \( t \); \( a \) is the ratio of wells added in period \( t + 1 \) to wells added in period \( t \); \( b \) is a similar ratio for initial production per well. For some base period \( 0 \),

\[
W_t = W_0 a^t
\]  \hspace{1cm} (4.1)

\[
q_t = q_0 b^t
\]  \hspace{1cm} (4.2)

Let \( Q_{st} \) be the quantity of production in period \( s \) from wells started in period \( t \); \( c \) is the ratio of production from any individual well in period \( t + 1 \) to production from the same well in period \( t \). (Hence, the decline rate is \( 1 - c \).) Then

\[
Q_{st} = W_t q_t c^{s-t} = W_0 q_0 (ab/c)^t c^s
\]  \hspace{1cm} (4.3)

Assume we shut wells in after \( T \) periods. Then the total production in period \( s \), \( Q^s \), is
\[ Q^s = \sum_{t=s-T+1}^{s} W_0 q^s_0 (ab/c)^t c^s = W_0 q^s_0 c^s \sum_{t=s-T+1}^{s} (ab/c)^t \]  

Similarly, the total number of wells in period \( s \), \( W^s \), is

\[ W^s = \sum_{t=s-T+1}^{s} W_t = W_0 \sum_{t=s-T+1}^{s} a^t \]

We can simplify (4.4) and (4.5) by noting that

\[ \sum_{t=s-T+1}^{s} (ab/c)^t = (ab/c)^s [((ab/c)^{-T} - 1)(1 - ab/c)^{-1}] \]

\[ \sum_{t=s-T+1}^{s} a^t = a^s [(a^{-T} - 1)(1 - a)^{-1}] \]

The measure TEGI uses to measure decline rate is

\[ 1 - \frac{Q^s}{W^s} / (Q^{s-1}/W^{s-1}) = 1 - \frac{Q^s/Q^{s-1}}{W^{s-1}/W^s} \]

Substituting (4.6) in (4.4) and (4.5) and substituting these in turn into (4.7) yields a calculated decline rate of

\[ 1 - (c^s/c^{s-1})(ab/c)^s(ab/c)^{1-s}(a^{s-1}/a^s) = 1 - b \]

The measured decline rate depends only on \( b \), the factor by which initial production per well changes over time. It is unrelated to \( c \), the factor by which production from individual wells changes and the factor relevant to analysis of tax effects.

Naturally, we are not suggesting that this simple model holds exactly. Indeed, the assumptions embedded in this model are highly restrictive. It is meant to illustrate the many factors affecting the
observed decline rate in average production per well beyond the parameter TEGI seeks in their analysis. Only analysis of highly disaggregated data can usefully improve on the analysis of oil severance taxes in this area.
V. CONCLUSIONS

How does TEGI's analysis affect the conclusions from Rand's study of a potential California severance tax on oil? It changes these conclusions in the following ways:

1. Rand initially estimated that a 6 percent tax would cut production from existing wells by about 0.6 percent. One point in TEGI's analysis suggests that we should raise that estimate by 0.6 percentage points to 1.2 percent.

2. Rand initially estimated that California oil companies would bear about 35 to 50 percent of a 6 percent tax in the first few years following a tax and 55 to 80 percent of the tax after ten years. The change in production response from existing wells above suggests that we should raise those estimates by about 3 percentage points.

Otherwise, we believe The Rand conclusions stand and are strengthened by TEGI's attention to the analysis underlying them. TEGI had some difficulty understanding Rand's analysis and conclusions. Nonetheless, while the authors of TEGI might disagree, we believe their use of Rand's analytic framework illustrates its usefulness in accommodating alternative points of view and helping to quantify their importance.

How much do TEGI's extensions of Rand's work on tax-induced production response add to Rand's initial results? Unfortunately, they add very little. TEGI's analyses of production response do not characterize oil production in California well enough to be helpful to policymakers. Policymakers would probably also find helpful better treatment of uncertainty and of the sensitivity of results to variations in assumptions.

In closing, we emphasize again that The Rand Corporation neither favors nor opposes a severance tax. We leave such a political decision to members of the Legislature. We designed our analysis to help members make this decision themselves. We continue to believe that the Legislature's consideration of a severance tax could benefit from additional analysis and we look forward to seeing more.