# Essays on Taxation and Firm Behavior



by

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B.S., Massachusetts Institute of Technology (2004)

Submitted to the Department of Economics
in partial fulfillment of the requirements for the degree of

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## Abstract

This dissertation consists of three essays that examine the impact of tax policy of firm behavior. The first chapter uses new well-level production data on California oil wells and after-tax producer prices to estimate how temporary taxes affect oil production decisions. Theory suggests that temporary taxes could lead producers to shut wells, and more generally that they create strong incentives for retiming extraction of the exhaustible resource to minimize tax burdens. The empirical estimates suggest small estimates of extensive responses to after-tax prices, meaning that wells are rarely shut, but they also suggest substantial retiming of production for operating wells. While the estimates vary with specifications, the elasticity of oil production with respect to the after-tax price is estimated to fall between 0.208 and 0.261. The estimates are used to calibrate a simple model of the efficiency cost of tax-induced distortions relative to the no-tax optimal extraction path. Calculations suggest that a 15 percent temporary excise tax on California oil producers reduces the present value of producer surplus by between one and five percent of the no-tax surplus or between 113 and 166 percent of the government revenue raised, depending on the original life of the well and the duration of the temporary tax.

The second chapter examines the impact of the federal R&D tax credit on research spending during the 1981-1991 period using both publicly available data from 10-Ks and confidential data from federal corporate tax returns. The key advance on previous work is the use of an instrumental variables strategy based on tax law changes that addresses the potential simultaneity between R&D spending and its user cost. The results yield a range of estimates for the effect of tax incentives on R&D investment. Estimates using only publicly available data suggest that a ten percent tax subsidy for R&D yields on average between \$3.5 (0.24) million and \$10.7 (1.79) million in new R&D spending per firm. Estimates from IRS SOI data suggest that a ten percent reduction in the usercost would lead the average firm to increase qualified spending by \$2.0 (0.39) million. Estimates from the much smaller merged sample suggest that qualified spending is responsive to the tax subsidy. A similar response in total spending is not statistically discernible in the merged sample. The inconsistency of estimates across datasets, instrument choice and specifications highlights the sensitivity of estimates of the tax-price elasticity of R&D spending.

How a corporate tax reform will affect a firms reported earnings in the year of its enactment, and how the firm may choose to react to the tax reform, depend in part on the sign and magnitude of the firms net deferred tax position. The final chapter, written jointly with Jim Poterba and Jeri Seidman, compiles new disaggregated deferred tax position data for a sample of large U.S. firms between 1993 and 2004. These data are used to assess the size and composition of deferred tax assets and liabilities and their magnitudes relative to the book-tax income gap. We find that temporary differences account for a substantial share of the book-tax income gap. The key contributors to the increase in the book-tax gap include mark-to-market adjustments, property and valuation allowances. In interpreting the data we collect on deferred tax assets and liabilities in the context of the behavioral incentives surrounding a tax rate change, we find that a pre-announced reduction in the corporate tax rate would give a third of the firms in our sample to a strong incentive to accelerate income to the high-tax period, contrary to typical expectations that fail to take deferred tax positions into account.

Thesis Supervisor: James M. Poterba
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# Contents

# Introduction

The provisions of the U.S. tax code by design and by effect influence corporate decision-making. Taxes on and subsidies for particular corporate activities lead to disparate tax treatment of different production and spending decisions, altering the incentives to engage in certain economic activities. Evaluating the effectiveness of any subsidy provision or the cost of any tax provision hinges critically on the underlying tax-price elasticities of production and investment decisions. The chapters of this dissertation generate empirical estimates of the short-to-medium run effects of changes to different aspects of corporate tax policy. The first two chapters estimate behavioral elasticities directly, using plausibly exogenous variation in the after-tax prices faced by firms. The third essay uses newly collected data and calibration to assess the behavioral response of firms to a hypothetical tax change typically considered by policymakers.

The first chapter uses new well-level production data on California oil wells for the period 1977-2008, along with rich variation in producer prices induced by federal oil taxes and pre-1980 price controls, to estimate how temporary taxes affect oil production decisions. Because oil is an exhaustible resource, the effects of excise taxes on production may be more complex than in many other markets. Theory suggests that temporary taxes could lead producers to shut wells, and more generally that they create strong incentives for retiming production to minimize tax burdens. The empirical estimates suggest small extensive responses to changes in after-tax prices, meaning that wells are rarely shut, but they also suggest substantial retiming of production for operating wells. While the estimates vary with specifications, the elasticity of oil production with respect to the after-tax price is estimated to fall between 0.208

and 0.261. The estimates are used to calibrate a simple model of the efficiency cost of tax-induced distortions relative to the no-tax optimal extraction path. The calibration takes into account the exhaustible nature of oil reserves. Because California oil producers, like all U.S. oil producers, are price-takers, the efficiency cost of tax-induced distortions falls solely on producers. Calculations suggest that a 15 percent temporary excise tax on California oil producers reduces the present value of producer surplus by between one and five percent of the no-tax surplus or between 113 and 166 percent of the government revenue raised, depending on the original life of the well and the duration of the temporary tax. Temporary excise taxes appear to curtail extraction along the intensive margin, reducing producer surplus but not triggering early shut-in.

The second chapter examines the impact of the federal R&D tax credit on research spending during the 1981-1991 period using both publicly available data from financial filings and confidential IRS data from federal corporate tax returns. The key advance on previous work is the use of an instrumental variables strategy based on tax law changes that addresses the potential simultaneity between R&D spending and its user cost. The results yield a range of estimates for the effect of tax incentives on R&D investment. Estimates using only publicly available data suggest that a ten percent tax subsidy for R&D yields on average between $3.5 (0.24) million and $10.7 (1.79) million in new R&D spending per firm. Estimates from IRS SOI data, which only reports qualified research expenditures, suggest that a ten percent reduction in the usercost would lead the average firm to increase qualified spending by $2.0 (0.39) million. Analysis of the components of qualified research spending shows that wages and supplies, which comprise the bulk of qualified spending, account for the increase in research spending. Estimates from the much smaller merged sample, which makes use of the more precise tax data to calculate the tax component of the user cost, suggest that qualified spending is responsive to the tax subsidy. A similar response in total spending is not statistically discernible in the merged sample. The inconsistency of estimates across datasets, instrument choice and specifications highlights the sensitivity of estimates of the tax-price elasticity of R&D spending.

Changes in tax policy can also generate incentives for firms to re-time their recognition of income. A firms deferred tax position, which reflects the estimated future tax effects attributable to past temporary differences between book and tax income, affects the impact of tax changes on the firm. How a corporate tax reform will affect a firms reported earnings in the year of its enactment, and how the firm may choose to react to the tax reform, depend in part on the sign and magnitude of the firms net deferred tax position. In particular, the disparate impacts of tax reform on firms with net deferred tax assets and liabilities create different incentives to re-time the recognition of income before and after an announced corporate tax rate change. The final chapter, written jointly with Jim Poterba and Jeri Seidman, compiles new disaggregated deferred tax position data for a sample of large U.S. firms between 1993 and 2004. These data are used to assess the size and composition of deferred tax assets and liabilities and their magnitudes relative to the book-tax income gap. We then analyze the incentives created by these positions for retiming income around tax changes. We find that temporary differences account for a substantial share of the book-tax income gap. The key contributors to the increase in the book-tax gap include mark-to-market adjustments, property, including leases and both tangible and intangible property, and valuation allowances. In interpreting the data we collect on deferred tax assets and liabilities in the context of the behavioral incentives surrounding a tax rate change, we find that a pre-announced reduction in the corporate tax rate would give a third of the firms in our sample to a strong incentive to accelerate income to the high-tax period, contrary to typical expectations that fail to take deferred tax positions into account. Although we are unable to gauge how much income would be shifted in response to such incentives, the nontrivial share of firms affected by such an incentive suggests that policy-makers should consider the revenue impact of income shifting when they estimate the short-run revenue effect of a change in the statutory corporate tax rate.

Taken together, the results presented here suggest that the tax policy changes examined had real effects on corporate economic activity in the cases of the windfall profit tax and the R&D tax credit and that there is ample scope for income retiming driven by incentives created by deferred tax positions. These empirical conclusions are based on short-to-medium run time horizons. Whether tax policy leads to long-term or permanent differences in economic behavior rather than just leading firms to re-time their activities to minimize their tax burdens is an important open question I hope to address in future work.

# Chapter 1

# Taxation and the Extraction of Exhaustible Resources: Evidence From California Oil Production

## 1.1 Introduction

Steep increases in oil prices often bring with them renewed calls to levy additional taxes on the oil industry. Most recently the rapid run-up in prices during 2008 led to legislative proposals and campaign trail discussions of new "windfall profit" taxes. Advocates of such taxes argue that the upfront drilling investments necessary for current production were made during periods of much lower prices and that profits from such investments are an unearned "windfall." Critics counter that additional taxes may have deleterious effects on domestic oil production, leading to increased U.S. dependence on foreign oil. The consequences of these types of taxes hinge critically on how producers respond to changes in after-tax price. The effects of taxes on the extraction of exhaustible resources like oil may be of increasing importance as proposals to tax fossil fuels emerge as part of the climate change debate.

Despite the importance of estimates of the elasticity of U.S. supply for assessing the impact of policy changes like the decontrol of oil prices in the late 1970s or current policy considerations like the levying of new oil industry taxes or imposing an oil import fee, consensus elasticity estimates have been lacking. Previous studies have relied exclusively on time-series variation and have mostly found very small and economically insignificant elasticities.[1] Most policy studies of oil markets rely on a range of plausible elasticities due to the lack of consistent credible estimates. In fact the 2006 Congressional Research Service report on proposed windfall profit taxes stated, "few studies generate reliable estimates and in fact some studies estimate negative supply elasticities, which are not plausible."[2] Thus CRS, like previous Congressional Budget Office and OECD studies, employed a number of assumed elasticities—CRS used supply elasticities of 0.2, 0.5 and 0.8—that were within the wide range of estimates rather than settling on a specific elasticity estimate.[3]

I estimate the supply response using a new rich data set that reports monthly production for all onshore wells in the state of California—the third-ranking state in oil production—over a thirty-one-year period beginning in 1977. The data come from mandatory monthly filings by well operators to the California Department of Conservation Division of Oil, Gas and Geothermal Resources. I construct a dataset of 30,025,957 observations describing 140,672 wells. These data cover all onshore production between 1977 and 2008; the sample includes wells that were already completed and wells completed during the period. In addition to monthly production, for each well, each month the data report the quality of the oil produced, the firm operating the well, the method of pumping, exact location, the field and pool it taps, and the status—whether it is capable of producing or shut-in. This level of detail allows me to assign each well its appropriate regulatory and tax regime treatment, following the *Federal Code of Regulations* for each year. Using this policy detail and

[1]Hogan (1989) and Ramcharan (2002) found significant supply elasticities of 0.09 (0,03) and 0.05 (0.02), respectively. Jones (1990) and Dahl and Yücel (1991) found insignificant elasticities of 0.07 (0.04) and -0.08 (0.06) and Griffin (1985) found a significant negative elasticity, -0.05 (0.02). Hogan (1989) also estimated a longer-run elasticity of 0.58 (0.18).

[2]Lazzari (2006)

[3]The OECD in its 2004 Economic Outlook based its projection of non-OPEC production on elasticities of 0.1, 0.3 and 0.5. The US Department of Energy's Energy Information Agency does not explicitly state the elasticities it uses in its analyses, but its forecasts indicate that an elasticity of 0.2 over a ten year window and virtually zero for one year responses.

monthly field-by-grade prices from Platt's *Oil Price Handbook and Oilmanac* for each year, I am able to trace over time the path of after-tax price for each well, taking into account differential regulatory and tax treatment across wells.

Because these federal policies created substantial variation in after-tax price over time, I am able to identify the supply response using only within-well variation. In fact, regulatory and tax policy generate enough across well variation in after-tax price in each month-year that I can also non-parametrically control for common unobserved time factors affecting well productivity.

Previous attempts to estimate the supply elasticity of oil production suffer from three difficulties. First, the use of the readily available but non-representative Department of Energy Monthly Energy Review (MER) average pre-tax first purchase price series introduces measurement error in the price variable, leading to potential downward biases in estimates of the supply response. When I estimate my oil production models with the MER price series rather than the more accurate field-by-grade prices adjusted for well-specific regulatory and tax treatment, I find elasticity estimates an order of magnitude smaller than my baseline estimates. These findings are similar to estimates found in the previous literature.

Second, the persistence of tax and price variation may potentially differ; the elasticity estimate and resulting cost parameter estimate used to evaluate the welfare cost of excise taxes on oil extraction should be generated by after-tax price variation of similar persistence as proposed tax policy.[4] As policy proposals largely describe temporary taxes, the temporary price changes induced by government policy isolated here may be more appropriate than movements in world price. In fact, comparing a supply elasticity estimate using my data that purges variation in world price through month-year fixed effects, 0.237 (0.029), to an estimate using my data that retains variation in world price, 0.071 (0.014), suggests that firms are less sensitive to pre-tax price variation.

[4]If variation in world price is more persistent than temporary tax variation, including price variation in the after-tax price variation used to generate elasticity estimates will lead to an overestimate of the elasticity since firms are responsive to longer-term changes in after-tax price. If tax variation was more persistent than world price variation, the opposite would be true.

Finally, time-series regressions use aggregate totals of U.S. oil production as the dependent variable, introducing "aggregation bias" since well productivity is not homogenous. U.S. oil wells lie along a gradient of productivity; when prices are higher the average producing well is less productive as some high cost wells are brought online. Aggregation will subsume this heterogeneity and bias the coefficient.

To assess the welfare cost of taxes on oil extraction it is important to distinguish between response along the extensive and intensive margins. If the reduction in production is driven by the shutting-in of wells, the high cost of reversing shut-in makes this a potentially permanent loss of oil. On the other hand, if production is reduced primarily along the intensive margin, operators are simply tilting their extraction paths forward in response to the tax: they will pump less today and more in the future. This intensive adjustment will still reduce producer surplus, but the welfare cost will come from the delay in revenues and the additional cost of sub-optimally pumping the well, not from an output gap. As my analysis examines the within-well supply response, the exploration margin is not a part of my assessment of the deadweight loss of temporary taxes.[5] Temporary taxes are more likely to delay rather than curtail exploration activities, meaning that temporary taxes could lead to even more production re-timing than is captured here. Potential additional adjustment on the exploration margin may make the estimates reported here a lower bound on the full elasticity.

My estimates suggest that production from existing wells is price-responsive. The main results show an after-tax price elasticity of oil production in California of 0.237, with a 95 percent confidence interval of 0.180 to 0.295. Response along the extensive margin is minimal; the main specification shows that a ten percent decrease in after-tax price would lead to at most a 1.17 percent increase in the shut-in rate. The estimates are used to calibrate a simple model of the efficiency cost of tax-induced distortions relative to the no-tax optimal extraction path. These calculations suggest that a 15 percent temporary excise tax on California oil producers reduces the present

[5] As new wells are completed they are added to the sample used to generate the empirical estimates, but since the analysis uses only within-well variation in after-tax price, the estimate does not measure the impact of new wells on aggregate production.

value of producer surplus by between one and five percent of the no-tax surplus, depending on the original life of the well and the duration of the temporary tax. On average each dollar of tax revenue raised reduces producer surplus by \$1.13 to \$1.66.

The paper proceeds as follows. Section 1.2 describes a simple model of the impact of excise taxes on the extraction of an exhaustible resource. Relevant background information on the U.S. and California oil industries and the relevant institutional knowledge regarding the decontrol of oil prices and the introduction of temporary federal excise taxes are discussed in Section 1.3. Section 1.4 describes the new rich production and price data I assembled. Section 1.5 details the estimation strategy. Section 1.6 presents the estimates of the supply response. Section 1.7 assesses how after-tax price affects the well closure decision. Section 1.8 demonstrates the value of micro-data and reconciles my elasticities with the much smaller elasticities estimated in prior studies. Section 1.9 illustrates how the empirical estimates of Section 1.6 and the model from Section 1.2 can be combined to assess the welfare cost of excise taxes on domestic oil production. Section 1.10 concludes and discusses directions for future research.

## 1.2 Taxes and the Extraction of Exhaustible Resources

This section focuses on the well operator's extraction decision. Subsection 2.1 presents a simple model of the oil well operator's problem, highlighting that exhaustibility reduces the extraction rate relative to production from an inexhaustible resource. Subsection 2.2 discusses the effects of excise taxes in the context of the model, which have been recently proposed in reaction to rapidly increasing oil prices.

### 1.2.1 The Extraction Problem

The well operator chooses an extraction path to maximize profit, taking into account the exhaustibility of the reserves of his well. Operators are assumed to be price-takers with known reserves; as in the Hotelling (1931) model, the operator chooses an extraction path by dynamically optimizing the present discounted value of total profit from extraction over the life of the well.[6] Because the typical U.S. well lacks sufficient natural subsurface reservoir pressure for the oil to flow to the surface, most wells are pumped, making extraction costly.

*Exhaustibility*

For an exhaustible resource the intertemporal sum of services from a given stock is finite.[7] Exhaustibility in effect makes extraction a 'pump today or pump tomorrow' decision for the operator. Extracting a unit today has an opportunity cost: the unit cannot be extracted in the future. This opportunity cost creates an incentive for holding the resource *in situ*, tempering the incentive to extract and sell. In the model, the operator of a drilled well is assumed to know his reserve level with certainty, thus exhaustibility means that the total amount of oil extracted from the well cannot exceed his initial known reserves, $R_0$:

$$\int_0^{\infty} q_t dt \leq R_0 \tag{1.1}$$

where $q_t$ is the extraction rate at time $t$. In addition $q_t$ is assumed to be non-negative, ruling out pumping oil into the reservoir.

*Exhaustibility*

For simplicity, it is assumed that the full price path is known at time 0. Because the operator is a price-taker, his problem is:

$$\max_{\langle q \rangle} \int_0^{\infty} e^{-rt} \left[ p_t q_t - c\left(q_t\right)\right] dt \tag{1.2}$$

[6]Hotelling's seminal work has been extended and discussed by numerous authors, including Dasgupta and Heal (1979).

[7]The sum of services is still finite even if the resource is recyclable since less than the full quantity can be recovered each time the output is recycled. Recycling, of course, is not relevant in the case of oil.

subject to:

$$\int_0^\infty q_t dt \leq R_0 \text{ and } R_t \geq 0 \tag{1.3}$$

where $p_t$ is the price, $c(q_t)$ is the cost of extraction and $R_t$ is the reserve level at time $t$. Though the operator's problem is dynamic, the shadow-value of reserves associated with the exhaustibility constraint along the optimal extraction path is time invariant. The non-negativity constraint can be ignored given the linearity of revenues and the convexity of cost in $q_t$—if $q_t$ is always non-negative and total extraction does not exceed initial reserves, then the reserve level will always be positive. Thus, the problem can be written as a Hamiltonian with a single constraint:

$$\Lambda(q_t, \lambda_t) = \int_0^T e^{-rt}\left[p_t q_t - c(q_t)\right] dt - \lambda_t \left[\int_0^T q_t dt - R_0\right] \tag{1.4}$$

where $T$ is the time at which all profitable oil has been extracted and the economic limit of the well has been reached. The first-order condition with respect to $q_t$:

$$e^{-rt}\left(p_t - c'(q_t)\right) - \lambda(t) = 0 \tag{1.5}$$

implicitly defines the optimal extraction rate at each time $t$, $q_t$, as a function of the price at time $t$, $p_t$, the interest rate, $r$, and the shadow value of an incremental addition to reserves, $\lambda$. The second necessary condition:

$$\dot{\lambda} = -\frac{\partial \Lambda(q_t, \lambda(t))}{\partial R_t} = 0 \tag{1.6}$$

implies that the multiplier, $\lambda$, is constant. The shadow value of reserves is pinned down by the terminal condition. At time $T$ the economic life of the well has been reached and the extraction rate falls to zero.[8] The transversality condition, $\Lambda(T) = 0$, combined with first-order condition at time at time $T$, imply that $q_T$ is the production level that equates the marginal and average costs of production. If the marginal cost

[8]In the last period of extraction the operator will choose an extraction quantity that equates the marginal and average cost of extraction, for the specific cost function employed below that is:
$q_T = \sqrt{\frac{f}{c}}$
After extracting $q_T$ the operator shuts the well and the extraction rate jumps to zero.

of producing $q_T$, $c'(q_T)$, exceeds the price, then the producer will opt to not produce and shut-in and exit instead. Plugging the terminal production quantity, $q_T$ into the static optimization condition at time $T$, the shadow value of reserves is pinned down:

$$\lambda = e^{-rT(\mathbf{p})} \left(p_T - c'(q_T)\right) \tag{1.7}$$

where the life of the well, $T$, is a function of the price path, $\mathbf{p}$, since higher average prices will accelerate extraction and shorten well life. The exact shape of the extraction path is determined by the marginal cost of extraction and the discount factor, with the shutdown condition, the equality of marginal and average cost, pinning down the extraction amount at time $T$. The reserves will be fully exhausted at time $T$ since $q_T$, the production quantity that equates marginal is, by virtue of minimizing average cost, is less than production quantity that equates marginal cost and price—the operator finds all remaining production profitable. Intuitively, once he has paid the fixed cost to produce in the last period, he will produce the remaining quantity (which is by optimality of the extraction path less than the quantity that equates price and marginal cost).

*The Cost of Extraction*

Even after the completion of the well, extracting oil is costly. Extraction costs include fixed costs such as the user-cost of pumping equipment and operating costs such as energy inputs to drive the pump and labor costs of monitoring. The cost function is modeled as convex in the extraction rate with an additional fixed cost of operating. Letting $q_t$ denote the extraction rate and $f$ the fixed cost of operation, the cost function can be written:

$$c(q_t) = \begin{cases} cq_t^2 + f & \text{if the well produces} \\ 0 & \text{if the well does not produce} \end{cases}$$

where $c$ is a parameter of the cost function.

*The Optimal Extraction Path*

Given the quadratic cost function, the optimal extraction rate and shadow value of reserves are:

$$e^{-rt}\left(p_t - 2cq_t\right) - \lambda = 0 \tag{1.8}$$

$$\lambda = e^{-rT}\left(p_T - 2\sqrt{fc}\right) \tag{1.9}$$

Combining equations 1.8 and 1.9, the optimal extraction at time $t$ is:

$$q_t^* = \frac{p_t}{2c} - \frac{e^{-r(T(\mathbf{p})-t)}\left(p_T - 2\sqrt{fc}\right)}{2c} \tag{1.10}$$

where again the economic life of the well, $T$, is a function of the price path, $\mathbf{p}$; a higher price today will lead to a faster extraction rate and a shorter well life. More specifically, $T(\mathbf{p})$ is implicitly defined by the exhaustibility constraint:

$$\int_0^T \left[\frac{p_t}{2c} - \frac{e^{-r(T(\mathbf{p})-t)}\left(p_T - 2\sqrt{fc}\right)}{2c}\right] dt = R_0 \tag{1.11}$$

The extraction rate defined in equation 1.10 declines over time due to the discounting of future profits. Wells that are further from their economic limit, $T$, will pump at a faster rate. The extraction rate is inversely proportional to the slope of the marginal cost function—wells with more steeply convex costs of extraction will extract more slowly.

## 1.2.2 Excise Taxes and the Extraction Path

*A Permanent Excise Tax*

After the introduction of a permanent excise at rate $\tau$ the operator's optimal extraction rate is:

$$q_t^* = \frac{p_t(1-\tau)}{2c} - \frac{e^{-r(T(\mathbf{p})-t)}\left((1-\tau)\,p_T - 2\sqrt{fc}\right)}{2c} \tag{1.12}$$

The permanent excise tax reduces extraction in all periods, tilting the whole extraction path downward. Because the tax reduces revenues in all periods including the final period of extraction when the well reaches its economic limit, the well may shut down with reserves remaining in the well if the marginal cost of production exceeds the after-tax price. In this sense, permanent taxes can induce shut-in.

This does not necessarily mean that the permanent excise tax reduces the life of a well. On one hand, lower extraction rates due to the tax will lead to a more than proportionate increase the amount of time necessary to pump the same reserves pumped in the no-tax case; for a given level of aggregate extraction a slower extraction rate extends the life of the well.[9] On the other hand, the tax could result in the well shutting down with reserves remaining in the well; the operator will extract less oil in total, which for a given extraction path reduces the life of the well. Whether this combination of forces leads to a net increase or decrease in the life of the well will depend on how close the well is to its economic limit when the permanent tax is levied. Wells near the end of their original economic lives are more likely to experience a net reduction in well life due to the permanent tax since the increase in abandoned reserves is a larger fraction of total oil remaining in the well when the tax is levied. Wells far from the end of their economic lives could actually experience an increase in well life since the decrease in extraction rates may extend the life of the well more than the new shutdown condition shortens it.

*A Temporary Excise Tax*

The introduction of an unanticipated temporary excise tax that is known to be in place until time $t_1$ reduces after-tax price in the near term, but leaves the after-tax

[9]For expositional clarity, assume that price is constant so that $p_t = p$ and that fixed costs are absent, $f = 0$. Then the exhaustibility constraint is:
$\int_0^T \left[\frac{(1-\tau)p}{2c} - \frac{(1-\tau)pe^{-r(T(\mathbf{p})-t)}}{2c}\right] dt = \frac{(1-\tau)}{2c}\left(pT - \frac{p}{r} - \frac{pe^{-rT}}{r}\right) \leq R_0$
so any change in $\tau$ must be offset by a more than proportional change in $T$. The increase must be more than proportional because the extraction rate declines over time; the additional reserves resulting from lower extraction rates are pumped when the extraction rate is low. At time $T^0$, the original life of the well, now $(1-\tau)$ additional reserves remain; these reserves will take longer than $(1-\tau)T^0$ to pump since the extraction rate at time $T^0$ is less than the average extraction rate up until $T^0$.

price after time $t_1$ unchanged. To simplify the analysis, but without loss of generality, price is assumed to be constant between time 0 and $t_1$ and between $t_1$ and the end of the well's life. The price between time 0 and $t_1$ is denoted by $p_1 = (1-\tau)\,p_1^W$ where $p_1^W$ is the pre-tax world price before $t_1$ and the price after $t_1$ is denoted by $p_2 = p_2^W$ where $p_2^W$ is the pre-tax world price after time $t_1$.

For wells with pre-tax economic lives that extend beyond time $t_1$, while the tax is in place between 0 and $t_1$ the operator's optimal extraction rate is:

$$q_t^* = \frac{p_1}{2c} - \frac{e^{-r(T(p_1,p_2)-t)}\left(p_2 - 2\sqrt{fc}\right)}{2c} \tag{1.13}$$

and after $t_1$ the optimal extraction rate is:

$$q_t^* = \frac{p_2}{2c} - \frac{e^{-r(T(p_1,p_2)-t)}\left(p_2 - 2\sqrt{fc}\right)}{2c} \tag{1.14}$$

The economic life of the well, $T(p_1, p_2)$, is a function of both prices: a higher tax rate in the first period will reduce extraction and lengthen the life of the well, higher pre-tax price in either period will increase extraction rates in that period and shorten the life of the well.

An increase in the tax rate reduces extraction in the first period. Assuming zero fixed costs for expositional clarity, the total impact of a change in $p_1$ on the extraction rate while the tax is in place is:

$$\frac{dq_t^*}{dp_1} \geq \frac{1}{2c} - \frac{e^{-r(T(p_1,p_2)-t)}}{1+e^{-r(T(p_1,p_2)-t)}}\frac{rt_1}{2c} \tag{1.15}$$

again, where $p_1 = (1-\tau)\,p_1^W$, meaning that higher tax rates lead to lower extraction rates. The impact of a change in the tax rate on the contemporaneous extraction rate has two components: the direct impact from the first term of equation 1.13 and the indirect impact from the effect the change in tax rate has on the economic life of the well. The first term of equation 1.15 describes the direct impact of the change in price on extraction: higher after-tax price accelerates extraction. The second term captures the mitigating impact of the exhaustibility constraint: higher prices before

$t_1$ reduces the life of the well, increasing the opportunity cost of extraction since the last barrel is pumped sooner which reduces the effect of discounting. The economic life of the well, $T(p_1, p_2)$, which is shortened by higher after-tax price in the first period, is implicitly defined by the exhaustibility constraint:

$$\begin{aligned} \int_0^{t_1} \frac{p_1}{2c} dt + \int_{t_1}^{T} \frac{p_2}{2c} dt - \int_0^{T} \frac{p_2 e^{-r(T-t)}}{2c} dt & \leq R_0 \\ \frac{p_1 t_1 + p_2 (T - t_1)}{2c} - \frac{p_2 \left(1 - e^{-rT}\right)}{2cr} & \leq R_0 \end{aligned} \tag{1.16}$$

Taking the total derivative of equation 1.16 reveals[10]

$$\frac{dT}{dp_1} \leq \frac{-t_1}{p_2} \frac{1}{1 - e^{-rT}} \tag{1.17}$$

meaning that a higher tax rate, which reduce $p_1$, extends the life of the well by reducing extraction rates between time 0 and time $t_1$. Higher temporary excise taxes lead the operator to retime production, shifting extraction from the tax period to the future when the tax has expired. This forward tilting extends the life of the well because the additional reserves that result from slower initial extraction will be pumped such that extraction costs are minimized, which means extending the life of the well.

For long lived wells, where $T(p_1, p_2)$ is large, the impact of the second term of equation 1.15 is small, especially if the tax is in place for a relatively short period of time. If $T(p_1, p_2)$ is large, then equation 1.15 is approximately:

$$\frac{dq_t^*}{dp_1} \geq \frac{1}{2c} \tag{1.18}$$

In other words the impact of a 10 percent decrease in the after-tax price, $p_1$, is a $(0.05/c)$ reduction in the extraction rate for wells that are not near the end of their economic lives. The empirical work aims to estimate the cost function parameter $c$.

[10]The total derivative of equation 1.16 is
$\frac{t_1}{2c} + \frac{p_2}{2c}\frac{dT}{dp_1} - \frac{p_2 e^{-rT}(-r)}{2cr}\frac{dT}{dp_1} \leq 0$

Finally, wells with high fixed or operating costs and little remaining reserves may shut-in in response to even a temporary tax; specifically the temporary tax could induce earlier shut-in of wells with little remaining productive life. If the well operator planned to shut his well before time $t_1$ prior to the introduction of the tax, the introduction of the tax will hasten his abandonment since for his purposes the temporary tax effectively is a permanent tax.

### 1.2.3 Summary

The extraction rate is an increasing function of the price today and a decreasing function of the price at the end of the well's life; the higher the ultimate price of oil, the greater the opportunity cost of extracting a unit today that would otherwise remain in the well until it's last period of production. Excise taxes affect both the current price and the opportunity cost of extraction. Temporary taxes mainly affect the current price for long-lived wells, thus creating strong incentives for operators to re-time production, shifting extraction from the tax period to the post-tax period. This shifting means that the shortrun output gap induced by a temporary excise tax on the extraction of an exhaustible resource overstates the welfare cost of such taxes; reserves not extracted while the tax is in place will be extracted later, albeit less profitably due to discounting and higher costs due to sub-optimal extraction. This retiming also reduces the tax revenue raised. The implications of a temporary tax based on the simple model described above suggest a strategy to assess the impact and welfare cost of such taxes. Empirically estimating the cost parameter $c$ would allow for assessments of the welfare cost of excise taxes on the extraction of exhaustible resources. The estimated cost parameter should be used to calculate total surplus from production, taking the dynamics of extraction into account.

## 1.3 Institutional Background

To identify to the supply elasticity and the cost parameter $c$, I examine domestic producer decisions during a period characterized by price regulation, decontrol and the imposition of federal excise taxes. These policies significantly altered producer prices and created considerable differences in producer price across wells. This section provides background information on the California oil industry and details the relevant history of government actions affecting producer prices. Subsection 1.3.1 describes the California oil industry and explains the exogeneity of world price to the production decisions of U.S. producers and its implications for domestic producer prices. Subsection 1.3.2 describes the decontrol of domestic oil prices and the levying of the 1980 Windfall Profit Tax (WPT). I use the over time and across well variation in after-tax price generated by decontrol and the WPT to indentify the after-tax price elasticity and the cost parameter $c$.

### 1.3.1 The California Oil Industry: Production and Producer Price

The United States is the third largest oil producer[11], behind only Saudi Arabia and Russia; California is the third largest oil producing state in the U.S. Onshore oil producers in California account for roughly one percent of total world production.[12] The oil produced in California is of lower quality than more prominent benchmark crudes such as West Texas Intermediate, the price of which is used in future and forward markets. API gravity measures the specific gravity, or "heaviness" of oil, which determines how efficiently the crude can be refined into petroleum products.[13] California oil was more than 60 percent heavy or very heavy crude during the 1977-1985 period. Heavy oil is generally more expensive to extract as its weight increases pumping costs. Given the result from Section 1.2 that wells with higher marginal costs will be less responsive to changes in after-tax price, it is reasonable to think that estimates based on California wells provide a lower bound on tax-price responsiveness

[11]The U.S. was the third largest producer in the 1970s and 1980s as well though U.S.S.R production totals were less accurately measured.

[12]U.S. Department of Energy, Energy Information Administration: http://tonto.eia.doe.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_m.htm

[13]API gravity is an inverse function of specific gravity:
$\text{API Gravity} = \frac{141.5}{\text{Specific Gravity}} - 131.5$

for the average U.S. well. In California heavy oil wells are also less productive than wells that produce lighter oil.[14]

U.S. producer prices are not sensitive to the production decisions of individual operators. Domestic pre-tax prices are set by the global oil market. Aggregate U.S. oil production comprised roughly 15 percent of total world production while price controls and windfall profit taxes were in place, a substantial but decidedly minority share. Unlike most other oil producing nations, oil extraction in the U.S. is a competitive market where large international oil firms operate alongside many smaller independent producers. Though the large international companies that operate in the U.S. also operate abroad, their market share was dramatically undercut by the organization of OPEC in 1960. By the mid-1970s OPEC nations accounted for roughly half of world production and coordinated their production decisions in an effort to influence price. Though the evidence on OPEC's effectiveness as a cartel is mixed,[15] if any group of producers had the market share and coordination necessary to affect prices it was and remains nationalized producers rather than the competitive fringe that operates in the U.S.[16] Since they account for a small share of world production and operate in a market alongside a cartel, U.S. oil producers, including California producers, can reasonably be assumed to be price takers.[17]

Refiners always had the option to purchase imported oil—which was exempt from both price controls and the WPT. During the price control era a permit trading system allocated low-price domestic crude among refiners.[18] Refiners did not face

[14]Heavy oil is oil with an American Petroleum Institute (API) gravity less than 20; very heavy oil is oil with an API gravity less than 16. API gravity is an inverse function of specific gravity—higher API gravity oil is lighter and sells for a premium. 11.6 percent of California crude during the 1977-1985 period was heavy while 49.8 percent was very heavy. These wells were on average less productive than wells that produced lighter crude as 52.9 percent of well-month observations produced very heavy oil and 12.3 percent of well-month observations produced heavy oil.

[15]Hamilton (2009) reviews recent production and quota discrepancies among OPEC nations and finds that OPEC members frequently cheat with respect to their quotas and there is little evidence of a clear enforcement mechanism. Also see Alhaji and Huettner (2000) for a review of 13 studies assessing the effectiveness of OPEC as a cartel.

[16]As the U.S., including California refiners, imports oil, within the range of transportation costs, domestic producers may have some pricing power. Given that transport costs comprise roughly 5 percent of oil prices, domestic producers have only a small scope of pricing power.

[17]Killian (2009) asserts "the price of crude oil is determined in global markets." Domestic pre-tax prices were assumed to track world prices in other empirical studies such as Smith et al (1986).

[18]Since only domestic crude was subject to price controls, refiners who procured domestic crude

shortages since imported oil was always available for purchase. Thus, refiners and perhaps consumers benefitted form price controls while domestic producers saw their prices reduced by the price ceiling. While the WPT was in place, the availability of tax-exempt imports fixed the refiner price at the world price; producer prices were reduced by the full amount of the tax.[19]

### 1.3.2 The Decontrol of Oil Prices and the Introduction of the 1980 Windfall Profit Tax

In an effort to combat inflation the Economic Stabilization Act of 1970 instituted a wide array of wage and price controls. Domestically produced crude oil and refined products were among the goods subject to price controls. While virtually all other price controls were eliminated, prices caps on domestically produced crude oil and refined products remained in place until 1980. The decontrol of oil prices began with the Energy Policy and Conservation Act of 1975, which authorized the President to rescind price controls at any point after May 1979 and the Energy Conservation and Policy Act of 1976, which decontrolled oil extracted from marginally productive wells called stripper wells. Decontrol was a reaction to the sudden increase in oil prices due to the 1973 Arab oil embargo. Rising prices and less stable foreign sources prompted concerns regarding U.S. oil independence and generated interest in increasing domestic oil production. The Carter Administration actively used the authority, and began decontrolling non-stripper domestic crude in June 1979. Decontrol went forward with the understanding that the sudden increase in domestic producer prices would be taxed at the federal level.[20] The 1980 Windfall Profit Tax was signed into

earned rents. The federal government created a system of tradable permits to allocate low-priced domestic crude among refiners to "fairly" distribute the potential windfall. Permits were allocated according to historic crude sourcing.

[19]Though transportation costs are small, roughly 5 percent of price domestic producers may have been able to pass a fraction of the tax equal to transport cost on to purchasers. All oil produced in California is refined within the state, but refiner demand exceeds production so imports comprise the difference. Imports come largely from Canada and Mexico and average transport costs run roughly $1.30 per barrel. Rodrigue (2009)

[20]According the Joint Committee on Taxation's General Explanation of the Crude Oil Windfall Profit Tax of 1980, "without such a tax, decontrol probably could not [have gone] forward."

law April 2, 1980 and virtually all non-Alaskan oil owned by a taxable private party was subject to the tax. Purchasers withheld the tax from the amounts otherwise payable to a producer and filed quarterly WPT tax returns with the IRS.

The name Windfall Profit Tax (WPT) is a misnomer. The tax was not a profit tax, but an excise tax applied to the selling price of a barrel of oil regardless of its production cost.

The timing of decontrol varied by API gravity, and by the age and productivity of the well from which oil was extracted. These same oil and well characteristics determined the Windfall Profit Tax (WPT) treatment as well. The WPT taxed oil that was typically more costly to extract at a lower tax rate. Tax favored oil included heavy, oil that had an API gravity of 16 or less, and oil from marginal wells, known as stripper wells, that produce on average less than 10 barrels of oil per day for at least 12 months.

All taxable oil was divided into three tiers under the WPT; each tier corresponded to a different tax rate.[21] An operator's WPT tax liability was equal to the product of the WPT tax rate and the difference between the selling price and the base price for each barrel of oil he sold. Oil in each tier was also assigned a different base price. Thus, for the operator of well $i$ at time $t$ each barrel of oil sold at price $P_{it}$ incurs a WPT liability of:

$$\text{WPT Tax}_{it} = \begin{cases} \tau_{it}^{W} \left(P_{it} - B_i\right) & \text{if } P_{it} > B_i \\ 0 & \text{otherwise} \end{cases}$$

where $B_{it}$ is the real base price. WPT payments were deductible form corporate taxable income, meaning that the after-tax price ($ATP_{it}$) received by the operator of well $i$ at time $t$ was:

$$\text{ATP}_{it} = \begin{cases} \left(1 - \tau_t^{Corp}\right) \left(P_{it} - \tau_{it}^{W} \left(P_{it} - B_i\right)\right) & \text{if } P_{it} > B_i \\ \left(1 - \tau_t^{Corp}\right) P_{it} & \text{otherwise} \end{cases}$$

[21] Specific categories of oil, largely state-, Native American- or charitable trust-owned oil, were exempt from the WPT. See Lazzari (2006) for further details.

The WPT was legislated as a temporary tax. At its height, the WPT raised $44 billion in gross revenue (before corporate income tax deductibility), or roughly half the revenue raised by the corporate income tax. Statue required the tax expire by 1991. In reality the tax became ineffective due to sharp decreases in oil prices in 1986. 1985 was the last year it raised any revenue. In fact, the WPT was repealed in 1988 to eliminate the administrative burden of a tax that did not raise revenue. The timing of decontrol and the simplified details of WPT treatment for each of the three tiers of oil follow.

*Tier I Oil*

Tier I oil was oil extracted from a non-stripper well that produced oil in 1978 which was not heavy, that is its API gravity exceeded 16. Tier I oil had been subject to price controls through the end of 1979. Price controls on Tier I oil were phased out gradually. Beginning in January of 1980 the selling price was a weighted average of the world market price and the price control price with the weight on the market price equal to 0.046 multiplied by the number of months since December 1979. At the end of January of 1981 the phase-out of price controls was abruptly ended and Tier I oil was fully decontrolled, raising the weight on the world price from roughly 60 to 100 percent. During the first 10 months of the WPT the windfall profit tax was applied to a selling price that was in part a controlled price. The base price for Tier I oil was 21 cents less than the May 1979 price control price for the property. The tax rate on Tier I oil was 70 percent.

*Tier II Oil*

Tier II oil consisted of non-heavy oil from stripper wells that produced oil in 1978, and oil produced from a Naval Petroleum Reserve field. A well is considered a stripper well if it has ever averaged less than 10 barrels of oil per day for 12 consecutive months after 1972. Oil produced from stripper wells was exempted from price controls in August 1976.

A Naval Petroleum Reserve is one of four fields owned by the federal government to which access is leased to private operators. The base price for Tier II oil was the December 1979 selling price of oil from the same property multiplied by 0.425, a conversion factor that achieved a statutorily set average base price of $15.20. The tax rate on Tier II oil was 60 percent.

*Tier III Oil*

Tier III oil was comprised by two types of oil, new oil from wells that did not produce oil in 1978 and heavy oil, which is oil with an API gravity of 16 or less. New oil was fully decontrolled in June 1979. Price controls on heavy oil were lifted August 17, 1979. The base price for both new and heavy oil was the December 1979 selling price of oil from the same property multiplied by 0.462, the ratio of the statutorily set average base price to average prices in December 1979. Heavy and new oil were the most tax-favored types of oil; the tax rate on Tier III oil was 30 percent initially and was gradually reduced to 22.5 percent beginning in 1982.

The three tiers of oil, and even different categories of oil within Tier III, were treated very differently by government policies. Differences in the timing of decontrol and differential tax treatment provide the variation in after-tax price that generates the supply elasticities estimated here. These policies created cross-sectional variation in after-tax price allowing for flexible controls for underlying common time-varying factors.

## 1.4 New Production and Price Data

The above section details the substantial variation in after-tax price over time and across wells created by the decontrol of oil prices and the introduction of federal excise taxes. These policies classified wells into different regulatory and tax tiers by the characteristics of the well and the oil it produced. Thus well-level data are necessary to account for and make use of this substantial variation. Wells within a field could be assigned very different after-tax producer prices depending on whether or not they produce the same kind of oil, share the same stripper status or produced in 1978. Thus even field aggregation would not be fine enough to correctly assign even average prices accurately to oil production by field. In order to use this well-level variation I assembled a new database of well-level production and after-tax producer prices that describes every onshore well in California starting in 1977, which encompasses the regulatory and tax periods. These data have not been used in previous studies.

### 1.4.1 Data Sources and Description

The data used in this study cover all potentially active onshore oil wells in the state of California beginning in 1977 and continuing through 2008. The main analysis regarding the impact of price regulation and excise taxes makes use of the more than 75,000 oil wells that were capable of producing at some point during the 1977 to 1985 period. The state of California's Department Conservation Division of Oil, Gas and Geothermal Resources requires operators to report monthly production and characteristics for all completed wells that are currently or potentially capable of production. Characteristics reported each month include the date of well completion, API gravity of the oil produced, the field and pool being tapped, operator name, and the status of the well. The data are particularly well suited for the analysis since they provide monthly level information that allows more precision in the timing of price changes relative to the annual or quarterly data used in other studies. More importantly, the data report the characteristics necessary to determine the timing of decontrol and WPT tax treatment for each well.

California is divided into six oil and gas districts. Figure 1.1 maps the districts and provides details on the geographic distribution of wells and production. Each month between 1977 and 1985, total California production ranged between 2.37 million barrels in February 1978 and 3.20 million barrels in August 1985. Roughly 16.1 percent of wells are shut-in on average; there is some variation in shut-in rates with the smallest share of shut-in wells, 14.5 percent, during October 1978 and the largest share, 17.5 percent, in December 1985. The top five producing wells each account for less than 0.5 percent of total production.

Some adjustments to the data were necessary. Of the more than 30 million well-month observations approximately 0.1 percent were duplicate observations; these were dropped. In months where oil production is zero either because the well is not yet complete or is shut-in, no API gravity data are reported; I assign these well-month observations the soonest future API gravity in the case of uncompleted wells and the most recent previous API gravity in the case of shut-in wells. API gravity information is necessary to determine the after-tax price each producer faced when he made the decision to either not complete the well that period or shut the well that period. Stripper well status is determined by examining production history within the data, so the share of wells qualifying for stripper status would rise mechanically at end of 1977 if only production history determined stripper status. In order to correct for this data challenge, I back-fill stripper status so that a well that is determined to be a striper well in January 1978 is classified as a stripper well in 1977 as well.

As explained in Section 1.3, all oil does not trade at a single price; different grades trade at their own prices. The price data are from Platt's *Oil Price Handbook and Oilmanac*, which provides field by field posted prices by month and API gravity for controlled and decontrolled oil during the price control period, and pre-tax selling prices after decontrol. Fields for which price data are not available are assigned the average price for oil of the same API gravity for wells in California that month. Because the prices of different grades do not track the world price in parallel, using the more precise prices could potentially be important.[22] Crude is globally traded and priced based on API gravity and location. Location provides information on the sulfur content of the oil since sulfur content is largely constant across the wells in a field.[23] Oil with low sulfur content, known as "sweet" crude, can be refined into light

[22]During the price control era oil from the same well was classified as lower and upper tier oil with upper tier oil receiving a higher price. Lower tier oil corresponded to what regulators believed was the "expected" level of production based on the property's production history. Until the well produced it's lower tier quota, all oil it produced would sell at the lower tier price. If the operator exceeded his lower tier quota, then all additional oil produced would sell at the higher upper tier price. The determination of whether a barrel of oil subject to price controls was upper- or lower-tier is beyond the capacity of the data. This analysis assigns all price-controlled wells the upper-tier selling price, as it is the more likely price for marginal production from a California well.

[23]Transportation costs will also vary by location. Refiners with the lowest transportation costs, typically those with the closest refineries, will purchase from a given field. As individual purchase

petroleum products such as gasoline or kerosene more cost effectively than high sulfur, "sour" crude which is typically processed into diesel or fuel oil.[24] For refining purposes, oil of the same API gravity and sulfur content is viewed as perfectly substitutable regardless of origin.

While various congressional acts created the systems of regulation, decontrol and excise taxation that provide the identifying variation in producer prices, the precise detailed rules of these legislative acts are found in the *Federal Code of Regulations* for each year. I drew the details of price control assignment and WPT tax treatment from "Title 10: Energy" of the *Federal Code of Regulations* for each year 1976-1980 and "Title 26: Internal Revenue" of the *Federal Code of Regulations* for each year 1981-1985, which detailed the implementation of price control and WPT legislation.

### 1.4.2 Summary Statistics

Table 1.1 presents summary statistics for the full sample of 75,342 wells used to assess the impact of the regulatory and tax regimes of the late 1970s and 1980s. The average well produces 443 barrels of oil per month; conditioning on non-zero production raises the average roughly 50 percent. Approximately 28 percent of well-month observations report zero oil production either because the well is shut-in or the well has not yet been completed. The median well produces 113 barrels of oil per month, the 75th percentile well-month observation produces 428 barrels per month and the 99th percentile observation produces 5,325 barrels per month. The production data are right skewed. The within-well production variation, 2,859, is comparable to the overall standard deviation, 3,071. The average producer price during the period, $18.3, is only 45 percent of the mean purchaser's price, with part of this difference attributable to the corporate income tax and part to the WPT. Producers for whom price controls were gradually phased out as they faced excise taxes under the

and production decisions are too small to move transport costs, the difference between price at the wellhead and price at the refiner is taken to be independent of the decisions of individuals firms.

[24]When oil prices are referred to in the popular media, the price frequently quoted is that of West Texas Intermediate, or UK Brent both of which are light and sweet. The OPEC basket, which is a weighted average of crudes produced by OPEC nations, is a third benchmark and is both heavier and sourer than WTI or Brent.

WPT received the lowest, less than \$12.30, after-tax prices. Producers of lighter oil received the highest prices in the sample, exceeding \$32.00, at the end of 1979 and the beginning of 1980 prior to the introduction of the WPT. The within-well deviations in average after-tax price is 15 percent smaller than the overall variation in after-tax price while the within and overall variation in pre-tax price is comparable. This discrepancy is driven by the differential regulatory and tax treatment of wells over the period. The average and median API gravities are 18.2 and 15.0, respectively, illustrating the heaviness of California oil. Finally, note that although there is considerable variability in API gravity in the sample (standard deviation of 6.8), each individual well has little variation in the API gravity of the oil it produces (standard deviation of 1.4).

## 1.5 Estimation Strategy

The way in which oil prices were decontrolled and oil production was taxed provide an unusual degree of variation in net-of-tax prices for identical commodities across producers and overtime. The decontrol of oil prices and the introduction of the WPT were policy changes implemented in tandem; oil prices were decontrolled by executive order while legislation enacting the excise tax was in committee in Congress. Figure 1.2 illustrates the timing of decontrol for different types of oil over the 1979 to 1981 period, starting with new oil and ending with old oil. These different categories of oil were also subject to different WPT tax rates and corresponding tax bases. Taken together these policy changes provide substantial deviations from the world market price.

The model described in Section 1.2 showed that the impact of a change in the after-tax price on the extraction rate for a long-lived well was a decreasing function of the cost parameter $c$. In other words, the cost parameter $c$ can be recovered from an estimate of the derivative of the extraction rate with respect to after-tax price. The impact of a level change in after-tax price on the extraction rate in levels is the empirical response of interest. The most natural regression framework that would yield estimates of $\frac{dq_t}{dp_t}$ is a simple linear model of the form:

$$q_{it} = \alpha + \beta (1 - \tau_{it}) p_{it} + X_{it}\gamma + u_i + \eta_{it} \tag{1.19}$$

where $q_{it}$ is extraction per month, $(1 - \tau_{it}) p_{it}$ is after-tax price, $X_{it}$ is a set of controls, and $u_i + \eta_{it}$ is the error term.[25] If the price ceilings and WPT tax rates were uncorrelated with the error term, the policy-based variation in after-tax price would yield an unbiased estimate of the tax response. But if after-tax price is correlated with an underlying well specific component of the error term, $u_i$, then pooled ordinary least-squares estimation will yield biased estimates. The bias of the estimate will depend on the correlation between the omitted well-specific effect and the tax rate or price ceiling. Price ceilings and excise tax rates were not randomly assigned to wells by price controls and the WPT. Well characteristics, such as well age and stripper status, and oil characteristics, namely specific gravity, which are key determinants of the cost of extraction were used to determine regulatory and tax treatment. Regulatory and tax treatment varied along these dimensions in part in an effort to favorably treat operators who would be most adversely impacted by the policies. Thus, pooled OLS estimates of equation 1.19 would be inappropriate.

Because extraction costs vary across wells even within tier, controls for the factors that determine tax treatment may not be sufficient to fully address heterogeneity in extraction costs. Instead, to isolate variation in the after-tax price not related to underlying differences in extraction costs, the analysis uses only *within-well variation.* Because of the considerable across time variation in after-tax price generated by the decontrol of oil prices and the levying of the WPT, there remains sufficient variation for each well over time to identify the supply response.

[25]The after-tax price here is denoted by $(1 - \tau_{it}) p_{it}$ although in reality price controls and the windfall profit tax can both be described as taxes on a price basis, where the basis is the difference between the selling price of a barrel of oil and a statutory base price. In the case of price controls, the tax rate is 100 percent. This type of basis tax is structured like a capital gains tax and as in the capital gains literature, the marginal incentive to sell a barrel of oil is captured by $(1 - \tau_{it}) p_{it}$ and the basis is a transfer.

### 1.5.1 Residual Variation in After-Tax Price

Figure 1.3 plots different price measures for two wells. The real posted price line reports the real purchase price of the oil. The upper plot describes a relatively tax disadvantaged well and the lower plot describes a relatively tax favored well.

The upper plot tracks an initially non-stripper well that was decontrolled gradually beginning in January 1980, then fully decontrolled in January 1981; the gradual decontrol can be seen in the nearly linear upward slope of the Real Posted Price line starting in January 1980 and continuing until January 1981 when the price discontinuously jumps with full decontrol. This well was initially subject to a 70 percent WPT excise tax. The onset of the tax is the sudden downward jump in After-Tax Price in March of 1980. In October 1982, the well qualified as a stripper well and thus shifted to the slightly more tax-favorable Tier II and became subject to a 60 percent excise tax rate, hence the uptick in After-Tax Price. The decrease in posted price in January 1983 led to decrease in all price measures. Starting in January of 1983 Real Post Price drifts slightly downward but is largely flat; After-Tax Price only further flattens this slight negative slope.

My estimation strategy removes well and time fixed effects. Purging the after-tax price measure of well fixed effects amounts to subtracting the well's average price over all periods from the price each period. Thus the Residual—Well FE line is simply a downward shift of the After-Tax Price line; the magnitude of the shift is the level of the Well Mean line. Further purging the post-well fixed effect after-tax price residuals of time fixed effects amounts to subtracting the average price each period over all wells from the post-well fixed effect residuals. This two-way residual isolates relative within-well price variation, where relative means relative to all other wells in the sample that period. Thus, this well's two-way residual declines beginning in June 1979 as Tier III oil is fully decontrolled and market oil prices rise. The Residual—Well, Time FE line slopes upward between January 1980 and March of 1980 as the well began gradual decontrol while already decontrolled wells faced less rapidly increasing prices. When the WPT is levied in March of 1980 the two-way residual continues its upward trend because the increases in after-tax price due to continued decontrol more than offset the tax. Even after full decontrol in January 1981, the relative within-well after-tax price remains negative because this well faces the highest tax rate of all wells. The disadvantage narrows as posted prices in the Livermore field increased relatively faster than other fields. When the well is re-classified as a stripper well there is a final uptick in the two-way residual as its WPT tax rate has fallen by 10 percentage points, which is short-lived as the Livermore price premium fades a few months later. From that point on, the two-way residual is near zero since declines in posted price result in after-tax prices nearly equal to average after-tax price for each well.

The lower plot tracks a relatively tax-favored well. The well did not produce oil in 1978 and thus the oil it produces is classified as new oil. The After-Tax Price line jumps upward in June 1979 when new oil was decontrolled and again several months later as world price increased and posted prices reflected the change. This Tier III well was initially subject to a 30 percent WPT tax rate, which was decreased by 2.5 percentage points each year starting in 1982 until the rate was 22.5 percent in 1984. Focusing on the two-way residual line, Residual—Well, Time FE the fact that this well was tax advantaged can be seen at several points in time. First when this well was decontrolled in June 1979 the two-way residual is large and positive. The strong upward movement of posted prices beginning in 1980 is mitigated in the two-way residual since other wells were beginning decontrol and receiving higher after-tax prices during this time though the residuals remain above zero reflecting the fact that this well was fully decontrolled. The residual remains positive even after the introduction of the WPT because it was tax favored, meaning it received a higher after-tax price than the average California well. Declining posted prices starting in 1983 brought the well's after-tax price in line with its average after-tax price, which resulted in a near zero two-way residual since nearly all wells experienced this convergence.

Price variation generated by temporary taxes is likely to be perceived as having different persistence than movements in price. Different forces generate price and policy induced changes in after-tax price; that they would be viewed identically seems unlikely. If producers perceive price as having greater persistence than tax-driven changes, then supply elasticities generated by price changes would overstate the supply response to temporary taxes. Thus within-well variation in after-tax price, which retains both price- and tax-driven changes in after-tax price may not be the appropriate price measure for the analysis. To isolate price differences due only to differential decontrol and tax treatment, the data are purged of time-series variation in price, in other words average after-tax price each period subtracted off. The plot for each well tracks this process of isolating relative within-well variation in after-tax price.

The key exclusion restriction of an identification strategy that purges after-tax prices of well and time averages is that outside a time invariant fixed factor, wells respond identically over time to changes in relative after-tax price. In other words, there are no time-varying well-specific factors, besides after-tax price, affecting well production.

## 1.6 Supply Response to Changes in After-Tax Price

Table 1.2 presents OLS estimates of,

$$q_{it} = \beta_0 + \beta_1 \left(1 - \tau_t^{Corp}\right) \left(B_{igt} + \left(1 - \tau_t^{W}\right) \left(P_{gt} - B_{igt}\right)\right) + \beta_2 age_{it} + \chi_t + \delta_i + \epsilon_{it} \quad (1.20)$$

using the full sample of California oil wells. The dependent variable is the quantity of oil produced by well $i$ in month $t$. All specifications include well-level fixed effects to absorb level differences across wells in the operator's response to changes in net price, namely production cost heterogeneity. The sample includes all wells, whether or not they shut-in. Month-by-year dummies absorb mean production and price variation in each month. The tax-price elasticity is identified by within-well variation in after-tax price relative to the within-well variation of other wells. As wells age their productivity declines, so an additional control for the age of the well, measured from its date of completion, is also included. Each column of Table 1.2 reports estimates from a different regression.

Column 1 reports results from an estimation of equation 1.20. The estimated coefficient on the after-tax price, $\beta_1$, implies that a one-dollar increase in the after-tax price leads the average well to produce 8.73 additional barrels of oil, a price elasticity of 0.237.[26] Because well age is considered an important determinant of well productivity, column 3 adds a quadratic term in well age. The insignificant increase in the elasticity to 0.238, and the fact that the precision of the tax-price coefficient estimate is unchanged, suggests that the linear control for well age is sufficient. Although over the course of a well's life there is little change in the API gravity of the oil extracted—the within-well standard deviation is only 1.4 degrees, less than 20 percent of overall variation—changes in API gravity could lead to changes in lifting costs if the changes are concentrated and thus large for wells that do experience changing gravity. API gravity fixed effects would undo the tax rate variation based on oil heaviness, so slightly coarser controls are employed. Column 4 reports a specification like that of column 1 but includes dummies and quadratic time trends for each decile of API gravity. The after-tax price coefficient is reduced by these added time-varying controls for oil quality, but the change, a reduction of the elasticity to 0.208, is statistically insignificant and economically minor.

The data cover all wells in the state of California, including wells located in the federally-owned and privately-leased Naval Petroleum Reserve (NPR), the Elk Hills field. The private firm extracting the oil made production decisions, but received less than the full posted price less taxes for each barrel it produced. Furthermore, because the firm only leased the reserves, it may not have taken the exhaustibility of the reserves into account in the same way that a reserve owner would. Thus, the production response of these NPR wells to changes in after-tax price might be smaller than the response for privately owned wells.[27] Column 5 presents estimates of a model

[26]Adding well fixed-effects only, retaining the full variation in after-tax price, yields a point estimate of 2.617 (0.500), which translates into a much smaller elasticity, 0.071.

[27]The NPR field was not tapped until 1976. In reaction to the 1973 Arab oil embargo the federal government opened the Elk Hills field to drilling in 1976. From 1976 until 1998 the federal government leased access to the field and a private firm extracted oil from the reserves. The oil is sold to private refiners at the market price with the proceeds divided between the extracting firm and the federal government; although the private firm determined production levels. Oil from the NPR

identical to that of column 1, but drops the Elk Hills wells from the sample. The point estimate is larger which is consistent with the idea that operator of the NPR wells was less price sensitive than other well operators. Though the estimated after-tax price elasticity is larger in terms of the point estimate, the difference is statistically insignificant. The NPR wells, in other words, were not significantly biasing the overall estimate of column 2. The supply elasticity of the NPR wells, 0.173 (0.097) is roughly 25 percent smaller than the overall elasticity, but statistically indistinguishable from the overall or non-NPR elasticities. Interestingly, dropping these wells reduces the standard error of the after-tax price coefficient estimate by 30 percent.

### 1.6.1 High and Low Marginal Cost Wells

Equation 1.15 makes clear that responses will be smaller for wells with high marginal costs, assuming that wells are far from the end of their economic life. Although the vast majority of wells in California are pumped, 13,198 wells produce oil based on their natural subsurface reservoir pressure for at least part of their lives. These flowing wells have low operating costs if they produce their natural flowing quantity but it is very costly to adjust their production either upward or downward. Adjustment involves the installation of pumping equipment to either increase subsurface pressure to accelerate extraction or to exert downward pressure to reduce the flow rate. In other words, very high costs of extraction rate adjustment make the operators of flowing wells unlikely to adjust their production levels to temporary changes

Table 1.3 presents estimates of equation 1.20 separately for flowing and pumped wells. Because some wells may initially flow but then need to be pumped, the number of wells in the flowing and pumped regressions exceeds the total number of wells. Column 1 reports the baseline specification, which corresponds to column 1 of Table 1.2. Column 2 reports elasticity estimates for pumped wells, evaluated at mean sample price and production quantities. Pumped wells—wells for which production levels are more of a choice variable—are significantly more price elastic than the average

was subject to both price controls and the Windfall Profit Tax, but the price per barrel received by the private extracting firm was less than the posted price minus taxes.

well. A ten percent increase in after-tax price results in a 3.56 percent increase in oil production; the baseline specification implies only a 2.37 percent increase in production. Flowing wells, on the other hand, do not show a statistically significant production response to changes in after-tax price. The 95 percent confidence interval, however, rules out supply responses larger than 0.072. All elasticities are evaluated at average price and quantity, separately for pumped and flowing wells.

## 1.7 Well Closure Decisions

Wells that have high fixed costs are more likely to incur losses once the tax is put into place. For wells near the end of their economic life, the post-tax profit from remaining reserves may not offset the losses they will incur during the tax period. Thus some well operators may choose to exit by shutting-in their wells. In fact, there was notable concern regarding response along this margin at the time the tax was introduced; two months before the enactment of the tax the *Wall Street Journal* ran a critical editorial about the proposed Windfall Profit Tax titled "The Close-the-Wells Tax."

Table 1.4 reports conditional logit and OLS estimates of,

$$S_{it} = \beta_0 + \beta_1 \left(1 - \tau_t^{Corp}\right) \left(B_{igt} + \left(1 - \tau_t^{W}\right)(P_{gt} - B_{igt})\right) + \beta_2 age_{it} + \chi_t + \delta_i + \epsilon_{it} \quad (1.21)$$

where $S_{it}$ is a dummy variable equal to one if the well is shut-in and $\beta_1$, the after-tax price coefficient, measures the percentage change in the probability of shut-in caused by a one-dollar increase in price. Columns 1-4 report marginal effects and semi-elasticities from conditional logit models. For comparison purposes, columns 5 and 6 report results from fixed effect OLS models. All of the regression models include well and time fixed effects to partial-out cost heterogeneity at the well-level and time-varying factors that affect production for all wells. If taxes motivate well operators to close their wells, then the short-run impact of the tax could translate into a longrun reduction in oil production as the reserves remaining in the shut wells are effectively lost.[28] The regressions reported in Table 1.4 are similar to the regressions of Table 1.2. Columns 1 through 4 report estimates of equation 1.21 from conditional logit models. As the predicted values of conditional logit models must lie between one and zero, the model excludes wells that experience no variation in shut-in status.[29] Identification again comes from relative within-well changes in after-tax price and the exclusion restriction requires that no time-varying well-specific factors affect production. Approximately 16.1 percent of well-month observations are shut-in during the 1977-1985 period; 27 percent of observations for wells that are neither always shut-in nor always open are shut-in. The estimated after-tax price coefficient reported in column 1 of Table 1.4 suggests that a 10 percent increase in the after-tax price only reduces the rate of shut-in by 0.95 of a percentage point. This small estimated response suggests that a temporary tax like the WPT has a negligible impact on firms' shut-in decisions. This could be because the fixed costs of operating are small relative to profit from production or because few wells are near the end of their economic life. Of the wells producing in 1977, 69 percent are still producing in 1987, 44 percent are still producing in 1997 and 34 percent are still producing in 2007.

Column 2 adds a quadratic term in well age to better adjust for the decline in productivity that typically occurs over the life of the well. The estimates are virtually identical, again suggesting that a linear control for well age is sufficient. Adding quadratic time trends by API gravity decile increases the semi-elasticity by almost 25 percent—controlling for changes in the gravity of oil pumped from a well increases the magnitude of the semi-elasticity estimate to -0.117. Column 4 excludes wells from the Elk Hills NPR field. Dropping wells from the NPR field increases the point estimate of price response along the extensive margin, suggesting again that firms that lease government reserves are less price responsive than other operators. In fact the after-tax price semi-elasticity of shut-in among Elk Hills wells is only -0.0002 (0.0002). The

[28]Shut-in wells can be re-opened but rarely are because reopening is very costly and shut-in reduces the share of remaining reserves that is feasibly extractable. Only extraordinary price events typically trigger the re-opening of shut-in wells.

[29]For wells that are always shut-in or always open to have predicted values between one and zero, implies unbounded well fixed effect coefficients. The conditional logit model thus excludes these observations.

difference between the results from column 4 and column 1, however, is statistically insignificant.

The conditional logit model requires variation in the dependent variable for each well in the sample. To assess the impact of limiting the sample this way I also report shut-in semi-elasticity estimates from fixed effect OLS models. For comparison, column 5 of Table 1.4 reports OLS estimates for the sample of wells with shut-in variation that is used to estimate the conditional logit model; column 6 reports OLS estimates from the full sample of wells. The estimate using the smaller sample is nearly three times as large as the estimate from the full sample and similar to the conditional logit estimates. The estimates of columns 5 and 6 imply that among operators that have meaningful discretion over the shut-in status of their wells the effect of after-tax price on the shut-in decision is more than significantly larger. This suggests that the sample restrictions of the conditional logit model may be partly responsible for the higher semi-elasticity estimates of columns 1 through 4 relative to column 6. Though the conditional logit coefficients are twice as large as the full sample OLS coefficient, they remain small in magnitude. Taken together, these estimates suggest that the temporary tax does not lead to economically important rates of shut-in.

## 1.8 Reconciliation with Estimates of the Previous Literature

The analysis presented in Section 6 uses well-level production data and after-tax prices carefully constructed from monthly field prices and complex regulatory and tax treatment rules. Previous studies, summarized in Table 1.5—such as Griffin (1985), which uses quarterly data from 1971 to 1983, or Hogan (1989) which uses annual data over the longer 1966 to 1987 interval, or Jones (1990) which examines the 1983 to 1988 time period using quarterly data, or Dahl and Yücel (1991) which uses quarterly data from 1971 to 1987, or Ramcharran (2002) which uses annual data from 1973 to

1997—estimate the supply response using aggregate national production and average pre-tax price.[30] In other words these studies use time-series variation alone. As Table 1.5 reports, these time-series elasticity estimates are 60 and 80 percent smaller than my preferred elasticity estimate, 0.237 (0.029), when positive and significant as in the cases of Hogan (1989) and Ramcharran (2002). Jones (1990) estimates a statistically insignificant supply elasticity of similarly small magnitude, 0.07 (0.04). In addition to these small positive elasticity estimates, Dahl and Yücel (1991) estimate an insignificant negative elasticity and Griffin (1985) estimates a significant negative elasticity of -0.05 (0.02), which he suggests could be attributable to price controls.[31]

The supply responses estimated in these studies may not be appropriate for assessing producer responses to excise taxes for three reasons. First, the use of the readily available but imprecise *Monthly Energy Review* (MER) mean pre-tax first purchase price series introduces measurement error in the price variable. As explained in Subsection 1.3.2 government policies created large deviations between after-tax price and world price that differed by well. These deviations are not reflected in this pre-tax price series. The average effective WPT tax rate—the ratio of after-WPT but before-corporate income tax price to posted price—in my California data is 21.2 percent and ranges from zero for wells for which the selling price eventually fell below their base price to 56.4 percent for wells in the highest WPT tax bracket. Since the variation in WPT rates across wells makes it impossible to construct the average after-tax price from the average pre-tax price, using the MER average first purchase price series introduces considerable measurement error for a significant fraction of sample years used in previous studies. Ignoring taxes, especially when producer prices are reduced by the full or nearly full amount of the tax, leads to measurement error in the producer price variable and biases the resulting supply elasticity estimate downward. As column 2 of Table 1.6 shows, even in a within-well specification, using the MER prices instead

[30]These studies estimated supply elasticities for total U.S. production as part of an examination of market structures among OPEC and non-OPEC countries; nonetheless most of these are the studies cited in supply elasticity surveys, such as Dahl and Duggan (1996).

[31]Griffin (1985) is vague as to the particular problems price controls cause for his estimation strategy. Presumably he means that the average price series from the Monthly Energy Review that uses somehow overstates prices during the price control era, creating an artificial negative relationship between price and production.

of well-specific after-tax price results in a small, statistically significant, elasticity estimate of 0.021 (0.01).[32] Column 1 reports the results of my baseline specification, which corresponds to Column 1 of Table 1.2. The pooled and times series regressions reported in columns 3 and 4 yield similarly small elasticity point estimates, though the pooled estimate, 0.024 (0.01) is statistically significant while aggregating to the time-series yields an insignificant elasticity estimate of 0.017 (0.015). Taken together columns 2 through 4 of Table 1.6 make clear that the MER average pre-tax price series leads to considerably downward biased estimates comparable to those found by previous studies and roughly one-tenth the size of my estimates based on more accurate well-specific prices.

Second, this paper aims to assess the impact of taxes on oil production, so the elasticity estimate should be generated by after-tax price variation of similar persistence as proposed tax policy. The persistence of after-tax price changes driven by movements in world price may be higher or lower than the persistence of changes in after-tax price driven by temporary taxes. The supply response of interest is the supply response to after-tax price movements of similar persistence as proposed policy. As proposals have largely described temporary taxes, the temporary price changes induced by government policy isolated here are more appropriate than movements in world price. Third, time-series regressions use aggregate totals of U.S. oil production as the dependent variable, introducing "aggregation bias" since well productivity is not homogenous. U.S. oil wells lie along a gradient of productivity; when prices are higher the average producing well is less productive as some high cost wells are brought online. Aggregation will subsume this heterogeneity and bias the coefficient.

Detailed well-level data make it possible for me to assign each well a more accurate measure of its after-tax price. Well-level data also allows me to control for underlying heterogeneity in well productivity overtime and across wells. Table 1.7 details the advantage of the micro-data. All the regression results reported in Table 1.7 use well-specific after-tax price as the key explanatory variables. The baseline estimate,

[32]Note that the preferred specification from my analysis using my constructed after-tax price also includes month-year fixed effects that are precluded by the within-month-year invariance of the MER time series.

corresponding the specification reported in column 1 of Table 1.2, is repeated in column 1 of Table 1.7. Column 2 drops the month-year dummies, meaning that the within-month variation in price isolated in column 1 is combined with overtime variation in pre-tax price, sans a linear time trend, to yield the 0.071 (0.014) elasticity estimate. In other worlds, adding the variation in world price shrinks the elasticity estimate by roughly 70 percent. Producers are less sensitive to pre-tax price variation, suggesting that producers may view underlying price variation as less persistent than variation due to temporary taxes. Columns 3 and 4, which report estimates from pooled OLS and time-series regressions, respectively, report negative elasticities. This surprising negative correlation is due to nature of federal policies during decontrol and the introduction of the WPT. Federal policy systematically treated less productive wells more favorably—both heavy oil wells, which face higher extraction costs, and stripper wells, which by definition are only marginally productive, were decontrolled earlier and assigned lower WPT rates than other wells. Thus wells that on average produced less oil received higher after-tax prices by fiat. While the well fixed effects of the specification of column 1 controls for these underlying differences, the pooled and time-series regressions of columns 3 and 4 reflect the imposed negative correlation.

I construct a subsample of wells for which after-tax price did not reflect such a fundamental difference in operating costs by dropping all heavy and stripper wells. In addition I restrict the sample to wells that began production before 1982 to make the sample even more homogenous, but this restriction is less empirically relevant.[33] This smaller sample retains cross-sectional variation in after-tax price since some wells were classified as favorably treated new oil wells while wells that produced oil in 1978 were classified as old oil wells. The key is that these remaining regulatory and tax treatment differences reflected less substantial systematic differences in production costs. Columns 5 and 6 report pooled and time-series estimates from regressions using this sample of more comparable wells. The elasticity estimates are statistically indistinguishable from each other and the baseline estimate of column 1. Interestingly,

[33]The estimates of columns 5 and 6 are statistically similar using later first-production date sample limits.

the sign of the time trend coefficient is negative in these specifications unlike in columns 3 and 4, suggesting that these more similar non-heavy non-stripper wells slowed their production over time, likely due to depletion, while other factors led heavy and stripper wells to not suffer the same declining trend.

## 1.9 Illustration of Lost Producer Surplus Calculation

The elasticity estimates discussed in Section 1.6 suggest that operators react to temporary excise taxes by reducing production; according to the preferred specification, reported in column 1 of Table 1.2, a ten percent increase in the excise tax rate leads to a 2.4 percent reduction in production. The model described in Section 1.2 explains that a temporary tax has both a direct and an indirect impact: the direct impact is the decrease in production while the tax is in effect; the indirect effect is the change in the economic life of the well.[34] Because production here is the extraction of an exhaustible reserve, reducing production while the tax is in place may extend the life of the well.

The simple model of in Section 1.2 and the estimates from Section 1.6 can be combined to illustrate how the welfare cost of a temporary tax on exhaustible resources can be calculated. The illustrative calculation is based on two key assumptions: first, that the simple quadratic cost function captures the cost of extraction, and second, that wells are far enough from the end of their economic lives that second term of equation 1.15 can be ignored. The second assumption is strengthened by the results reported in Section 1.7, temporary price movements did not cause economically meaningful increases in the well shut-in rate, suggesting that few wells were very close to the end of their economic lives. In addition, the model assumes that the operator

[34] Alternative cost functions, namely ones where the cost of extraction is strongly impacted by the amount of reserves remaining in the well, may not yield as long an extension in the life of the well. If the cost of extraction in the post-tax period is substantially reduced by the larger reserves resulting from slower extraction while the tax was in place, then the operator will pump more in the post-tax period. This increase in the pumping rate may lead to a smaller increase in the life of the well.

knows the price path with certainty. The importance on this assumption hinges on whether or not the general form of the extraction rules of equations 1.13 and 1.14 generalize to models that add uncertainty in prices. With these assumptions in mind, the elasticity estimates from Section 1.6 can shed light on the welfare cost of the temporary taxes like the WPT.

As Section 1.3 explains, excise taxes that apply to only domestic producers cannot be passed on to refiners or consumers because imported oil was exempted from the WPT. No change in consumer surplus results from such a tax. Because there is very little shut-in in response to changes in the after-tax price, the change in producer surplus is nearly equal to the change in producer profits; the only deviations arising from the small number of wells that shut-in and thus save their fixed costs. The welfare cost of the tax, the reduction in producer surplus less the tax revenue, will be assessed here for a typical well, that is, a well that does not shut-in in reaction to the tax.

For clarity, the pre-tax price of oil is assumed to be constant, so that $p_1 = (1 - \tau)\, p$ and $p_2 = p$. The change in the life of the well for a small change in the tax rate, according to equation 1.17, is:

$$dT \leq \frac{t_1 \tau}{1 + e^{-rT^0}}$$

where $\tau$ is the excise tax rate, $t_1$ is the duration of the tax starting at time 0, $r$ is the interest rate and $T^0$ is the original economic life of the well.[35] For example, a 15 percent excise tax in place for five years extends the life of an initially 40-year well by approximately 0.75 of a year, assuming a pre-tax price of \$25 and an interest rate of five percent. Once the tax has been introduced, the operator reduces his extraction rate before $t_1$, extending the life of his well by $dT$. Producer surplus is reduced by three factors: the tax liability incurred due to the tax, the profit loss from delaying extraction and the add cost of sub-optimal extraction of the reserves due to tilting of

[35]This $dT$ is an estimate of the increase in the life of the well that results from the introduction of a temporary tax. The estimate assumes that that well life in the denominator is the original well life. The actual change in well life would be calculated allowing this variable to increase along the interval over which we integrate with respect to $dP$.

the extraction path in response to the tax. The total change in producer surplus due to the introduction of the temporary tax will be:

$$\Delta PS = \int_0^{T^1} e^{-rt}\left[\left(pq_t - (1-\tau_t)\,p\hat{q}_t\right) - \left(c\left(q_t\right) - c\left(\hat{q}_t\right)\right)\right] dt$$

where $q_t$ is the extraction rate at time $t$ if the tax had never been levied, and $\hat{q}_t$ is the extraction rate at time $t$ in light of the temporary tax. The time horizon is $T^1 = T^0 + dT$, the new economic life of the well extended by the reduction in extraction between time 0 and time $t_1$; the no-tax extraction rate $q_t$ will be zero after time $T^0$. The tax rate, $\tau_t$, varies over time, as it is initially positive while the tax is in place but is zero after time $t_1$ once the tax expires.

The average impact of a change in after-tax price on oil production implies an average value of $c$ of the cost function used in the model described in Section 1.2, $c\left(q_t\right) = cq_t^2 + f$. For the baseline specification, column 2 of Table 1.2, the coefficient estimate, that is $\frac{dq_t}{dp_t}$, is 8.730 (1.082). This coefficient implies that for the average well $c = 0.0573$.

Figure 1.4 plots the optimal extraction path before and after the introduction of a 15 percent temporary tax that is in place for five years. Pre-tax price is $25 over the whole life of the well. The well has an original life of 40 years, which increases to approximately 40.74 years due to the tax. The area between the two curves to the left of their intersection is the amount of oil not extracted while the tax is in place that would have been extracted had their been no tax. The area between the two curves to the right of their intersection represents the delayed extraction of this oil. The product of these areas and after-tax price, discounted appropriately, is the change is revenue due to the forward tilting of the extraction path caused by the introduction of the tax.

Figure 1.5 plots the cost of extraction over the original extraction path and the extraction path once the tax has been introduced. Cost-savings from extracting less oil during the five years while the tax is in place are offset by increased costs later as the "additional reserves" are extracted over the post-tax life of the well. The difference in total extraction costs—the difference between the area to the left of the intersection of the two curves and the area to the right, discounted appropriately—represents the added costs of suboptimal extraction due to the introduction of the tax.

Government revenue from the temporary excise tax:

$$GR = \int_0^{t_1} e^{-rt} \tau p \hat{q}_t dt$$

partially offsets the reduction in producer surplus. The total welfare cost of the tax is thus:

$$\Delta PS + GR = \int_0^{T^1} e^{-rt} \left[ \left( pq_t - (1 - \tau_t) p\hat{q}_t \right) - \left( c\left(q_t\right) - c\left(\hat{q}_t\right) \right) \right] dt - \int_0^{t_1} e^{-rt} \tau p \hat{q}_t dt$$

Table 1.8 reports the decrease in welfare due to a 15 percent excise tax as a fraction of original producer surplus, using the implied cost parameter, for different well lives, $T$, and tax durations, $t_1$. The interest rate and pre-tax price used are five percent and \$25, respectively. Table 1.9 reports the decrease in producer surplus as a fraction of the government revenue raised from the tax. These ratios represent the average cost of a dollar of revenue in terms of lost producer surplus. Producer surplus before and after the tax and government revenue in dollars can be found in the appendix tables. As we would expect, the estimates suggest that a temporary 15 percent excise tax reduces surplus more for short-lived wells and that its burden rises with the length of time it is in place. Overall the numbers suggest that the welfare cost of temporary taxes like the WPT is much smaller than a static estimate would suggest. In fact, a five-year tax on a well with an original life of ten years reduces welfare by less than 5 percent. The welfare loss falls precipitously for wells with longer economic lives. The welfare loss of the five-year tax falls to 2 percent for a well with a 20-year life, and is less than 1 percent for a 40 year well. The welfare cost outpaces the revenue raised from the tax, by as little as 13 percent in the case of a five-year tax on a 40-year lived well and as much as 66 percent in the case of a one-year tax on a 10-year lived well.

If the tax were permanent instead of temporary, the shape of the extraction path would not be affected but the well will be abandoned with more oil remaining in the well if there are any fixed costs of production. In this case, the tax revenue raised would exactly offset the loss in producer surplus while the well is extracting since the production path is unaffected by a permanent tax. The welfare loss would arise from the permanent loss of oil due to early shut-in; the size of this loss depends on the fixed and variable costs of production.

These calculations only capture the change in producer surplus from raising revenue through oil excise taxes. In the case of the WPT the revenues were earmarked for specific purposes, namely subsidies for the production on synthetic fuels and conservation programs. The ultimate welfare impact of the decontrol and taxation of U.S. oil production hinges not only on the welfare cost of the tax but on the welfare impact of these projects as well.

## 1.10 Conclusion

This paper uses new detailed data on the quantity of oil produced by wells in California to estimate the effect of tax- and price control-induced variation in oil prices on production decisions. The unusual cross-sectional variation in after-tax price provided by these government interventions allows for flexible controls for underlying changes in technology and time-varying factors, like world price, that affect oil production. The estimated coefficients imply an elasticity of approximately 0.24, suggesting that a 10 percent excise tax leads to a 2.4 percent reduction in domestic oil production.

I find that while oil production from existing wells is responsive to after-tax price, the after-tax price has no appreciable impact on wells that flow in accord to their natural subsurface pressure. Because these estimates imply the producers alter their behavior in response to tax changes, they suggest that the incidence of an oil excise tax cannot be modeled simply as a tax on the rents of oil producers.

Under the assumption that world oil prices are insensitive to U.S. producer decisions, an excise tax on U.S. producers will reduce producer profits—a reduction only partly offset by the government revenue raised from the tax. To illustrate how the production elasticity estimates can be used to assess the efficiency effects of a temporary tax on exhaustible resources, I calculate the changes in production, extraction costs and time path, and revenue from a temporary 15 percent excise tax. The calculations suggest that the distortion in production decisions reduces the present value of producer surplus by between one and five percent of its original value, depending on the original life of the well and the duration of the temporary tax. Put differently, these calculations suggest that the average dollar of revenue raised from an excise tax on California oil producers costs between \$1.13 and \$1.66 in lost producer surplus.

The supply responses measured here are potentially relevant to the evaluation of a range of fiscal policies that could affect crude oil production. These include changes in gasoline excise taxes, introduction of carbon taxes, and oil import fees that could raise the price received by domestic oil producers. The results are particularly important for the analysis of policies such as oil import fees that seek to promote energy independence by raising producer prices of fossil fuels, since they suggest that one impact of such policies will be acceleration of U.S. oil production from currently producing wells. My estimates do not provide any evidence on how such fees might affect exploration for new oil reserves or the decision to bring shut-in wells back into production.

The empirical findings bear on short-run production decisions, and it is important to remember several cautions about their broader interpretation. First, temporary taxes are likely to delay exploration and development activities—the taxes delay profits so firms will want to delay investments. This response margin is not captured by the analysis presented above. Though exploration within the continental U.S. has waned over time, firms could delay the exploration and development of offshore reserves in reaction to temporary taxes, making the inclusion or exemption of these areas from proposed taxes a policy question with potentially important ramifications.

Second, California wells and the oil they produce have higher extractions costs than the average U.S. well. Because the oil is of such high specific gravity (low API gravity) it is costly to extract, or lift, to the surface. The extraction rules derived in Section 1.2 imply that the estimates from California may well provide a lower bound on after-tax responsiveness for the average American well. Third, the estimates generated here are identified by policies from the late 1970s and 1980s and are thus historic. Although most major technological breakthroughs in the oil industry over the last 30 years, such as horizontal drilling methods, have affected drilling rather than pumping, technological changes that have improved extraction efficiency may make these estimates less applicable to current proposals.

An important area for future work is how tax-induced distortions of the extraction path affect the total quantity of reserves extracted. If perturbing the extraction path relative to its no-tax level leads to less aggregate extraction over the life of the well, then even temporary taxes will lead to permanent reductions in production and corresponding welfare losses. The effect of temporary taxes on total extraction is an open empirical question. One way such production loss can occur is if the well is shut-in earlier than otherwise, but this is not the only channel. While the estimates from California data presented here imply that shut-in decisions are relatively tax insensitive, shut-in elasticities could potentially be higher in other parts of the U.S. Shut-in elasticities are predicted to be higher where wells either have shorter lives or higher fixed and variable costs; although California wells have higher than average variable costs, fixed costs may be larger and wells shorter lived in other parts of the U.S. I hope to address these issues in future work.

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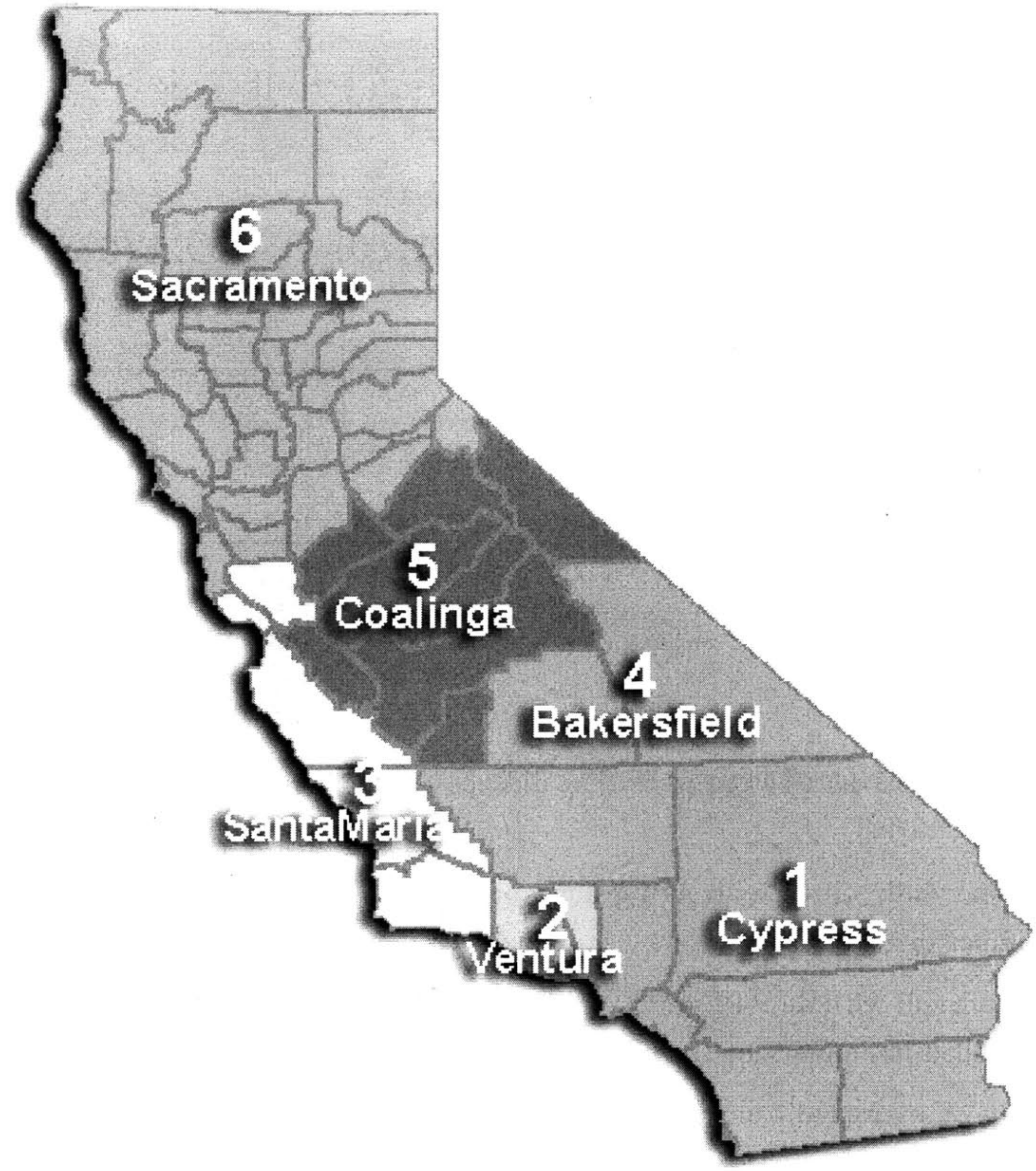
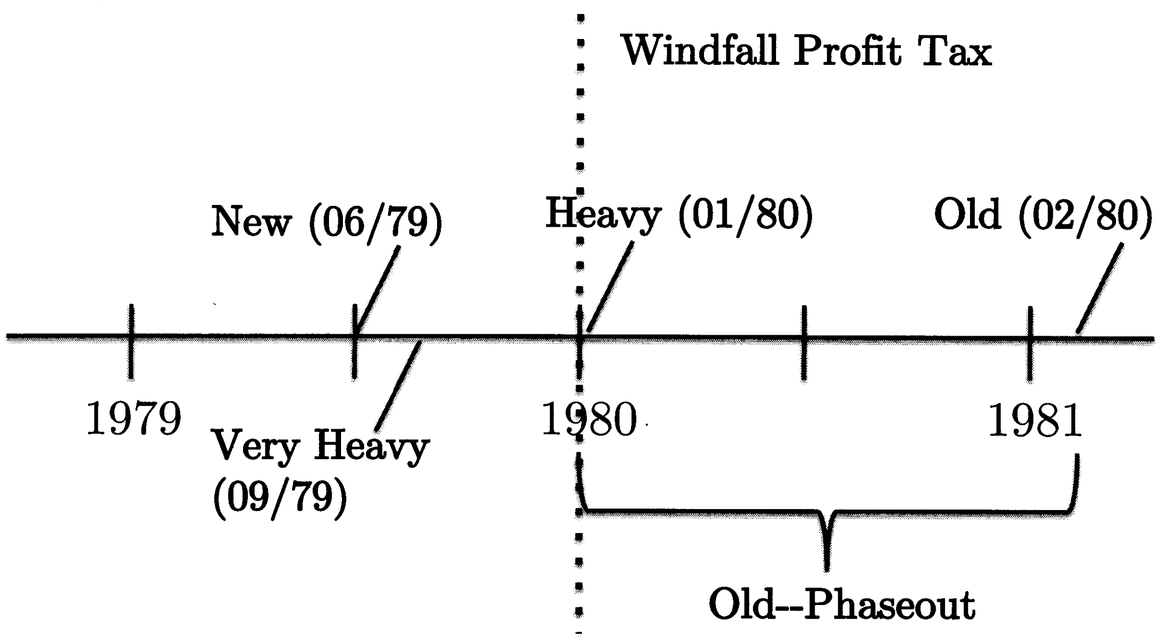
Figure 1.1: California Oil and Gas District Map




The Bakersfield district accounts for roughly 61 percent of well-month observations and oil production; the next most productive district, Cypress, accounts for 18 percent of well-month observations but 24 percent of oil production. Ventura and Santa Maria, which are both coastal each account for approximately 6 percent of production and the final district, Coalinga, pumps the remaining 3 percent of California oil production.

Source: California Department of Conservation, Division of Oil, Gas and Geothermal Resource

Figure 1.2: Timeline of Price Decontrol and Enactment of 1980 Windfall Profit Tax

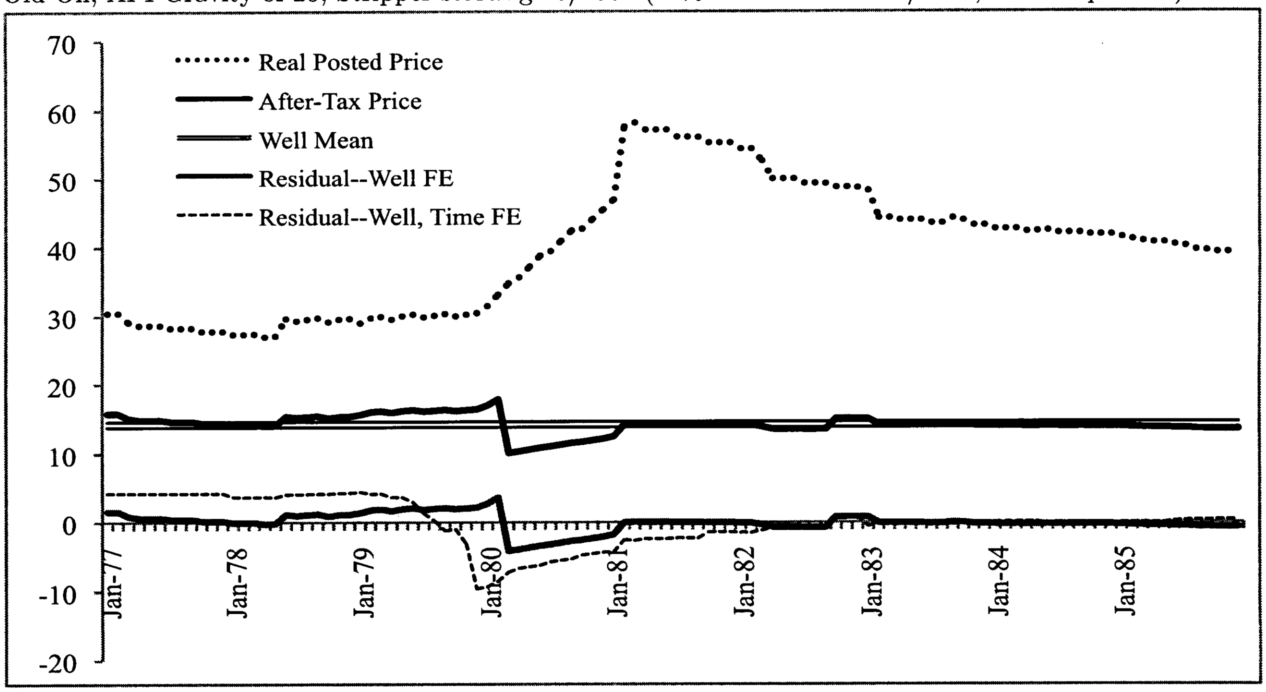



- **New oil:** oil extracted from wells that did not produce oil in 1978, was decontrolled in June of 1979.
- **Very heavy oil:** oil with an API gravity of less than 16 degrees, was decontrolled in September of 1979.
- **Heavy oil:** oil with an API gravity of less than 20 but at least 16 degrees, was decontrolled in January of 1980.
- **Old oil:** oil extracted from wells that produced oil in 1978, was gradually decontrolled between January of 1980 until January 28, 1981. During the phase-out period old oil sold at a price that was equal to the weighted average of the world market price and the price control price ceiling, with the weight on the world market price growing by 0.046 each month. Old oil was fully decontrolled by President Reagan on January 28, 1981. February 1981 was the first full month old oil was decontrolled.
- The 1980 Windfall Profit Tax was signed into law April 2, 1980 and went into effect immediately.

Figure 1.3: Prices, Before and After Taxes and Fixed Effects, Two Wells

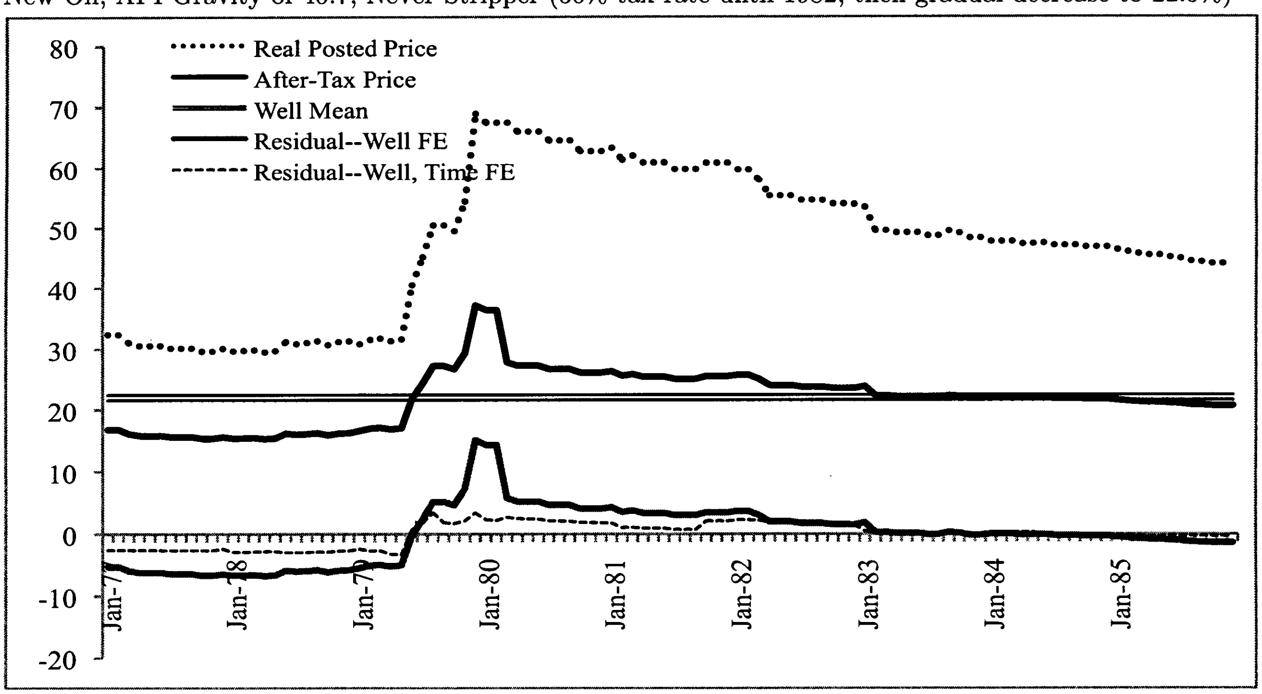
Well 120005: Livermore Field, Operator: Hershey Oil Corp.

Old Oil, API Gravity of 23; Stripper starting 10/1982 (70% tax rate until 10/1982, then 60 percent)

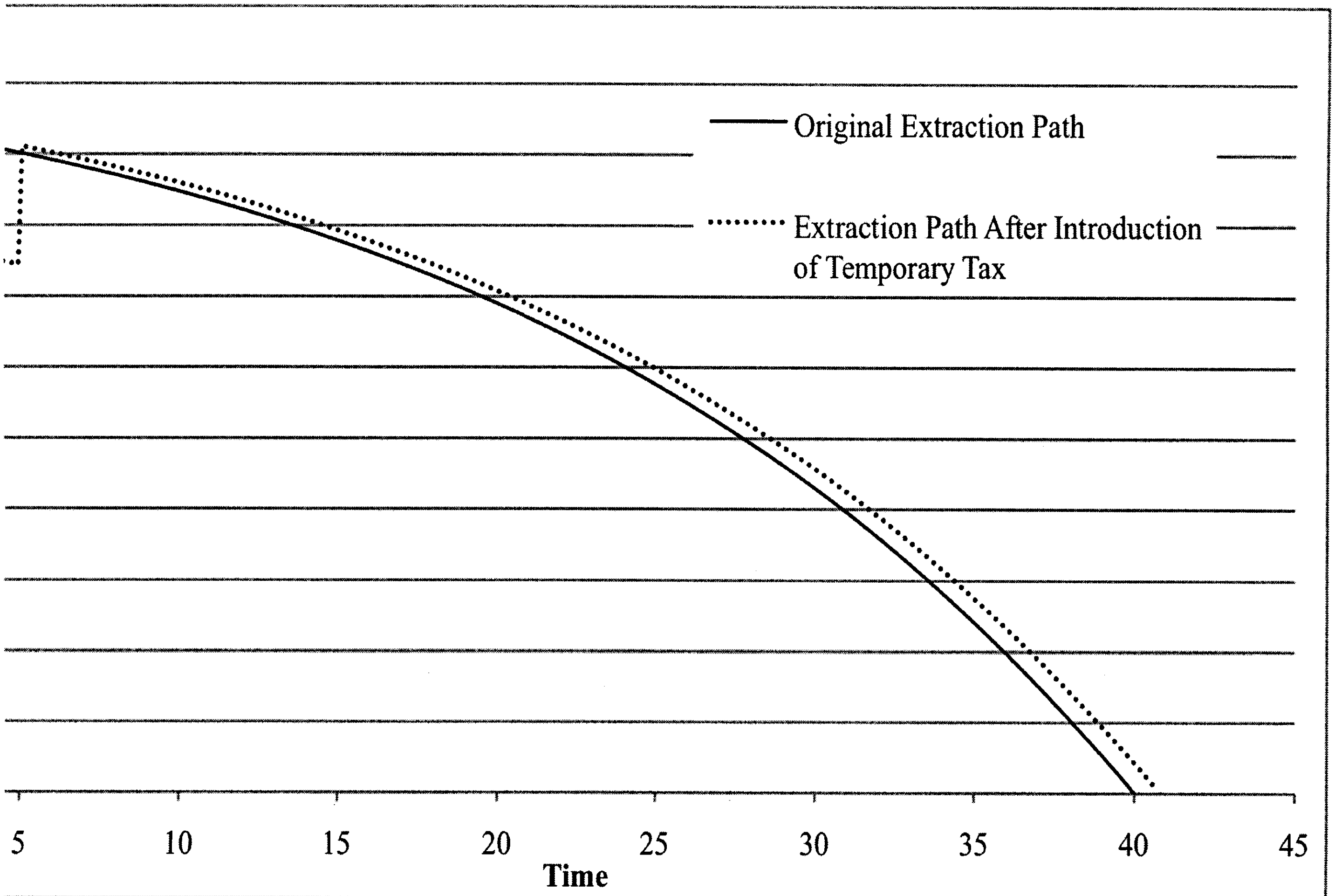



Well 1300071: Brentwood Field, Operator: Occidental Petroleum Corp.

New Oil, API Gravity of 40.7; Never Stripper (30% tax rate until 1982, then gradual decrease to 22.5%)



l Extraction Path Before and After the Introduction of a 5-year 15% Excise Tax.
.nal life, 5 percent interest rate.



Optimal Extraction Before and After the Introduction of a 5-year 15 % Excise Tax.
.nal life, 5 percent interest rate.

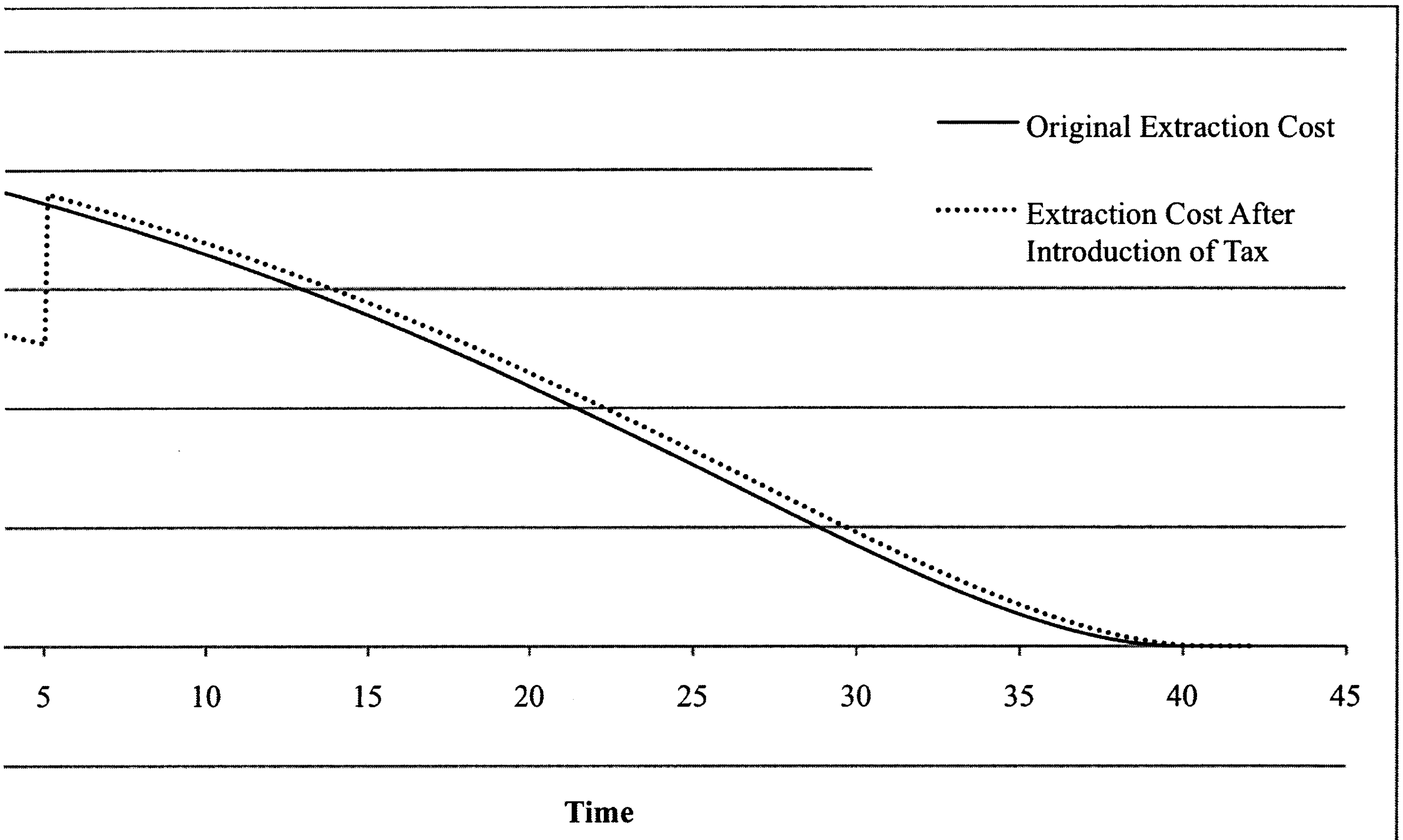


Table 1.1: Summary Statistics

| | Mean | Standard Deviation | |
|---|---|---|---|
| | | Overall | Within-Well |
| Oil Production (barrels) | 443.3 | 3071.1 | 2858.5 |
| Oil Production if Producing | 666.1 | 3745.0 | 3460.5 |
| After-tax Price ($) | 18.3 | 4.1 | 3.5 |
| WPT Tax Rate | 0.21 | 0.24 | 0.19 |
| Purchase Price | 41.1 | 10.1 | 9.78 |
| API Gravity (degrees) | 18.2 | 6.8 | 1.4 |
| Number of Wells | 75,342 | | |
| Observations | 6,517,140 | | |

Note: These summary statistics describe the observations that comprise the sample for the regression analysis. Not all 75,342 wells report 108 observations since both new wells are drilled and old wells are abandoned during the sample period.

Table 1.2: Well-Specific Output: Panel Data Estimates

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| After-tax Price | 8.730 | 8.741 | 7.659 | 9.598 | -18.230 |
| | (1.082) | (1.082) | (0.979) | (0.765) | (1.026) |
| Well Age | -1.269 | -1.228 | 6.531 | -1.258 | -0.917 |
| | (0.069) | (0.081) | (1.885) | (0.050) | (0.028) |
| Well Age Squared | | -(0.0003) | | | |
| | | (0.0002) | | | |
| Well Dummies | Y | Y | Y | Y | N |
| Time Dummies | Y | Y | Y | Y | N |
| API Gravity Decile Dummies | N | N | Y | N | N |
| API Gravity Decile Time Trends | N | N | Y | N | N |
| After Tax-price Elasticity | 0.237 | 0.238 | 0.208 | 0.261 | -0.496 |
| | (0.029) | (0.029) | (0.027) | (0.021) | (0.028) |
| Number of Wells | 75,342 | 75,342 | 75,342 | 73,548 | 75,342 |
| Observations | 6,517,140 | 6,517,140 | 6,517,140 | 6,350,820 | 6,517,140 |

Note: This table presents OLS estimates of

$$q_{it} = \beta_0 + \beta_1(1 - \tau_t^C)(B_{igt} + (1 - \tau_{igt}^W)(P_{gt} - B_{igt})) + \beta_2 age_{it} + \chi_t + \delta_i + \varepsilon_{it}$$

The dependent variable is the quantity of oil produced by well $i$ in month $t$. After-Tax Price is the posted price at which oil from well $i$ was sold during month $t$, net of corporate and Windfall Profit taxes. The coefficient on After-Tax Price, $\beta_1$, reports the supply response of operators to net price.

Column 1 is the baseline specification; it includes time and well dummies and a control for well age. Column 2 adds a quadratic well age term. Column 3 includes separate quadratic time trends, slopes and coefficients, by API gravity decile. Column 4 drops all observations from the federal Naval Petroleum Reserve. The elasticity calculations for all specifications is the product of the coefficient estimate and the ratio of average after-tax price to average quantity for the sample of 4,681,973 producing oil wells.

All heteroskedasticity robust standard errors are clustered at the individual well level.

Table 1.3: Regressions of Quantity Produced on After-Tax Price, Flowing vs. Pumped Wells

| | (1) | (2) | (3) |
|---|---|---|---|
| | Baseline | Pumped | Flowing |
| After Tax-price Elasticity | 0.237 | 0.356 | -0.101 |
| | (0.029) | (0.024) | (0.088) |
| p-value | 0.000 | 0.000 | 0.253 |
| 95% Confidence Intervals | [0.180, 0.295] | [0.083, 0.108] | [-0.274, 0.072] |
| | | | |
| After-tax Price | 8.730 | 11.520 | -12.180 |
| | (1.082) | (0.784) | (10.649) |
| Well Age | -1.269 | -1.570 | -0.377 |
| | (0.069) | (0.055) | (0.866) |
| Well Dummies | Y | Y | Y |
| Time Dummies | Y | Y | Y |
| | | | |
| Number of Wells | 75,342 | 72,797 | 13,198 |
| Observations | 6,517,140 | 5,698,198 | 818,942 |

Note: This table presents OLS estimates of

$$q_{it} = \beta_0 + \beta_1(1 - \tau_t^C)(B_{igt} + (1 - \tau_{igt}^W)(P_{gt} - B_{igt})) + \beta_2 age_{it} + \chi_t + \delta_i + \varepsilon_{it}$$

The dependent variable is the quantity of oil produced by well $i$ in month $t$. After-Tax Price is the posted price at which oil from well $i$ was sold during month $t$, net of corporate and Windfall Profit taxes. The coefficient on After-Tax Price, $\beta_1$, reports the supply response of operators to net price.

All specifications include well and time dummies. Column 1 is the baseline specification; it reports the same estimates as column 1 of Table 2. Column 2 restricts the sample to only pumped wells. Column 3 restricts the sample to only flowing wells, which do not require mechanical lift to produce oil. The elasticity calculations for all specifications is the product of the coefficient estimate and the ratio of average after-tax price to average quantity for the estimation sample of producing oil wells.

All heteroskedasticity robust standard errors are clustered at the individual well level.

Table 1.4: Conditional Logit Models of Well Shut-in Decisions

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | Cond. Logit | Cond. Logit | Cond. Logit | Cond. Logit | OLS | OLS |
| | Shut-in Var. | Shut-in Var. | Shut-in Var. | No NPR | Shut-in Var. | Full Sample |
| After-tax Price | -0.0052 | -0.0052 | -0.0064 | -0.0060 | -0.0043 | -0.0015 |
| | (0.0008) | (0.0008) | (0.0002) | (0.0009) | (0.0004) | (0.0002) |
| Well Age | 0.0126 | 0.0126 | 0.0455 | 0.0121 | 0.0014 | 0.0005 |
| | (0.0007) | (0.0007) | (0.0008) | (0.0007) | (0.0000) | (0.0000) |
| Well Age Squared | | 0.000 | | | | |
| | | (0.0000) | | | | |
| Well Dummies | Y | Y | Y | Y | Y | Y |
| Time Dummies | Y | Y | Y | Y | Y | Y |
| API Gravity Decile Dummies | N | N | Y | N | N | N |
| API Gravity Decile Time Trends | N | N | Y | N | N | N |
| After Tax-price Semi-Elasticity | -0.095 | -0.095 | -0.117 | -0.111 | -0.080 | -0.027 |
| | (0.0148) | (0.0148) | (0.0037) | (0.0169) | (0.0078) | (0.0034) |
| Number of Wells | 29,297 | 29,297 | 29,297 | 29,297 | 29,297 | 75,342 |
| Observations | 2,694,267 | 2,694,267 | 2,694,267 | 2,694,267 | 2,694,267 | 6,517,140 |

Note: This table presents conditional logit estimates of

$$S_{it} = \beta_0 + \beta_1(1 - \tau_t^C)(B_{igt} + (1 - \tau_{igt}^W)(P_{gt} - B_{igt})) + \beta_2 age_{it} + f(t) + \delta_i + \varepsilon_{it}$$

The binary dependent variable is one if well $i$ is shut-in in month $t$ and zero if it is not. After-Tax Price is the posted price at which oil from well $i$ was sold during month $t$, less corporate and Windfall Profit taxes. The coefficient on After-Tax Price, $\beta_1$, reports the extensive response of operators to net price.

Column 1 includes a full set of month-year and well dummies. Column 2 adds a quadratic term in well age. Column 3 adds dummies and quadratic time trends for each API gravity decile. Column 4 excludes observations from the federal NPR. The semi-elasticity calculations for all specifications is the product of the marginal effect estimate and average after-tax price. Column 5 estimates an OLS model with well and time fixed effects using the full sample of wells. Column 6 estimates the fixed effect OLS model using the smaller sample of wells that experience variation in shut-in status. Columns 1-4 and 6 use a sample of wells that experience variation in shut-in status—a requirement of the conditional logit model.

All standard errors are clustered at the individual well level.

Table 1.5: U.S. Supply Elasticities From Previous Studies

| Study | Sample Period | Data | Elasticity Estimate |
|---|---|---|---|
| Griffin (1985) | 1971Q1 - 1983Q3 | Quarterly data on total U.S. production and average pre-tax posted price from 1971Q1 to 1976Q2, average pre-tax first purchase price from 1976Q3 to 1983Q3. No controls. | -0.05 (0.02) |
| Hogan (1989) | 1966 - 1987 | Annual data on total U.S. production and average pre-tax first purchase price. | 0.09 (0.03) |
| Jones (1990) | 1983Q3 - 1988Q4 | Quarterly data on total U.S. production and average pre-tax first purchase price. No controls. | 0.07 (0.04) |
| Dahl and Yücel (1991) | 1971Q1 - 1987Q4 | Quarterly data on total U.S. production and average first purchase price. Added controls for production cost, wells drilled, U.S. income, and world oil production. | -0.08 (0.06) |
| Ramcharran (2002) | 1973 - 1997 | Annual data on total U.S. production and average pre-tax first purchase price. Linear time trend included. | 0.05 (0.02) |

Note: These studies estimated supply elasticities for total U.S. production as part of an examination of market structures among OPEC and non-OPEC countries; nonetheless most of these are the studies cited in supply elasticity surveys, such as Dahl and Duggan (1996). All of these analyses rely on time-series data for the U.S. These models were all estimated in logs. Standard errors are in parentheses.

Table 1.6: Alternative Specifications Using National Average Price Series

| | (1) Baseline | (2) Within Well | (3) Pooled | (4) Time-Series |
|---|---|---|---|---|
| WTI Price | 8.730 | 0.320 | 0.365 | 11,223 |
| | (1.082) | (0.148) | (0.153) | (10,036) |
| Well Age | -1.269 | - | - | - |
| | (0.069) | - | - | - |
| Time | - | | -0.1474995 | 48,874 |
| | - | | 0.0806413 | (4,468) |
| Well Dummies | Y | Y | N | N |
| Time Dummies | Y | N | N | N |
| After Tax-price Elasticity | 0.237 | 0.021 | 0.024 | 0.017 |
| | (0.029) | (0.010) | (0.010) | (0.015) |
| p-value | 0.000 | 0.030 | 0.017 | 0.263 |
| Number of Wells | 75,342 | 75,342 | 75,342 | 75,342 |
| Observations | 6,517,140 | 6,517,140 | 6,517,140 | 6,517,140 |

Note: This table presents OLS estimates of the equation,

$$q_{it} = \beta_0 + \beta_1 \overline{P}_t + f(t) + \varepsilon_{it}$$

The dependent variable is the quantity of oil produced by well $i$ in month $t$ in the baseline, within-well and pooled specifications; the dependent variable is the total quantity produced across all wells in month $t$ in the time-series specifications. Average price is the average pre-tax first purchase price from the Department of Energy's Monthly Energy Review price series. The coefficient on After-Tax Price, $\beta_1$, reports the supply response of operators to this price measure.

Column 1 is the baseline specification where the price variable is the well-specific after-tax price, corresponding to column 2 of table 2; it includes time and well dummies and a control for well age. Column 2 uses average pre-tax price from the Monthly Economic Review (MER) price series rather than the well-specific after-tax price and drops the time dummies; it controls linearly for time and omits the well age control to better match previous time-series specifications. Column 3 excludes both time and well dummies but retains the linear time control. Column 4 reports estimates from a time-series regression of total production across all wells each month on MER average pre-tax price. As in the previous literature no attempt to correct for autocorrelation is made. Columns 5 and 6 restrict the sample to non-heavy, non-stripper wells that began production prior to January 1982 in an attempt to construct of sample of more comparable wells. These wells were treated differently by decontrol policies and the WPT as some are new wells and others are old wells. Column 5 reports estimates from a specification identical to that of column 3 but uses this smaller, more comparable sample. Column 6 reports estimates from a specification identical to that of column 4 but again on the smaller sample of non-heavy non-stripper wells that are both new and old. The elasticity calculations for 1, 2, 3 and 5 are the product of the coefficient estimate and the ratio of average MER pre-tax price to average quantity for the sample of 4,681,973 producing oil wells. For columns 4 and 6 the in-sample average MER pre-tax price and oil production are used to construct the elasticity.

For columns 1, 2, 3 and 5 heteroskedasticity robust standard errors are clustered at the individual well level.

Table 1.7: Alternative Specifications Using After-Tax Price

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | Baseline | Within Well | Pooled | Time-Series | Pooled | Time-Series |
| After-Tax Price | 8.730 | 2.617 | -19.676 | -58,302 | 13.432 | 158,262 |
| | (1.082) | (0.500) | (1.015) | (39,283) | (4.946) | (44,607) |
| Well Age | -1.269 | - | - | - | - | - |
| | (0.069) | - | - | - | - | - |
| Time | - | -1.260 | 0.315 | 0.098 | -3.476 | -56,305 |
| | - | (0.080) | (0.081) | (0.007) | (0.362) | (2,164) |
| Well Dummies | Y | Y | N | N | N | - |
| Time Dummies | Y | N | N | N | N | - |
| After Tax-price Elasticity | 0.237 | 0.071 | -0.535 | -0.036 | 0.149 | 0.208 |
| | (0.029) | (0.014) | (0.028) | (0.024) | (0.055) | (0.059) |
| p-value | 0.000 | 0.000 | 0.000 | 0.138 | 0.000 | 0.000 |
| Number of Wells | 75,342 | 75,342 | 75,342 | - | 20,699 | - |
| Observations | 6,517,140 | 6,517,140 | 6,517,140 | 108 | 1,090,659 | 108 |

Note: This table presents OLS estimates of the equation,

$$q_{it} = \beta_0 + \beta_1(1 - \tau_t^C)(B_{it} + (1 - \tau_{it}^W)(P_t - B_{it})) + f(t) + \varepsilon_{it}$$

The dependent variable is the quantity of oil produced by well $i$ in month $t$ in the baseline, within-well and pooled specifications; the dependent variable is the total quantity produced across all wells in month $t$ in the time-series specifications. After-Tax Price is the posted price at which oil from well $i$ was sold during month $t$, net of corporate and Windfall Profit taxes. The coefficient on After-Tax Price, $\beta_1$, reports the supply response of operators to net price.

Column 1 is the baseline specification, corresponding to column 2 of table 2; it includes time and well dummies and a control for well age. Column 2 drops the time dummies; it instead controls linearly for time and omits the well age control to better match previous time-series specifications. The coefficient on after-tax price in a within-well specification that controls linearly for well age but not for time is 2.617 (0.500), within rounding error of the estimate reported in column 2. Column 3 excludes both time and well dummies but retains the linear time control. Column 4 reports estimates from a time-series regression of total production across all wells each month on average after-tax price. As in the previous literature no attempt to correct for autocorrelation is made. Columns 5 and 6 restrict the sample to non-heavy, non-stripper wells that began production prior to January 1982 in an attempt to construct of sample of more comparable wells. These wells were treated differently by decontrol policies and the WPT as some are new wells and others are old wells. Column 5 reports estimates from a specification identical to that of column 3 but uses this smaller, more comparable sample. Column 6 reports estimates from a specification identical to that of column 4 but again on the smaller sample of non-heavy non-stripper wells that are both new and old. The elasticity calculations for 1, 2, 3 and 5 are the product of the coefficient estimate and the ratio of average after-tax price to average quantity for the sample of 4,681,973 producing oil wells. For columns 4 and 6 the in-sample average after-tax price and oil production are used to construct the elasticity.

For columns 1, 2, 3 and 5 heteroskedasticity robust standard errors are clustered at the individual well level.

Table 1.8: Percentage Decrease in Total Surplus Due to the Introduction of a 15% Temporary Excise Tax

| | Duration of Temporary Tax ($t_1$) | | | |
|---|---|---|---|---|
| $T^0$ | 1 | 2 | 3 | 5 |
| 10 | -0.015 | -0.027 | -0.037 | -0.049 |
| 15 | -0.007 | -0.014 | -0.020 | -0.030 |
| 20 | -0.005 | -0.009 | -0.013 | -0.020 |
| 25 | -0.003 | -0.007 | -0.009 | -0.015 |
| 30 | -0.003 | -0.005 | -0.007 | -0.012 |
| 40 | -0.002 | -0.004 | -0.005 | -0.008 |

Note: This table reports the ratio of the change in total surplus, the loss in producer surplus less government revenue, over the government revenue, for a single well whose cost function parameter $c = 0.0573$, which corresponds to the average elasticity response reported in column 1 of Table 2. Pre-tax price is assumed constant and equal to \$25. The interest rate is 5 percent. Producer surplus before the tax is calculated using the following equation:

$$PS^0 = \int_0^{T^0} e^{-rt}\left[p\left(\frac{p}{2c} - \frac{pe^{-r(T^0-t)}}{2c}\right) - c\left(\frac{p}{2c} - \frac{pe^{-r(T^0-t)}}{2c}\right)^2\right]dt = \frac{p^2}{4cr}\left(1 - e^{-rT^0}\right)^2$$

Producer surplus after the tax is calculated using the following equation:

$$PS^1 = \int_0^{t_1} e^{-rt}\left[(1-\tau)p\left(\frac{(1-\tau)p}{2c} - \frac{pe^{-r(T^1-t)}}{2c}\right) - c\left(\frac{(1-\tau)p}{2c} - \frac{pe^{-r(T^1-t)}}{2c}\right)^2\right]dt + \int_{t_1}^{T^1} e^{-rt}\left[p\left(\frac{p}{2c} - \frac{pe^{-r(T^1-t)}}{2c}\right) - c\left(\frac{(p}{2c} - \frac{pe^{-r(T^1-t)}}{2c}\right)^2\right]dt$$

$$= \frac{p^2}{4cr}\left(\left((1-\tau)^2 - 1\right)\left(1 - e^{-rt_1}\right) + \left(1 - e^{-rT^1}\right)^2\right)$$

Government revenue from the temporary tax is calculated using the following equation:

$$GR = \int_0^{t^1} e^{-rt}\tau p\left(\frac{(1-\tau)p}{2c} - \frac{pe^{-r(T^1-t)}}{2c}\right)dt = \frac{\tau p^2}{2c}\left(\frac{(1-\tau)}{r}\left(1 - e^{-rt_1}\right) - e^{-rT^1}t_1\right)$$

where $T^1 = T^0 + dT$, the new economic life of the well. The original economic life of the well, $T^0$, varies down the rows while the duration of the temporary tax, $t_1$, varies along the columns. The entries are $(PS^0\text{-}PS^1+GR)/\ PS^0$.

Table 1.9: Ratio of the Change in Surplus to Government Revenue Raised From the Introduction of a 15% Temporary Excise Tax

| | Duration of Temporary Tax ($t_1$) | | | |
|---|---|---|---|---|
| $T^0$ | 1 | 2 | 3 | 5 |
| 10 | -1.66 | -1.63 | -1.59 | -1.52 |
| 15 | -1.38 | -1.38 | -1.37 | -1.36 |
| 20 | -1.27 | -1.27 | -1.27 | -1.27 |
| 25 | -1.21 | -1.21 | -1.21 | -1.21 |
| 30 | -1.17 | -1.17 | -1.17 | -1.17 |
| 40 | -1.13 | -1.13 | -1.13 | -1.13 |

Note: This table reports the ratio of the change in total surplus, the loss in producer surplus less government revenue, over the government revenue, for a single well whose cost function parameter $c = 0.0573$, which corresponds to the average elasticity response reported in column 1 of Table 2. Pre-tax price is assumed constant and equal to \$25. The interest rate is 5 percent. Producer surplus before the tax is calculated using the following equation:

$$PS^0 = \int_0^{T^0} e^{-rt}\left[p\left(\frac{p}{2c}-\frac{pe^{-r(T^0-t)}}{2c}\right)-c\left(\frac{p}{2c}-\frac{pe^{-r(T^0-t)}}{2c}\right)^2\right]dt = \frac{p^2}{4cr}\left(1-e^{-rT^0}\right)^2$$

Producer surplus after the tax is calculated using the following equation:

$$PS^1 = \int_0^{t_1} e^{-rt}\left[(1-\tau)p\left(\frac{(1-\tau)p}{2c}-\frac{pe^{-r(T^1-t)}}{2c}\right)-c\left(\frac{(1-\tau)p}{2c}-\frac{pe^{-r(T^1-t)}}{2c}\right)^2\right]dt + \int_{t_1}^{T^1} e^{-rt}\left[p\left(\frac{p}{2c}-\frac{pe^{-r(T^1-t)}}{2c}\right)-c\left(\frac{(p}{2c}-\frac{pe^{-r(T^1-t)}}{2c}\right)^2\right]dt$$

$$= \frac{p^2}{4cr}\left(\left((1-\tau)^2-1\right)\left(1-e^{-rt_1}\right)+\left(1-e^{-rT^1}\right)^2\right)$$

Government revenue from the temporary tax is calculated using the following equation:

$$GR = \int_0^{t^1} e^{-rt}\tau p\left(\frac{(1-\tau)p}{2c}-\frac{pe^{-r(T^1-t)}}{2c}\right)dt = \frac{\tau p^2}{2c}\left(\frac{(1-\tau)}{r}\left(1-e^{-rt_1}\right)-e^{-rT^1}t_1\right)$$

where $T^1 = T^0 + dT$, the new economic life of the well. The original economic life of the well, $T^0$, varies down the rows while the duration of the temporary tax, $t_1$, varies along the columns. The entries are $(PS^0\text{-}PS^1+GR)/GR$.

## Appendix 1: Producer Surplus Before and After the Introduction of a Temporary Excise Tax and Government Revenue Raised

Table A1.1: Producer Surplus Before the Introduction of a 15% Temporary Excise Tax

| | Duration of Temporary Tax ($t_1$) | | | |
|---|---|---|---|---|
| $T^0$ | 1 | 2 | 3 | 5 |
| 10 | $8,447 | $8,447 | $8,447 | $8,447 |
| 15 | 15,190 | 15,190 | 15,190 | 15,190 |
| 20 | 21,801 | 21,801 | 21,801 | 21,801 |
| 25 | 27,776 | 27,776 | 27,776 | 27,776 |
| 30 | 32,929 | 32,929 | 32,929 | 32,929 |
| 40 | 40,792 | 40,792 | 40,792 | 40,792 |

Note: This table presents producer surplus for the operator of a single well whose cost function parameter $c = 0.0573$, which corresponds to the average elasticity response reported in column 1 of table 2. Pre-tax price is assumed constant and equal to $25. The interest rate is 5 percent. Producer surplus is calculated using the following equation:

$$PS^0 = \int_0^{T^0} e^{-rt}\left[p\left(\frac{p}{2c} - \frac{pe^{-r(T^0-t)}}{2c}\right) - c\left(\frac{p}{2c} - \frac{pe^{-r(T^0-t)}}{2c}\right)^2\right]dt = \frac{p^2}{4cr}\left(1 - e^{-rT^0}\right)^2$$

The economic life of the well, $T^0$, varies down the rows while the duration of the temporary tax, $t_1$, varies along the columns. Before the tax is in place, the "duration" of the tax is irrelevant, thus the surplus is equal across columns.

Table A1.2: Producer Surplus After the Introduction of a 15% Temporary Excise Tax

| | Duration of Temporary Tax ($t_1$) | | | |
|---|---|---|---|---|
| $T^0$ | 1 | 2 | 3 | 5 |
| 10 | $8,132 | $7,857 | $7,619 | $7,246 |
| 15 | 14,780 | 14,405 | 14,064 | 13,477 |
| 20 | 21,318 | 20,870 | 20,455 | 19,718 |
| 25 | 27,236 | 26,731 | 26,260 | 25,410 |
| 30 | 32,345 | 31,797 | 31,281 | 30,345 |
| 40 | 40,148 | 39,538 | 38,963 | 37,906 |

Note: This table presents producer surplus for the operator of a single well whose cost function parameter $c = 0.0573$, which corresponds to the average elasticity response reported in column 1 of table 2. Pre-tax price is assumed constant and equal to $25. The interest rate is 5 percent. Producer surplus is calculated using the following equation:

$$PS^1 = \int_0^{t_1} e^{-rt}\left[(1-\tau)p\left(\frac{(1-\tau)p}{2c} - \frac{pe^{-r(T^1-t)}}{2c}\right) - c\left(\frac{(1-\tau)p}{2c} - \frac{pe^{-r(T^1-t)}}{2c}\right)^2\right]dt + \int_{t_1}^{T^1} e^{-rt}\left[p\left(\frac{p}{2c} - \frac{pe^{-r(T^1-t)}}{2c}\right) - c\left(\frac{(p}{2c} - \frac{pe^{-r(T^1-t)}}{2c}\right)^2\right]dt$$

$$= \frac{p^2}{4cr}\left(\left((1-\tau)^2 - 1\right)\left(1 - e^{-rt_1}\right) + \left(1 - e^{-rT^1}\right)^2\right)$$

The economic life of the well, $T^0$, varies down the rows while the duration of the temporary tax, $t_1$, varies along the columns. Before the tax is in place, the "duration" of the tax is irrelevant, thus the surplus is equal across columns.

Table A1.3: Government Revenue From the Introduction of a 15% Temporary Excise Tax

| | Duration of Temporary Tax ($t_1$) | | | |
|---|---|---|---|---|
| $T^0$ | 1 | 2 | 3 | 5 |
| 10 | $190 | $363 | $519 | $789 |
| 15 | 297 | 569 | 819 | 1,258 |
| 20 | 380 | 734 | 1,062 | 1,646 |
| 25 | 446 | 863 | 1,253 | 1,956 |
| 30 | 497 | 965 | 1,403 | 2,201 |
| 40 | 569 | 1,106 | 1,613 | 2,544 |

Note: This table presents government revenue from temporary taxation of a single well whose cost function parameter $c = 0.0573$, which corresponds to the average elasticity response reported in column 1 of table 2. Pre-tax price is assumed constant and equal to $25. The interest rate is 5 percent. Government revenue is calculated using the following equation:

$$GR = \int_0^{t^1} e^{-rt} \tau p \left( \frac{(1-\tau)p}{2c} - \frac{p e^{-r(T^1-t)}}{2c} \right) dt = \frac{\tau p^2}{2c} \left( \frac{(1-\tau)}{r} \left(1 - e^{-rt_1}\right) - e^{-rT^1} t_1 \right)$$

The economic life of the well, $T^0$, varies down the rows while the duration of the temporary tax, $t_1$, varies along the columns. Before the tax is in place, the "duration" of the tax is irrelevant, thus the surplus is equal across columns.

# Chapter 2

# Do Tax Credits Stimulate R&D Spending? Revisiting the Effect of the R&D Tax Credit in its First Decade

## 2.1 Introduction

In an attempt to stanch a decade-long decline in the GDP-share of private R&D spending, Congress adopted a tax credit for R&D expenditures in 1981. The Research and Experimentation Credit (R&D Credit) awards firms that increase their research spending a tax credit of up to 25 percent of their expenditures in excess of their past research spending. As the credit is incremental, the research credit offers no subsidy to firms that fail to increase their R&D spending. Along with existing provisions that allowed firms to expense R&D spending, the research credit lowers the after-tax cost of qualified research in hope of incentivizing firms to increase their R&D investments.

As the primary tax provision designed to encourage private R&D expenditures, the effectiveness of the Research and Experimentation Credit (R&D credit) has been of interest to both researchers and policymakers alike. Although early work (Eisner et al (1984)[1] and Mansfield (1986)[2] ) suggested that the credit had an insignificant or modest impact on R&D spending, more recent studies have found surprisingly large user cost elasticities. Using confidential IRS data, Altshuler (1988) found that between 1981 and 1984 average effective credit rates were just a fraction—less than one-tenth—of the period's 25 percent statutory credit rate. Later studies, most notably Hines (1993) and Hall (1994), found that the R&D tax credit proffered much more bang-for-the-buck. Hines (1993) explored the effect of changes in the allocation rules of R&D expensing on the R&D activity of multinational firms. Using a special Compustat data panel describing foreign pretax earnings and foreign taxes paid between 1984 and 1989 for a subset of firms, Hines exploited variation in the fraction of U.S. R&D expenses firms can deduct against U.S. income for tax purposes to estimate the response of R&D spending to its after-tax price. His short-run estimates ranging from -1.2 to -1.6 and long-run estimates ranging from -1.3 to -2.0 suggest a tax-price elasticity of R&D that well exceeds unity. Although the changes in the allocation rules are conceivably exogenous, Hines' tack relies on variation in the tax treatment of R&D expenditures across firms—it essentially compares firms with and without excess foreign tax credits, an experiment that is different than the changes in the main statutory provisions of the R&D tax credit that are examined here.

The closest antecedent to this paper is Hall (1994), which used Compustat data from financial filings beginning in 1981 and ending in 1991. In her log first-difference specifications, Hall uses cross-time within-firm variation in tax positions and marginal R&D tax subsidies to estimate a short-run elasticity of -1.5 (0.3) and a long-run

[1]Eisner, Albert and Sullivan (1984) took a natural experiment approach and made use of special survey data describing the composition of firm R&D spending to construct a difference-in-difference estimate of the effect of the R&D tax credit. They found that spending on research that qualified for the R&D tax credit grew 25.7 (5.0) percentage points faster than unqualified research spending between 1980 and 1981. They found that difference in spending growth was statistically insignificant in 1982, suggesting that the policy change did not fundamentally alter spending patterns. Comparing changes in aggregate qualified and unqualified R&D spending implicitly assumes that absent the introduction of the R&D tax credit these types of R&D spending would have increased identically; systematic spending trend differences among firms with different R&D spending mixes would violate this assumption.

[2]Mansfield (1986) compared the experiences of the US, Canada and Sweden using firm-level survey data; executives of a stratified sample of firms were asked to estimate the effect of the relevant tax incentives on the firm's R&D expenditures. According to the executives, each dollar of forgone tax revenue resulted in 30 to 40 cents of induced R&D spending.

elasticity of -2.7 (0.8).

More recent work examining the impact of state tax credits and international experiences has found more modest elasticities (Wilson (2007), Bloom et al (2002)). Cross-country analysis by Bloom, Griffith and Van Reenen (2002) suggests much lower short- and long-run user cost elasticities. In their preferred dynamic specification they estimate a -0.14 short-run elasticity and a -1.09 long-run elasticity. Bloom et al worry that OLS estimates of the user cost elasticity would be upward biased because the user cost of R&D is a function of the interest rate which is positively correlated with R&D spending. They instrument the R&D user costs with the tax component of the user cost to address this endogeneity issue as well as attenuation bias concerns. Although some countries in their sample have incremental R&D credit regimes, where high spending firms receive higher credit rates, Bloom et al do not address this potential source of bias. Wilson (2009) uses variation in state tax preferences for R&D to estimate both the impact of a state's R&D policy on R&D conducted in that state and the impact on R&D in neighboring states. Using state aggregate data he finds that R&D spending is negatively impacted by tax preferences in other states, suggesting that firms shift R&D to proximate states with lower R&D user costs. The magnitude of this response nearly offsets the in-state response of R&D to changes in the in-state user cost. Wilson concludes that the aggregate R&D user cost elasticity is small and near-zero; state subsidies draw R&D across state borders rather than encouraging a new dollar of R&D spending. His state-level analysis yields an elasticity estimate of 0.17 in the short-run and 0.68 in the long-run. Wilson assumes that all R&D subject to an incremental R&D tax credit receives the highest statutory rate, abstracting from simultaneity between R&D spending and R&D user costs.

This paper re-examines the impact of federal tax advantages for R&D between the inception of the R&D tax credit in 1981 and 1991. Data after 1991 are excluded because the credit was allowed to first lapse in 1992. Since this and other lapses likely affected firms' expectations of the after-tax user cost of R&D, the analysis here is limited to only the first 11 years after the introduction of the research credit. Furthermore, during this period the R&D credit underwent several substantial revisions that allow for an instrumental variables strategy based on tax changes. Unlike previous efforts to assess the impact of tax subsidies on R&D spending, this paper incorporates restricted-access IRS corporate return data. As explained in more detail below, the structure of the R&D tax credit makes a firm's marginal tax subsidy difficult to infer from annual R&D spending as reported in its public financial statements alone. Data from the corporate tax return allows for accurate measurement of the tax subsidy each firm faces on its marginal R&D dollar each year and allows for unbiased assessment of the impact of the tax credit on R&D expenditures.

The main contributions of this paper are the use of IRS Statistics of Income (SOI) data that accurately describe marginal credit rates and a more direct correction for potential biases due to the simultaneity of R&D spending and marginal credit rates. Tax subsidy terms constructed using only publicly available Compustat data, and constructed using IRS data, differ and the differences often vary from year to year. This finding at a minimum suggests potential measurement error in subsidy rates calculated using public use data. Instrumental variable estimates suggest that different instrument sets produce different estimates of the effect of tax subsidies on R&D expenditures. These findings raise questions about the robustness of many panel data strategies for estimating the elasticity of R&D spending.

Using an instrumental variables strategy based on tax law changes to disentangle any potential simultaneity between R&D spending and its user cost, I estimate a short-run user cost elasticity for R&D spending. The results yield a range of estimates for the effect of tax incentives on R&D investment. Estimates using only publicly available data suggest that a ten percent tax subsidy for R&D yields between \$3.5 (0.24) million and \$10.7 (1.79) million in new R&D spending by the average firm. Estimates from IRS SOI data, which only reports qualified research expenditures, suggest that a ten percent reduction in the usercost would lead the average firm to increase qualified spending by \$2 .0 (0.39) million. Analysis of the components of qualified research spending shows that wages and supplies, which comprise the bulk of qualified spending, account for the increase in research spending. Estimates from the much smaller merged sample, which makes use of the more precise tax data to calculate the tax component of the usercost, suggest that qualified spending is responsive to the tax subsidy. A similar response in total spending is not statistically discernible in the merged sample. The inconsistency of estimates across datasets, instrument choice and specifications highlights the sensitivity of estimates of the tax-price elasticity of R&D spending.

The paper proceeds as follows. Section 2.1 sketches the conceptual framework underlying the regression analysis. R&D is viewed as a durable input into the firm's production function. Tax subsidies are modeled as inducing relatively small changes in steady-state investments in R&D. Section 2.2 briefly describes key aspects of the R&D tax credit and their impact on the user cost of R&D spending. Section 2.3 discusses and contrasts public financial and restricted-access SOI data and details measurement issues. Section 2.4 lays out the empirical model and methodology, including a description of the instrumental variables used. Section 2.5 presents the results of different specifications using the two data sets. Section 2.6 concludes.

## 2.2 Conceptual Framework

Like most other R&D studies, this paper treats R&D, specifically the services of R&D capital, as an input into a firm's production function.[3] Research projects are undertaken by private firms to develop new products or new methods that increase sales. The price of output is normalized to one. The output of firm $i$ in time $t$, $Y_{it}$, is generated via a production function with a constant elasticity of substitution ($\sigma$) between the stock of R&D capital, $S_{it}$, and all other inputs, $I_{it}$:

$$Y_{it} = F\left(S_{it}, I_{it}\right) = \left[\theta_i S_{it}^{\frac{\sigma-1}{\sigma}} + \left(1-\theta_i\right) I_{it}^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \tag{2.1}$$

where $\theta_i$ is the firm-specific CES distribution parameter. Note that $\sigma$ captures both the elasticity of substitution and the user cost elasticity of R&D spending. R&D

[3]Though only a small share of R&D spending is directly for capital goods, more than half of all expenditures consist of wages and fringe benefits and only 5 percent of costs are attributable to depreciation (NSF 2003), R&D expenditures are thought to buildup a stock of R&D knowledge. The service flows from this knowledge stock is the input into firm production.

investments, $R_{it}$, add to the R&D capital stock, $S_{it}$, without adjustment frictions; R&D capital depreciates at a constant rate $\delta$. The R&D stock is governed by:

$$\dot{S} = R_{it} - \delta S_{it} \tag{2.2}$$

The standard derivation of the Hall-Jorgenson user cost of capital formula can be extended to reflect both federal tax subsidies for R&D and the impact of the tax status of the firm. A firm that is taxable at marginal rate $\tau_{it}$ can expense its R&D spending in the current year and earn a tax credit at marginal rate $c_{it}$, which is indexed by firm because the marginal credit rate is a function of the firm's R&D spending as explained in further detail in section 2.1.2.[4] Firms discount the future at a common real interest rate, $r_t$, purchase R&D and other inputs at prices $p^{S_t}$ and, $p^{I_t}$, and face a common constant depreciation rate on R&D capital, $\delta$. The taxable firm maximizes profit according to the following present-value Hamiltonian:

$$\begin{aligned} H_{it}\left(S_{it}, I_{it}, \omega_{it}\right) \;=\; & \int_0^{\infty} \left\{e^{-rt}\left[\left(1-\tau_{it}\right)\left(F\left(S_{it}, I_{it}\right) - p_t^I I_{it}\right) - p_t^S R_{it}\left(1-\tau_{it}-c_{it}\right)\right]\right. \\ & \left. - \,\omega_{it}\left[R_{it} - \delta S_{it} - S_{it}\right]\right\} dt \end{aligned} \tag{2.3}$$

where $\omega_{it}$ it is the shadow value of R&D capital.

From the requisite first-order conditions the analogous Hall-Jorgenson arbitrage condition for the optimal R&D capital stock can be written:

$$\left(1-\tau_{it}-c_{it}\right)\left(r_t + \delta - \pi_t^S\right) p_t^S = \left(1-\tau_{it}\right) F_{S_{it}} \tag{2.4}$$

where $\tau_{it}$ is the marginal corporate tax rate, $c_{it}$ is the marginal research credit rate, $r_t$ is the common real interest rate, $\delta$ is the depreciation rate of R&D capital, $\pi_t^S$ is the time-varying growth rate of R&D input prices, $p_t^S$ is the price of R&D inputs, and $F_S$ is the first-derivative of the production function, $F\left(S_{it}, I_{it}\right)$, with respect to

[4]The corporate tax rate is indexed by firm to account for the progressivity of federal corporate taxes. In 2007 the 35 percent flat corporate tax rate applied to income greater than $18.333 million; incomes less than this level were taxed at a lower rate except for small intervals of more heavily taxed income. Some small firms subject to a marginal tax rate less than 35 percent do spend on R&D; their R&D credit rate reflects their smaller marginal tax rate.

R&D capital.

Note that the credit rate, $c_{it}$, enters the relation linearly because the depreciation base is not typically reduced by the amount of the credit. Firms are viewed as discounting at their real borrowing rates; although R&D is risky, the firms that account for the lion's share of R&D spending are large highly-rated firms that could fund their R&D by borrowing at generally low interest rates. The depreciation rate for R&D, $\delta$, is thought to be high since a sizable fraction of R&D spending does not yield intellectual capital and goes to wages, supplies and equipment rental, none of which are durable. Since the wages comprise the bulk of R&D spending, R&D price inflation, $\pi_t^S$, should closely track wage growth for scientists and engineers.

Rearranging equation 2.4, the user cost of R&D capital, $\rho_{it}$, for a taxable firm can be written:

$$F_{S_{it}} = \rho_{it} = \frac{\left(r_t + \delta - \pi_t^S\right) p_t^S \left(1 - \tau_{it} - c_{it}\right)}{\left(1 - \tau_{it}\right)} \tag{2.5}$$

A nontaxable firm with $k_{it}$ years of tax losses will not use the R&D expensing provision to offset income until those losses are exhausted; it will offset income in $k_{it}$ years at the prevailing tax rate. Similarly, a firm that has insufficient tax liabilities to fully apply any R&D credit earned this year will carry its credit forward $j_{it}$ years until it can fully use it. The tax terms in the user cost formula for nontaxable firms must be appropriately discounted to reflect the delayed use of the subsidies. Finally, the loss-laden firm does not contemporaneously pay taxes on income arising from current R&D services because currently accrued losses offset these earnings; but it is absorbing losses that would have otherwise remained unused and available in available in $k_{it}$ years when the firm first reports taxable income. The user cost of the nontaxable firm must also reflect the value of these used losses. The relevant tax rate for valuing these absorbed losses is the tax rate prevailing in $k_{it}$ years:

$$\rho_{it} = \frac{\left(r_t + \delta - \pi_t^S\right) p_t^S \left(1 - \tau_{it+k_{it}} \left(1 + r_t\right)^{-k_{it}} - c_{it} \left(1 + r_t\right)^{-j_{it}}\right)}{\left(1 - \tau_{it+k_{it}} \left(1 + r_t\right)^{-k_{it}}\right)} \tag{2.6}$$

where $r_t$ is the interest rate, $\delta$ is the depreciation rate, $p_t^S$ is the price of R&D inputs,

$\tau_{it}$ is the marginal tax rate, $k_{it}$ is the number of years until any losses are exhausted, $c_{it}$ is the marginal research credit rate, and $j_{it}$ is the number of years any R&D tax credits must be carried forward. Note that in the case of the taxable firm, $k_{it}$ and $j_{it}$ will be zero and the user cost formula will be identical to equation 2.5.

As noted above, the firm's marginal R&D credit rate, $c_{it}$, varies across firms as well as over time. Initially, the marginal credit rate was a nonlinear function of the firm's current R&D spending, its recent R&D spending and its future R&D spending. Legislative modifications to the R&D credit's provisions changed the definition of the credit and the marginal credit rates firms faced. These changes are detailed below.

## 2.3 The R&D Tax Credit

In addition to direct federal support for R&D, such as research performed by federal agencies and grants for basic and applied research, the federal government provides indirect support for privately sponsored research through the tax code. Federal tax law offers two incentives for private R&D: a deduction for qualified research spending under Section 174 of the Internal Revenue Code (IRC), and a non-refundable tax credit for qualified research spending above a base amount under IRC Section 41. These two tax advantages reduce the after-tax price of R&D investment; they are jointly referred to here as the "R&D tax credit" and their combined effect on the after-tax price of and impact on R&D spending is assessed.[5]

The Section 41 credit, known legislatively as the Research and Experimentation Tax Credit, was introduced as part of the Economic Recovery Tax Act of 1981, allowing firms to earn a tax credit on spending they were already able to expense under the existing Section 174 expensing provision. The credit is available for qualified research expenditures, which were defined as salaries and wages, certain property and equipment rental costs and intermediate materials expenses incurred in research

[5]Net Operating Loss (NOL) carry-forwards resulting from Section 174 expensing can be carried forward up to 20 years—five years longer than Section 41 tax credits can be carried forward. Although this discrepancy in carry forward life has real implications for some firms, this level of detail is beyond the descriptive capability of the Compustat and IRS data used here and is ignored.

undertaken to discover knowledge that is technological in nature for a new or improved business purpose. The tax credit was initially effective beginning July 1, 1981 and ending December 31, 1985.

In its original form the incremental tax credit was equal to 25 percent of qualified research expenditures (QREs) above a firm-specific base amount. A firm's base was its average nominal qualified spending on R&D in the previous three years, or 50 percent of current spending, whichever was greater. For the first nine years of the R&D tax credit the firm's base was defined as:

$$B_{it} = \text{Base for R\&D Credit} = max\left[\frac{1}{3}\left(R_{it-1} + R_{it-2} + R_{it-3}\right), 0.5R_{it}\right] \text{ for } t\text{=1981-1989} \tag{2.7}$$

where $R_{it}$ is R&D spending by firm $i$ in year $t$.

Because a firm's base was a moving average of its past spending, additional research spending in the current year increased the firm's base by one-third of the increase in each of the subsequent three years. This 'claw-back' muted the credit's incentive effects; some firms were even left with negative marginal credit rates.

The marginal credit rate between 1981 and 1988 is:

$$c_{it} = \begin{cases} 0 & \text{if } R_{it+m} < B_{it+m} \text{ for } m = 0\text{–}3 \\ -s_t\left\{\frac{1}{3}\sum\limits_{m=1}^{3}(1+r_t)^{-(m+k_{it})}\right\} & \text{if } R_{it} < B_{it} \text{ and } B_{it+m} < R_{it+m} \\ & \text{and } R_{it+m} < 2B_{it+m} \text{ for any } m = 1\text{–}3 \\ s_t\left\{(1+r_t)^{-j_{it}} - \frac{1}{3}\sum\limits_{m=1}^{3}(1+r_t)^{-(m+k_{it})}\right\} & \text{if } B_{it+m} < R_{it+m} < 2B_{it+m} \\ & \text{for any } m = 0\text{–}3 \\ s_t\left\{\frac{1}{2}(1+r_t)^{-j_{it}} - \frac{1}{3}\sum\limits_{m=1}^{3}(1+r_t)^{-(m+k_{it})}\right\} & \text{if } R_{it} > 2B_{it} \text{ and } B_{it+m} < R_{it+m} \\ & \text{and } R_{it+m} < 2B_{it+m} \text{ for any } m = 1\text{–}3 \end{cases}$$

where $s_t$ is the statutory credit rate, $k_{it}$ is the number of years until any tax losses are exhausted, $j_{it}$ is the number of years the credit must be carried forward (it will be negative if it can be carried back), and $r_t$ is the real interest rate. The negative summation term in the above equation represents the claw-back provision.

In the credit's original incarnation, a firm's marginal credit rate was highest when its current year R&D spending, $R_{it}$, exceeds its current base amount, $B_{it}$, but is anticipated to not exceed its base in the following three years. Spending less than its base amount, the firm would not be eligible for credits in the next three years and thus not subject to the claw-back provision. In this case, if it has sufficient tax liabilities to fully offset its R&D tax credit, the firm's marginal credit rate is the statutory credit rate, $s_{it}$, or half the statutory credit rate if its current year spending exceeds twice its base. In terms of the preceding equation, if the firm is eligible for the full statutory rate, its current spending would exceed its base but be less than twice its base, and sufficient tax liabilities would mean $j_{it}$ is zero. If the firm expected its spending in the subsequent three years to be below its base amounts, the second summation term would be zero. From 3.5 to 9.5 percent of firms (5 to 16 percent of firms earning a credit) between 1981 and 1990 had marginal credit rates equal to the statutory rate, depending on the year.

Because a firm's base can never be less than half of current expenditures, when R&D spending exceeds twice its historically defined base, the redefined base is increased 50 cents for every additional dollar of R&D spending. When this is the case, the first additive term of the preceding equation is halved, and the maximum marginal credit rate is reduced from 25 percent to 12.5 percent.

A firm that claimed the tax credit but had insufficient current-year tax liabilities to offset was allowed to carry the excess credit back up to three tax years and/or forward up to 15 tax years; carrying back (forward) the credit increases (decreases) the present value of the R&D credit. In other words, jit can range from -3 to 15.

The Tax Reform Act of 1986 extended the credit through 1988, but also reduced the statutory credit rate from 25 to 20 percent.[6] This rate reduction was not mo-

[6]TRA86 also folded the tax credit into the General Business Credit under IRC Section 38, subjecting the credit to a yearly cap. The tax credit was also expanded to include research contracted to universities and certain other nonprofits. The definition of QREs was also changed so that it applied to research aimed at producing new technical knowledge deemed useful in the commercial development of new products and processes. These changes in the definition of QRE are beyond the

tivated by any careful assessment of the tax credit, but was instead part of one of the primary goals of TRA86—reducing the differences in tax burdens among major business asset categories (CRS 2007). The tax credit was extended through 1989 by the Technical and Miscellaneous Revenue Act of 1988, which also reduced the total tax preference for R&D by requiring firms to reduce the tax credit they claim by half the value of any deductions they claim under Section 174.[7] This partial recapture of the credit effectively cut a firm's marginal credit rate from 20 percent to 16.6 percent if its R&D spending exceeded its base by less than 100 percent, and from10 to 8.3 percent if its R&D spending exceeded its base by more than 100 percent. The marginal credit rate in 1989 is:

$$c_{it} = \begin{cases} 0 & \text{if } R_{it+m} < B_{it+m} \\ & \text{for } m = \text{0-3} \\ -s_t\left(1-\frac{1}{2}\tau_{it}\right)\frac{1}{3}\sum\limits_{m=1}^{3}(1+r_t)^{-(m+k_{it})} & \text{if } R_{it} < B_{it} \text{ and } B_{it+m} \leq R_{it+m} \\ & \text{and } R_{it+m} < 2B_{it+m} \text{ for any } m = \text{1-3} \\ s_t\left(1-\frac{1}{2}\tau_{it}\right)\left\{(1+r_t)^{-j_{it}} - \frac{1}{3}\sum\limits_{m=1}^{3}(1+r_t)^{-(m+k_{it})}\right\} & \text{if } B_{it+m} \leq R_{it+m} < 2B_{it+m} \\ & \text{for any } m = \text{0-3} \\ s_t\left(1-\frac{1}{2}\tau_{it}\right)\left\{\frac{1}{2}(1+r_t)^{-j_{it}} - \frac{1}{3}\sum\limits_{m=1}^{3}(1+r_t)^{-(m+k_{it})}\right\} & \text{if } R_{it} \geq 2B_{it} \text{ and } B_{it+m} \leq R_{it+m} \\ & \text{and } R_{it+m} < 2B_{it+m} \text{ for any } m = \text{0-3} \end{cases}$$

where $\tau_{it}$ is the marginal tax rate, $s_t$ is the statutory credit rate, $k_{it}$ is the number of years until any tax losses are exhausted, $j_{it}$ is the number of years the credit must be carried forward (it will be negative if it can be carried back), and $r_t$ is the real interest rate. The additional corporate tax rate term, $\left(1-\frac{1}{2}\tau_{it}\right)$, in the marginal credit formula for 1989 reflects the recapture of half of the deduction. In 1989 the

capability of the data, including the IRS data, used here as research expenditures are only reported in terms of contemporaneous definitions.

[7]Firms could alternatively reduce the depreciation basis of their R&D expenses by the value of the credit; this was less tax advantageous since losses have longer carry-forward periods than credits. Firms are assumed to have reduced the value of their credit rather than the value of their deduction.

credit was revamped. The claw-back provision created dynamic disincentives for current R&D spending, leading to negative marginal credit rates for some firms and lower than statutory rates for many others. Addressing this concern, the Omnibus Budget Reconciliation Act of 1989 altered the base formula, replacing the moving average with a base unrelated to recent R&D spending. The new formula for the base was the greater of 50 percent of current qualified spending, and the product of the firm's average gross receipts in the previous four tax years and the firm's "fixed-base percentage," a measure of historic research intensity. The firm's fixed base percentage is its ratio of total qualified R&D expenditures to total gross receipts between 1984 and 1988, subject to a 16 percent ceiling. The base formula from 1990 on is:

$$B_{it} = max\left[\frac{1}{4}\sum_{m=1}^{4} G_{it-m}\min\left(\left(\sum_{n=1984}^{1988} R_{in}/\sum_{n=1984}^{1988} G_{in}\right), 0.16\right), \frac{1}{2}R_{it}\right] \tag{2.8}$$

where $G_{it}$ is gross receipts or sales and $R_{it}$ is the R&D expenditures of firm $i$ in year $t$. As the base definition changed, the tax credit subsidy on the marginal dollar of R&D spending changed as well. Beginning in 1990 the marginal credit rate is:

$$c_{it} = \begin{cases} 0 & \text{if } R_{it} < B_{it} \\ s_t\left(1-\tau_{it}\right)\left(1+r_t\right)^{-j_{it}} & \text{if } B_{it} < R_{it} < 2B_{it} \\ \frac{1}{2}s_t\left(1-\tau_{it}\right)\left(1+r_t\right)^{-j_{it}} & \text{if } R_{it} > 2B_{it} \end{cases}$$

where again, $s_{it}$ is the statutory R&D credit rate in year $t$, $r_t$ is the interest rate, $\tau_{it}$ is the firm's marginal corporate tax rate, and $j_{it}$ is the number of years of tax losses.

Start-ups, firms lacking gross receipts or QREs for three of the five years between 1984 and 1988, were assigned a three percent fixed-base percentage. OBRA89 extended the credit through 1990 and required firms to reduce their Section 174 deduction by the entire amount of research credits claimed. The Omnibus Budget Reconciliation Act of 1990 and Tax Extension Act of 1991 extended the research credit through 1991 and 1992 respectively. Pay-as-you-go rules adopted as part of

OBRA90 were a major obstacle to more lasting extension (CRS 2007). From its inception until 1992 the credit was always extended before it expired. The first of several retroactive extensions occurred in 1993 after the credit was allowed to lapse in 1992. Even the retroactive extension covered only the last two quarters of 1992. Because this and other lapses likely affected firm expectations, the analysis here is limited to just the first 11 years of the R&D tax credit. Table 2.1 provides a summary of the legislative history of the R&D tax credit.

If corporate tax rates are expected at the time of R&D investment to remain constant in the future, they have no impact on R&D spending decisions—firms expect to expense their investments and pay taxes on the income from those investments at the same rate. The 1980s, however, were a time of changing corporate tax rates. The value of the Section 174 expensing provision was reduced by the Tax Reform Act of 1986; as the corporate tax rate was reduced to 40 percent in 1987 and to 34 percent in 1988, the benefit of expensing fell in parallel. If firms expected these reductions in the corporate tax rate, they would have invested in R&D with a higher cost of capital in mind. These corporate tax rate changes and their impact on the after-tax cost of R&D are assumed to have been expected by firms and are part of the analysis presented here. Taken together, changes in the expensing provision and tax credit significantly affected the user cost of R&D; their joint impact on the user cost of the marginal dollar of R&D spending is assessed below.

## 2.4 Data

The analysis presented here draws on two data sources, public data that has previously been used to assess the impact of the R&D tax credit and restricted-access IRS Statistics of Income (SOI) data that has not previously been used to estimate the user cost elasticity of the R&D credit. Each of these data sets has its advantages and disadvantages as does their combined use.

### 2.4.1 IRS Statistics of Income (SOI) Data

The IRS SOI data are drawn from a panel sample of corporate tax returns. The data for each firm-year observation comes from the firm's basic tax return, Form 1120. Data items relating to R&D spending are pulled from the firm's Form 6765, part of its Form 1120. The data report the firm's annual qualified R&D expenditures, base amount, tentative R&D tax credit, and limitations due to insufficient tax liabilities among other details. SOI data provide an accurate measure of the actual credit rates firms face each year on their marginal dollar of R&D spending. Only SOI data describe qualified spending with enough detail for this level of accuracy. But for all the detail and accuracy the SOI data afford, they have limitations as well. First, is the issue of censoring. A firm only reports the details of its research spending in those years when it applies for the R&D tax credit; in years where it will not earn a credit, it is unlikely to complete Form 6765. Thus in years when the firm does not apply for a credit, its qualified spending is not known (SOI data report missing values as zeros.) So as not to drop these observations, I assign firms that have previously claimed the R&D credit, but did not complete Form 6765 a zero marginal credit rate. Effectively, I assume that firms are not leaving potential R&D tax credits on the table. Only firms that have ever claimed the R&D tax credit, that is filed a form 6765 as part of its 1120 are included in the sample used in the analysis. This amounts to a sample of 3,500 and 6,500 firms per year; the exact count is reported in the tables. The qualified spending of these 'missing' firms remains unknown, however. It is treated as it appears in the data, as a zero, but this likely understate R&D spending; robustness checks that limit the sample to only those firms that complete Form 6765 each year and analysis that also makes use of public data provide checks for this treatment. Second, IRS data only report qualified research expenditures. Although these are exactly the type of expenditures that are needed to accurately calculate the marginal credit rate, we are not only interested in the impact of tax subsidies on these expenditures. If firms respond to larger tax subsidies by shifting their R&D spending from unqualified to qualified spending, we will interpret the impact of the R&D tax credit differently than if they are increasing total research spending by the same amount they are increasing qualified spending. IRS data do not provide any sense of how a firm's non-qualified spending responds to subsidies for qualified spending.

### 2.4.2 Compustat Data

Compustat data are drawn from firms' annual SEC (10-K) filings. The Compustat sample includes essentially all publicly traded firms that report the information required to compute their marginal R&D tax credit rates. There are roughly between 1,200 and 1,800 firms per year in the Compustat sample. These data have two key advantages. Compustat data are available for years prior to the introduction of the R&D credit in 1981. Financial statements provide a more comprehensive measure of R&D spending. Nonetheless, Compustat data have three major weaknesses.

First, because Compustat data describe only publicly traded firms, large firms are overrepresented in the sample. NSF surveys report that between 1981 and 1992 firms with at least 5,000 employees conducted more that 80 percent of all R&D, suggesting that data concerning large public firms will describe the lion's share of R&D dollars. Nonetheless, if private firms are more (or less) responsive to changes in the tax-price of R&D, estimates based on the Compustat data understate (or overstate) the effectiveness of the tax credit.

Second, the accounting rules that govern financial reporting differ from the Internal Revenue Code (IRC) in their definition of R&D. A firm's marginal credit rate is a function of its qualified R&D spending, not its total spending as reported in its financial statements. To qualify for the federal tax credit, R&D expenditures must meet a set of criteria relating to the experimental and technological nature of the project and the stage of the product development it aims to enhance. The R&D expenses reported in financial filings (referred to here as total R&D spending) conform to a broader definition that includes both R&D conducted abroad and domestic research expenditures that do not qualify for the R&D tax credit because they fail to meet the experimental and technological criteria.

If firms respond to changes in subsidies for qualified R&D by changing their qualified and non-qualified spending shares, constructing the tax component of the firm's user cost of R&D using only data describing total R&D spending will lead to a biased measure of the usercost. For example, if firms increase the qualified share of their spending when subsidies are high, the effective credit rate could be understated if this disproportionate increase in qualified spending lifts the firm's spending above its base or the effective credit rate could be overstated if the increase in qualified spending leaves the firm above twice its base level. Because a firm's credit rate is determined by its relative QREs, changes in the composition of spending can affect credit rates.

Using the broader measure of R&D will result in non-classical mis-measurement of the tax-price, which is a function of qualified R&D spending. Only SOI data can overcome this measurement issue. Similarly, because financial data do not describe unused previously earned tax credits, the present value of currently earned R&D tax credits may be overstated; overstating the value of the credit understates the price of R&D, potentially under-estimating the magnitude of the tax-price elasticity.[8]

Third, firms only report R&D expenditures in their financial statements if these expenditures are "material" by accounting standards. The data are therefore censored with a firm-specific threshold. To assess the influence of materiality censoring, robustness checks report the results of a specification limited to only those firms with data in all years and a specification employing a control function to correct for selection.

Combining IRS and Compustat data overcomes many of the weaknesses of the individual datasets. Measuring the impact of the accurately measured after-tax user cost (from SI data) on total (from Compustat data) R&D spending can gauge whether any responsiveness of qualified spending is due primarily to shifting. Furthermore, research spending is likely to be reported in Compustat even in years when the firm does not complete its Form 6765 because it fails to earn a credit. Materiality remains an issue, however. The main disadvantage of the merged sample is size. Because the

[8]This lack of information on other tax credits is even more important after 1986 when the R&D tax credit was folded into the General Business Credit (GBC). The GBC not only caps the total amount of credits that can be used in any year but also prescribes the order in which they must be used. A firm that has a lot of higher priority credits would value currently earned R&D credits less.

IRS data sample describes private and public firms, only a fraction are public firms and a smaller fraction still ever apply for the R&D tax credit and have sufficient data to compute their marginal credit rates. Thus the merged sample consists of fewer than one thousand firm-year observations.

### 2.4.3 Measuring R&D Expenditures

Using Compustat data to determine whether a firm's current year spending qualifies it for an R&D tax credit and if it is subject to the 50 percent of current year spending limitation (i.e. whether current year qualified spending exceeds the firm's base or twice its base) incorrectly assesses the firm's credit status for 44 percent of the 755 firm-year observations that appear in both the Compustat data, drawn from financial statements, and the IRS data. For the average firm over the whole period, qualified research was 38 percent of total research. Among firms with positive QREs, the average firm spent 68 percent of its total research expenses on qualified research, but weighting by QRE the average falls to 56 percent, meaning that qualified spending represented a smaller a share of total spending for firms with high QREs. Table 2.2 illustrates the heterogeneity in the ratio of QREs to total R&D as reported in financial statements for the subset of firms that appear in both data sets and have sufficient data to be included in later regression analysis.[9] For five of the sample's eleven years more than half of the firms reported no QREs but did report R&D expenditures in their financial statements; most of these years follow the 1986 absorption of the R&D credit into the General Business Credit (GBC). Qualified research ranged between 40 and 80 percent of total research for the lion's share of the sample that reported non-zero QREs. For a non-trivial share of the sample, on average 12 percent, qualified spending represented more than 90 percent of its total spending.

The distribution of qualified spending shares varies over time, including between years when the parameters of the R&D credit changed. In 1986 when the R&D credit

[9] The accounting definition of R&D includes all the categories that comprise IRS QREs but is less strict in terms of the experimental and technological nature of these expenditures. For example, expenses related to testing and the modification of alternative products is classified as R&D for accounting purposes but generally do not qualify for the R&D tax credit.

was folded into the GBC the share of firms reporting no QREs but still reporting research expenses for financial purposes rose by more than 11 percentage points while the share of firms for which qualified research represented between 20 and 80 percent fell by more than 12 percentage points. Again in 1990 when the credit was revamped and base amounts were redefined, the distribution changed markedly. The fraction of firms reporting no QREs fell by more than ten percentage points, mostly accruing to the 20 to 40 percent and 60 to 80 percent categories. The distribution varied in other years as well, some when other policy changes occurred such as 1985, but also between years when the credit's structure remained unchanged such as between 1983 and 1984. Although Table 2.2 only describes the evolution of the distribution of qualified spending shares for a limited sample of firm that report R&D spending in both data sets, it makes clear that the ratio of qualified to total R&D spending varied considerably from year to year. This type of variation makes clear that using Compustat data describing total R&D expenditures to construct marginal credit rates will often lead to incorrect measures of the marginal tax subsidy for R&D investment.

### 2.4.4 Computing the User Cost

Each firm's marginal credit rate is computed according to the prevailing structure of the R&D tax credit and its tax position as described above in marginal credit rate equations above. Credit rates are computed both using Compustat data and IRS data; as explained above, credit rates constructed from Compustat data are likely to be inaccurate but are widely used in previous studies that rely on publicly available data. Further details of the formulas' components can be found in the appendix.

Table 2.3 reports the average percentage reduction in R&D user costs due to tax preferences, the share of firms eligible for an R&D tax credit and the fraction with negative marginal credit rates. Because actual receipt of a credit is not observed in public financial data, a firm is considered eligible for an R&D credit if its R&D spending exceeds its base; firms not receiving a credit are firms who report enough information to calculate their marginal credit rates, but whose R&D expenditures do not exceed their base amounts. In the SOI panel data a firm is considered eligible for an R&D tax credit if it claims a positive tentative R&D tax credit on form 6765 of its corporate return.[10] Changes in tax policy and changes in R&D spending both drive changes in the tax-adjustment term of the user cost of R&D, making it difficult to infer the impact of policy changes from observed user costs. When only the expensing allowance was in place, tax factors did not affect the user cost of a firm that had sufficient tax liabilities in the year it expensed its R&D spending; changing tax rates did affect the user costs of firm who carried forward their losses. The introduction of the R&D credit in 1981 reduced the average tax-adjustment term from near unity to 0.914 according to IRS SOI corporate return data as shown in Table 2.3.

The average tax-adjustment term according to the Compustat data, which only reports total R&D spending, was 0.884 in 1981, three percentage points less than the average in the IRS sample. This is largely because the IRS sample contains a larger fraction of firms that face negative marginal credit rates, 24.1 versus 14.9 percent, which reduces the average subsidy level. These negative rates are driven by firms that fail to earn a credit in 1981 but face higher bases in subsequent years when they do qualify for a credit; in the Compustat data 65.7 percent of firms earned a credit in 1981, but according to the IRS sample only 52.1 percent for firms earned a credit. The two samples are comprised of largely different firms and dissimilarities in the averages in Table 2.3 reflect both the inaccuracy of calculations based on the Compustat data and differences in the composition of the samples. Between 1982 and 1984 the Compustat data suggest a higher average user cost than the IRS data with differences between three and six percentage points; in part this is driven by a much larger share of negative credit rate firms in the Compustat sample during these years.

[10]A firm's tentative tax credit is the product of the statutory credit rate (including any decrease in the rate due to expensing after 1989) and the excess of its qualified research spending over its base amount, subject to the 50 percent of current research spending limit. It is the IRS analogue to the definition of eligibility I use in the Compustat data. The actual credit a firm realizes in a given tax year also includes any R&D credits carried back or forward and any flow-through credits from partnerships, subchapter S corps, estates or trusts, and is limited by its current year pre-credit tax liability. The order in which credits are applied in calculating the firm's pre-R&D tax credit tax liability varied slightly from year to year, but in general the R&D credit was a more senior credit. Eligibility was measured using tentative rather than total allowable R&D credit for comparability reasons and because total allowable credit data is not available for all years, particularly after the R&D tax credit was folded into the GBC.

Average user costs converge beginning in 1985 and continue to track through 1988. For the last three years of the sample average user costs are four to five percentage points higher in IRS sample than the Compustat sample.

Examining the variation in average tax-adjustment factors over time in the IRS sample provides a sense of how the tax subsidy affected true user costs. The five percentage point reduction in the statutory R&D credit rate in 1986 coincided with a rise in the tax-adjustment term from 0.906 in 1985 to 0.94 in 1986 and finally to 0.947 in 1987 the first year the rate reduction was in place for a full year; the nearly nine percentage point drop in the share of firms eligible for the R&D credit over the two-year period, however, suggests other forces were also at play. Other factors countervailed the impact of partial credit recapturing in 1989, leading to only a small increase in the tax-adjustment term of the user cost. The 1990 reformulation of the R&D credit, which eliminated the claw-back provision and complete credit recapture, barely affected average tax subsidy or the credit recipiency rate.

Although the Compustat tabulations show a nearly twelve percentage point decline in the fraction of firms qualifying for a credit—a pattern consistent with the findings of Gupta, Hwang and Schmidt (2004)—this decline in 1990 is not apparent in the more accurate IRS data. Between five and ten percent of firms were subject to negative credit rates between 1982 and 1990 when the claw-back provision was eliminated; their average marginal credit rate was roughly -8 percent. Firms in several situations could face negative marginal credit rates. For example, assuming tax liabilities in all years and a three percent real interest rate, a firm whose spending this year exceeds twice its base but for the next three years lies between 100 to 200 percent of its base would have faced a marginal credit rate of -11.1 percent under the 1982 to 1985 regime, -8.9 percent under the1986 to 1988 regime and -7.4 percent in 1989. The unusually high fraction of firms that had negative credit rates in 1981, nearly a quarter of firms were tax disadvantaged by marginal R&D spending, may be due by delays in increasing research spending in reaction to the credit's introduction. Firms may not have been able increase their spending enough to qualify for a credit in 1981 but every dollar they did spend increased base amounts in subsequent years, leading to negative marginal credit rates. The 1990 reformulation improved incentives for marginal R&D investment for a substantial fraction of firms.

The averages presented in Table 2.3 belie substantial heterogeneity in the impact of tax preferences on firm user costs. Using confidential IRS data Altshuler (1988) also found substantial heterogeneity in the effective R&D tax credit rates firms faced depending on their near-term R&D spending pattern and tax status. Table 2.4 provides more detail regarding the dispersion of tax-adjustment factors each year according to the IRS data. In 1980, prior to the introduction of the R&D credit, in the Compustat sample tax policy had no impact on R&D user costs for more than 80 percent of firms; tax loss carry-forwards decreased the present discounted value of the Section 174 deduction and increased R&D user costs for the remaining firms. Once the R&D tax credit was adopted in 1981, in the IRS sample few firms—roughly five percent—had user cost tax-adjustment factors of one since even firms ineligible for a credit in the current year were increasing their bases for the following three years with every additional dollar they spent on R&D. Between 1981 and 1989, 53.2 percent of firms on average had tax-adjustment factors that ranged between 0.95 and 1.25. Average tax-adjustment factors were above 0.75 and below 1.25 for nearly 89 percent of firms over the same period. A substantial fraction of firms, however, experienced much higher and much lower user costs due to tax factors prior to the 1990 reform. Some firms, as many 11.1 percent of firms in 1981, experienced marginal credit rates so negative as to push their tax-adjustment factors above 1.25; for eight firms between 1981 and 1985 tax factors increased their user costs by more than 150 percent. During the same period, up to 18.8 percent of firms had marginal R&D tax credit rates so high that tax preferences reduced their user cost by 25 percent or more. After the 1990 reform, no firm was subject to a negative marginal credit rates, depopulating the right tail of the tax-adjustment factor distribution. Some firms, as many or even more than before, continued to have tax-adjustment factors that modestly exceeded unity after the 1990 base redefinition—firms with zero (99.2 percent) or low marginal credit rates (0.8 percent) and at least one year of tax losses—the mean tax-adjustment factor of these firms was 1.033. Starting in 1990, all firms in the sample had tax factors between 0.75 and 1.25 as fewer firms had tax factors in the tails of the distribution; firms were more concentrated between 0.75 and unity than in the preceding half-decade. In effect the 1990 reformulation eliminated both very high and very low tax-adjustment factors, but largely left the fraction of firms receiving a credit and average tax subsidy rates unchanged.

## 2.5 Empirical Model

Applying the arbitrage condition described in equation 2.4 to the CES production function yields the factor demand equation: $S_{it} = \theta_i^{\sigma} Y_{it} \rho_{it}^{-\sigma}$. The user cost, as laid out in Section 2.1, is a function of the firm's current R&D spending, the relationship between the firm's spending and its base this year and for as long as the next three years, its loss position, and the corporate tax rate. Again, the Hall-Jorgenson tax-adjusted user cost of R&D capital per dollar of investment is:

$$\rho_{it} = \frac{\left(r_t + \delta - \pi_t^S\right) p_t^S \left(1 - \tau_{it+k_{it}} \left(1 + r_t\right)^{-k_{it}} - c_{it} \left(1 + r_t\right)^{-j_{it}}\right)}{\left(1 - \tau_{it+k_{it}} \left(1 + r_t\right)^{-k_{it}}\right)} \tag{2.9}$$

where $r_t$ is the interest rate, $\delta$ is the depreciation rate, $\pi_t^S$ is the one-year growth rate in the prices of R&D inputs, $P_t^S$ is the price of R&D inputs, $\tau_{it}$ is the marginal corporate tax rate, $j_{it}$ is the number of years the credit must be carried forward (it will be negative if it can be carried back), $k_{it}$ is the number of years until any tax losses are exhausted and $c_{it}$ is the marginal R&D credit rate. The log linear form of the factor demand equation forms the empirical foundation of most previous empirical analyses of the cost elasticity of R&D and is the initial basis of the analysis presented here. Differencing the log linear equation to purge any unobserved firm heterogeneity yields the following regression equation:

$$\log\left(\frac{S_{it}}{S_{it-1}}\right) = \sigma \log\left(\frac{\rho_{it}}{\rho_{it-1}}\right) + \eta \log\left(\frac{Y_{it}}{Y_{it-1}}\right) + \epsilon_{it} \tag{2.10}$$

In the absence of adjustment costs, the optimal stock of R&D capital will be attained each period in accordance to any changes in the tax or non-tax terms of the user cost. I assume that the flow of R&D services in a year is proportional to R&D investment. Under these assumptions, the change in the R&D capital stock will be captured by the change in R&D investment. Equation 2.10 can be written instead in terms of the log-difference in R&D investment:

$$\log\left(\frac{R_{it}}{R_{it-1}}\right) = \sigma \log\left(\frac{\rho_{it}}{\rho_{it-1}}\right) + \eta \log\left(\frac{Y_{it}}{Y_{it-1}}\right) + \epsilon_{it} \tag{2.11}$$

Aggregate macroeconomic factors such as technology opportunities, changes in U.S. patent policy and IRS regulations, and aggregate demand will affect firm R&D decisions. Year fixed effects are added to the model to absorb these potentially confounding factors. I assume that the non-tax components of the cost of capital, $\left[r_t + \delta\pi_t^S\right] p_S^t$, together vary over time but not across firms and time. Since $\rho_{it}$ enters the regression in log form, under my assumptions, $\left[r_t + \delta\pi_t^S\right] p_S^t$ is fully absorbed by the year fixed effects, leaving just the tax factor:

$$\lambda_{it} = \frac{\left(1 - \tau_{it+k_{it}}\left(1+r_t\right)^{-k_{it}} - c_{it}\left(1+r_t\right)^{-j_{it}}\right)}{\left(1 - \tau_{it}\left(1+r_t\right)^{-k_{it}}\right)} \tag{2.12}$$

to vary across firms and over time. The regression equation becomes:

$$\log\left(\frac{R_{it}}{R_{it-1}}\right) = \sigma \log\left(\frac{\lambda_{it}}{\lambda_{it-1}}\right) + \eta \log\left(\frac{Y_{it}}{Y_{it-1}}\right) + \chi_t + \epsilon_{it} \tag{2.13}$$

As was explained in Section 2.2, a firm's R&D tax credit rate is a non-monotonic function of its R&D spending. A firm whose spending is less than its base receives a zero credit and has a zero marginal credit rate; a firm whose spending exceeds its base, but is less than twice its base receives a credit equal to the product of the effective statutory rate and its spending above its base and has a marginal credit rate equal to the effective statutory rate; a firm whose spending exceeds twice its base receives a credit equal to the product of the effective statutory rate and its spending above its base and has a marginal credit rate equal to one-half of the effective statutory rate.

A firm's marginal R&D credit rate and it R&D spending level are clearly jointly determined; the term capturing the tax-price change, $\log(\lambda_{it}/\lambda_{it-1})$, is correlated with $\epsilon_{it}$. For example, if there is a positive shock to R&D spending ($\epsilon_{it} > 0$) then, due to the structure of R&D tax credit, the marginal credit rate could mechanically increase if the firm was otherwise below its base or decrease if the firm was otherwise above its base. An OLS regression of equation 2.13 would therefore lead to a biased estimate of the behavioral elasticity.

To disentangle this endogeneity I rely on an instrumental variables strategy similar to those Auten and Carroll (1999) and Gruber and Saez (2002) use in studying individual taxpayer decisions. The strategy to build instruments for the user cost variable, $\log(\lambda_{it}/\lambda_{it-1})$, is to compute $\lambda_{it}^{S}$, the marginal tax-price the firm would face in year $t$ if its real R&D spending did not change from the previous year. The natural instrument for the actual change in the tax factor of the after-tax user cost, $\log(\lambda_{it}/\lambda_{it-1})$ is the difference in the logarithms of the firm's "synthetic" tax factor under current law and their actual lag tax price, $\log\left(\lambda_{it}^{S}/\lambda_{it-1}\right)$. The instrument by construction eliminates the effect of R&D spending changes on the change in tax price so that the synthetic change in tax price only reflects the exogenous changes in the provisions of the R&D tax credit. It is the exogenous changes in the effective tax price of R&D spending due to changes in the corporate tax code and provisions of the R&D credit that are the source of identification of the behavioral response. Firm fixed-effects purge firm-specific correlation in the evolution of R&D spending while time fixed effects purge changes in R&D spending common across all firms. The resulting residual variation in the tax-price that identifies the estimated elasticity arises from within-firm changes in the tax-price of R&D relative to the changes experienced by the average firm. In other words, the identifying variation measures how a firms tax subsidy compares with its own average subsidy across time and the average subsidy of other firms within a given year.

Only observations from years where a tax policy change went into effect are used in the analysis.[11] The key exclusion restriction is that the constructed synthetic tax

[11]The years used are 1982, 1986, 1987, 1988, 1989 and 1990. For a summary of the changes made

factor does not affect R&D spending other than through the actual tax factor, conditional on firm and year fixed effects and sales. In later regressions, as explained in section 2.5, a polynomial in lagged R&D spending is added as a control to account for reasons other than the tax price why firms in different parts of the R&D spending distribution might experience different patterns of R&D growth. These added controls tighten the exclusion restriction; the identifying assumption now only assumes that the R&D spending distribution is not evolving on its own in a way that is correlated with the year-specific changes in the tax treatment of R&D. Given the strong nonlinearities of the firm-specific credit function, this assumption seems innocuous.

Table 2.5 presents a comparison of average actual and synthetic tax-adjustment factors by year; the actual tax-adjustment factor averages differ from those in Table 2.2 because the sample of firms is constrained to those that report sufficient data to also construct the synthetic factor, namely the first lag of R&D spending. Between 1985 and 1986, when the statutory credit rate fell from 25 to 20 percent, the actual tax-adjustment term increased by 3.8 and 4.5 percentage points in the Compustat and SOI data respectively while the synthetic tax-adjustment term increased similarly in the SOI data but by more than 15 percentage points in the less accurate Compustat data. Comparing 1986 synthetic tax factors to 1985 actual tax factors, which are both a function of 1985 R&D spending, shows that in the IRS data tax changes led to a decrease in average user costs while the Compustat data point to a marked nearly 10 percentage point increase, further highlighting the difficulty of using Compustat data.[12] In the Compustat data average actual tax factors fell by 1 percentage point with the introduction of recapturing in 1989 but barely moved in the IRS data; in both datasets synthetic factors increased by roughly 1.5 percentage points. The 1990 base redefinition reduced user costs as is made clear by the 2.4 and 5.4 percentage point differences between 1989 actual and 1990 synthetic tax factors in the Compustat and SOI data, respectively. Actual tax factors fell by less or increased slightly in the

to the R&D tax credit in these years, please see Section 2.1 or Table 2.1. Data from 1982 are used in lieu of data from 1981 because the 1982 was the first full year the credit was in effect.

[12]In the much smaller sample of observations found in both the Compustat and SOI data the pattern of a decrease between 1985 actual and 1986 synthetic in IRS data and an increase in Compustat data also holds.

case of the SOI data, signaling that firms also changed their R&D spending such that their marginal credit rates decreased.

## 2.6 Results

### 2.6.1 Compustat Data from Financial Filings

The framework of the analysis presented here is similar to earlier studies, including Hall (1994). As a baseline, my best effort to replicate the relevant Hall results and reconcile them with my own estimates is presented in Table 2.7. Hall used instrumental variables for several reasons: first, the simultaneity of her regressors with the firm's future R&D expenditure path; second, measurement error in the tax price due to the inaccuracy of using financial data to calculate tax prices; third, measurement error due differences between the tax price as forecasted by the firm when making its spending decisions and observed by the econometrician. To address these issues she instruments for all right hand side variables with the regressors lagged two and three times as well as with lagged tax status and lagged growth rates in R&D and sales. Column 1 of Table 2.7 reports the results of my attempt to replicate the results in column 4 of Table 2.6 in Hall (1994), which corresponds to the first-differenced log-log specification.

Column 2 instruments with lagged right-hand side variables and uses data from the entire decade after 1981 but includes non-manufacturing firms; the addition of these firms does not significantly affect the estimated tax-price elasticity. Years where the parameters of the R&D tax credit remained unchanged are dropped in column 3's specification as my instrumenting strategy relies on tax changes. Again limiting the sample to 1982 and 1986-1990 does not dramatically affect the estimated elasticity. Column 4 uses the synthetic tax-price instruments, which are described in detail in Section 2.2. These instruments, which are more plausibly exogenous than the instruments used in columns 1-3, reduce the tax-price elasticity estimate by nearly fifty percent. Because the change in sales, which is included as a control in equation

2.13 could conceivably be endogenous, column 5 reports the results from a model that does not include contemporaneous or lagged sales as a regressor. Dropping the log-change in sales has no impact on the estimate.

The IV regression of equation 2.13 might itself be biased if $\epsilon_{it}$ and $R_{it-1}$ are correlated. Mean reversion, for example, would lead to a negative correlation between the error term and R&D spending the previous year. If $\epsilon_{it}$ and $R_{it-1}$ are correlated then the instrument will be also be correlated with the error term since the instrument is constructed using spending last period. Like Auten and Carroll (1999), and Gruber and Saez (2002) last period spending, $\log R_{it-1}$, is added as a control. Because changes in the R&D tax credit may affect any relationship between current and last period spending, these controls are allowed to vary by year as a robustness check (see column 2 of Table 2.8). Of course including a control for the lag dependent variable in a differenced model leads to a biased estimator in finite samples. I instrument for lag spending as suggested by Hausman, Hahn and Kuersteiner (2001) using further lags. The results of this regression are reported in column 6 of Table 2.7. Again the inclusion of these further controls does not change the estimated elasticity.

To investigate the sensitivity of the relationship between R&D spending and its user-cost to alternative specifications a series of robustness checks were conducted; the results are presented in Table 2.8. The baseline specification from column 6 of Table 2.7, which instruments for the endogenous tax-price with the synthetic tax-adjustment factor and includes controls for the logs of lag R&D spending and lag sales, is reported in column 1 to facilitate comparisons. As described above, because changes in tax policy may affect the underlying relationship between current and lag R&D spending, for example if more generous tax treatment leads to the undertaking of new projects that require many years of funding, column 2 interacts the lag spending terms with year fixed effects. Allowing the effect of $\log R_{it-1}$, to vary from year to year has virtually no impact on the user-cost elasticity estimate. Columns 3 and 4 control for industry specific factors. Neither industry fixed effects, column 3, nor linear industry time trends, column 4, appreciably impact the elasticity estimate. Because only firms with material R&D expenditures must report their R&D expenditures in financial filings, the data are censored by a firm-specific threshold. Column 5 reports estimates from a specification that includes a control function to correct for selection; identification is from functional form. Correcting for selection reduces the magnitude of the point estimate by a statistically insignificant 1.2 percentage points. Column 6 assess the impact of selective reporting by limiting the sample to only those firms that report R&D spending in all years. The estimated elasticity is roughly 1.7 percentage points larger, but again the difference is statistically insignificant. Firms end their fiscal years in all months of the year; tax policy is largely tied to the calendar year. Tax-price variables are likely to be mis-measured for firms whose fiscal years do not coincide with the calendar year. To assess the impact of this mis-measurement the model is estimated using only firms with December fiscal year ends. As column 7 reports, the point estimate is statistically indistinguishable from the baseline estimate.

The log-log specification includes only observations with non-zero R&D expenditures. In the Compustat data this does not necessitate dropping many firms, in fact only 40 firm-year observations have zero R&D expenses but report all other necessary data, including previous spending, to be included in a regression of the form of Column 4 of Table 2.6. In other words, if a firm ever reports R&D expenses in its SEC filings, it does so in every year and once it engages in material R&D it continues to do so. The log-log specification is less appropriate for analysis of the IRS data. Firms only report the specifics of their R&D spending and credit status in years they claim the credit; if a firm does not qualify for a R&D tax credit it likely does not file a form 6765 and it does not disclose the details of its research activities. The IRS data in short has many more zeros than the Compustat data. Though a firm that does not file a 6765 form likely has non-zero research expenditures, in the main analysis using only the IRS data these observations are treated as the appear in the data as zeros. The appropriateness of this treatment is assessed in later analysis that uses both Compustat and IRS data. To retain observations with zero spending but also scale for disparate firm size in the remaining analysis the dependent variable of regression equation 2.13 is replaced with the change in R&D spending divided by first lag of sales. Sales is a natural choice for the scaling variable since research-intensity, the ratio of R&D to Sales, has been an outcome of interest in previous research including (Griliches (1984)) and is used as a benchmark, the fixed base percentage, in the formula for the R&D credit as well.

The regressions reported in Tables 2.9-2.12 are of the basic form:

$$\left[\frac{R_{it} - R_{it-1}}{S_{it-1}}\right] = \alpha + \sigma\left[\lambda_{it} - \lambda_{it-1}\right] + \eta\left[\frac{S_{it} - S_{it-1}}{S_{it-1}}\right] + \gamma R_{it-1} + \chi_t + \epsilon_{it} \qquad (2.14)$$

Table 2.9 reports the results of regressions of the above form using only Compustat data. Column 1 reports the OLS results, which suggest that a ten percent decrease in the tax component of the user cost of R&D would increase the average firm's R&D-to-lagged-Sales ratio by 4.3 percent. Adding flexible time controls, as in column 2, does not affect the estimated coefficients. Because a firm's credit rate is a function of its R&D spending column 3 instruments for the firm's tax component to disentangle this simultaneity. As described earlier, the instrument is constructed using the first lag of R&D spending, which must be controlled for in the regression. Because the first lag of R&D spending is also a lagged dependent variable, it must also be instrumented for with other lags.[13] Instrumenting for both the endogenous tax component and the first lag of R&D expenditures shrinks the point estimate from -0.045 (0.01) to -0.035 (0.008), a statistically insignificant reduction in magnitude. The estimates reported in column 3 imply that a ten percent decrease in the user cost, or a 9.36 percent subsidy, would result in a 3.56 percent increase in the average firm's R&D intensity. In other words, if sales levels remained unchanged, the average firm's R&D expenditures would increase by roughly \$10.7 million. The estimates from column 4 of Table 2.8 suggest that a ten percent decrease in the usercost would result in a \$3.5 million increase in R&D spending; the specification differences lead to somewhat different answers. Estimating the specification of column 3 of Table 2.9 on the 6,339 observations from the sample of column 4 of Table 2.7 that have sufficient data, yields a coefficient of -0.036 (0.008)—almost identical to the estimates reported in column

[13]Here the third lag of R&D spending is used, but the results are invariant to instrumenting with other lags.

3 of Table 2.8.[14] It is not the difference in selection resulting from dropping the zero spending firms that drives the difference in elasticity estimates but the difference in specification. Different specifications clearly yield different estimates of the impact of tax subsidies on R&D spending. Though the estimates are robust within a class of specifications, as illustrated by Table 2.8 for the log-log specification, using R&D intensity as the outcome of interest triples the implied effect of a ten percent reduction in usercost.

### 2.6.2 IRS SOI Data

Table 2.10 reports the results of regressions of the basic form of equation 2.14 but uses only IRS data. While providing unbiased measures of the subsidies to qualified R&D spending, the IRS data does not describe total R&D spending by firms. The IRS data come from the research credit form, Form 6765, and describe only qualified research expenditures, in other words only the spending to which the credit applies. Though using IRS data alone cannot capture how tax subsidies affect total R&D spending, they can describe how subsidized R&D spending responds to its subsidy. OLS estimates reported in columns 1 and 2 of Table 2.10 suggest that a ten percent decrease in the user cost of R&D would result in approximately \$3.8 million in additional qualified research spending by the average firm. Instrumenting for the tax factor, however, halves the estimate, suggesting a ten percent reduction in user cost only increases average qualified research spending by \$2 million. The average firm in the sample reports roughly \$8 million in QREs; among firms with non-zero QREs average qualified spending is \$27.5 million. Although the coefficient estimates in Table 2.10 are similar in magnitude to those of Table 2.9, because qualified research expenditures (QREs) comprise less than forty percent of total R&D expenditures, the implied elasticities of Table 2.10 are much larger than those of Table 2.9.[15] The

[14]Estimating the specification of column 4 of Table 2.6 using just the 6,171 observations that have sufficient data for both specifications yields an elasticity of -0.461 (0.032), virtually identical to the estimate reported in column 4 of Table 2.6.

[15]Qualified R&D comprises 39 percent of total R&D for the subsample of 953 firms found in both data sets that report both measures of research expenditures.

fully instrumented specifications have standard errors too large to make precise comparisons, but the point estimates of the two tables suggest that qualified research spending is more elastic that total R&D. These comparisons should also be caveated by the fact that the regressions in Table 2.9 make use of an inaccurate measure of the tax component of the usercost.

IRS data report as many as five categories of QREs. Using the same regression specification as column 3 of Table 2.10, but replacing total QREs with each component of spending, the impact of tax subsidies on different types of qualified research spending is reported in Table 2.11. Qualified spending broken down by category was unavailable for 1990, so the number of observations reporting R&D spending on wages and salaries, supplies, equipment rental, and contracted research is only 14,394 rather than 18.691 as in column 3 of Table 2.10. Data regarding research payments to universities and other eligible nonprofit organizations for the conduct of basic research were not reliably available after 1986, hence only one year of data is included in the column 5 regression. Interestingly, changes in usercost only significantly impact wages and salaries and supplies, columns 1 and 2 respectively. Wages and salaries and supplies, comprising 66.6 and 19.2 percent of qualified R&D respectively, are the two largest categories of research spending. Although contracted research accounts for 11.6 percent of QREs, usercost does not appreciably affect contracted research spending as shown in column 4.

The elasticities reported in Tables 2.10 and 2.11 show that qualified research spending is responsive to tax-based subsidies. The magnitude of the elasticity is larger than that of total spending as measured in the Compustat data and reported in Table 2.9, suggesting that the portion of research that the credit is applied to is more measurably responsive than overall spending. It is notable that the same choice of instruments that reduced the elasticity estimated in the public data still yields a large elasticity estimate for qualified research. The different impacts of different choices of instruments, specifications and research spending measures make it difficult to draw strong comparative conclusions, but highlight the fact that estimates of the elasticity of R&D spending with respect to the tax-price are sensitive to these choices.

### 2.6.3 Merged Sample of Compustat and IRS SOI Data

By merging the Compustat and SOI samples the impact of tax subsidies on total and qualified R&D spending can accurately be assessed using a common sample as described in Section 2.3. Because the SOI data is a sample of firms that includes both public and private firms, and more important because only a fraction of firms report R&D spending in their financial filing or file for the R&D tax credit, only 953 observations can be matched between the two data sets. The instrumenting strategy I employ, which requires multiple lagged values of R&D spending as well as other data, further reduces the sample. Table 2.12 presents estimates from regressions identical to those of Table 2.11 but restricted to this merged sample. IRS data is used to construct the tax factor for all four columns of estimates. Columns 1 and 2 and describe the impact of changes in the tax factor on total R&D spending while columns 3 and 4 describe the impact on qualified spending. Interestingly, for both the OLS and IV specifications changes in user cost have no statistically discernible impact on total R&D spending, despite the relatively small standard errors. Estimating the specification of Column 3 of Table 2.9, which is identical to column 2 of Table 2.12 except the user cost measures are based on Compustat rather than the more accurate IRS data, on the sample of roughly 200 merged firm-years yields a coefficient estimate of -0.058 (0.028)—a statistically significant estimate similar to those of Table 2.7. This suggests that the mis-measurement of the tax subsidy in Table 2.8 may play a role in generating statistically significant estimates that are not apparent when the correct tax subsidy measure is used as in Table 2.12.

Columns 3 and 4 of Table 2.12 report estimates for the impact of changes in the user cost on qualified research expenditures. Again, much like Table 2.10, usercost decreases result in statistically significant increases in R&D spending according to both the OLS and IV specifications. The results reported in columns 2 and 4 suggest that when the correct measure of the tax-adjustment factor is used, only qualified research spending is significantly affected by tax subsidy for qualified spending. Total R&D expenditures include other forms of spending, such as R&D conducted abroad or by subsidiaries unconsolidated for tax purposes or R&D that is not deemed experimental or technological enough, that make it difficult to discern the impact of the tax subsidy on total R&D spending. It is important to note that these different measured impacts come from a very small sample. Because the merged sample is so small, the pattern of these estimates is more suggestive than definitive. They do show, however, that the estimated impact of tax subsidies for R&D is sensitive to the choice of spending measure.

## 2.7 Conclusion

This paper uses public data from financial filings and new restricted-access data from tax returns to assess the impact of tax credits on R&D expenditure decisions. An instrumental variables strategy that relies on tax policy changes disentangles the simultaneity of incremental credit rates and R&D spending. The empirical findings demonstrate that tax-price elasticity estimates for R&D are sensitive to choices of instruments, specifications and spending measures. Estimates using only publicly available data suggest that a ten percent tax subsidy for R&D yields between \$3.5 (0.24) million and \$10.7 (1.79) million in new R&D spending. Estimates from IRS SOI data, which only reports qualified research expenditures, suggest that a ten percent reduction in the usercost would lead firms to increase qualified spending by \$2 .0 (0.39) million. Analysis of the components of qualified research spending shows that wages and supplies, which comprise the bulk of qualified spending, account for the increase in research spending. These estimates come from different samples and use different data to construct measures of the tax component of the usercost of R&D. Estimates from the much smaller merged sample which makes use of the more precise tax data to calculate the tax component of the usercost suggest that qualified spending is responsive to the tax subsidy. A similar response in total spending is not statistically discernible in the merged sample.

These disparate and inconsistent results from different data samples illustrate the sensitivity of estimates of the tax-price elasticity of R&D to choices of instrumental variables, specifications and spending measures. Rather than yielding a single, consistent, number for the elasticity, the various analyses presented here instead show that estimates of the tax price elasticity are not robust across datasets and methods. Nonetheless, some conclusions can be drawn. First, there is considerable evidence that qualified research spending—the exact research efforts that are subsidized by the tax credit—is responsive to the reductions in the usercost due to the R&D credit. Second, comparisons between Compustat and SOI data show that relying on the public data results in significant mis-measurement of the tax-adjustment factor of the usercost. Third, non-qualified research spending is a significant fraction of total research spending as reported in financial filings, averaging more than 60 percent, and is a potentially important margin of adjustment when firms increase research spending in light of tax subsidies.

The empirical findings reported here bear on short-run research spending decisions, and there are several important considerations regarding broader interpretations. First, longer run impacts may differ from the short-run response investigated here. Long-run elasticities may exceed the one-year response if changes in research spending incur adjustment costs. Long-run elasticities could conceivably be smaller than the one-year response if firm's react to changes in their effective R&D tax subsidies by simply retiming research spending to maximize their credits. Second, the analysis here uses changes in the provisions of the research credit from the 1980s to identify the user-cost elasticity; research patterns from up to 30 years ago may not represent current R&D patterns in terms of shares of spending by firms in different industries, of different sizes, etc. Third, throughout the analysis firms' expectations of the future of the R&D tax credit are ignored. During its first decade the R&D credit was always renewed before it expired. Since then the credit has been allowed to lapse several times, most of the time being put into place retroactively, but on one occasion the credit was simply allowed to expire for a year. In the current, less predictable environment, firms' expectations regarding the future of the R&D credit likely impact how they react to the subsidy while it is in place. Estimates from an era of greater certainty may not be fully applicable today.

The inconsistency of estimates across the datasets and specifications make clear that further work is needed to assess the impact of tax subsidies on R&D spending. Larger datasets that allow for accurate measurement of the tax subsidy each firm faces and broad measures of R&D spending would allow researchers to better assess how non-qualified research spending reacts to subsidies for qualified spending. While it may be worthwhile to incentivize firms to direct nonqualified spending toward activities that qualify for the credit, if the increase in qualified spending reported here comes largely at the cost of nonqualified spending, the effect of the policy has a very different interpretation than if the increase in qualified spending was new research dollars. The degree to which spending is being redirected to qualified research is an important open question for future work. The question of relabeling has also drawn attention in policy circles. If firms are not even redirecting research, but just relabeling activities as qualified activities, the policy would be ineffective. Perhaps assessments of how IRS audit outcomes change with subsidy rates could help shed some light on how the R&D tax credit creates incentives for relabeling. These are issues I would like to pursue in future work.

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ɿive History of the Research and Experimentation Credit

| Corporate Tax Rate | Definition of Base | Qualified Research Expenditures | Sec. 174 deduction** | Foreign allocation rules | Carryback/ Carryforward |
|---|---|---|---|---|---|
| 48% | Maximum of previous 3-year average or 50% or current year | Excluded: research performed outside US; humanities and soc. science research; research funded by others | None | 100% deduction against domestic income | 3 years/15 years |
| 46% | Same | Same | Same | Same | Same |
| 34% | Same | Definition narrowed to technological research. Excluded leasing | Same | Same | Same |
| Same | Same | Same | Same | 50% deduction against domestic income; 50% allocation | Same |
| Same | Same | Same | Same | 64% deduction against domestic income; 36% allocation | Same |
| Same | Same | Same | Same | 30% deduction against domestic income; 70% allocation | Same |

| | | | | | |
|---|---|---|---|---|---|
| Same | Same | Same | -50% credit | 64% deduction against domestic income; 36% allocation | Same |
| Same | 1984-1988 R&D to sales ratio times current sales (max of 16%); 3% of current sales for startups | Same | -100% credit | Same | Same |
| Same | Startup rules modified | Same | Same | Same | Same |
| 35% | Same | Same | Same | 50% deduction against domestic income; 50% allocation | Same |
| Same | None | - | - | Same | Same |
| Same | 1984-1988 R&D to sales ratio times current sales (max of 16%); 3% of current sales for startups | Same as before lapse | -100% credit | 50% deduction against domestic income; 50% allocation | Same |
| Same | Also includes research undertaken in Puerto Rico and U.S. possessions. | Same | Same | Same | Same |
| Same | Same | Same | Same | Same | Same |

| | | | | | |
|---|---|---|---|---|---|
| Same | Same | Transition rules altered slightly and alternative credits modified as outlined on next sheet. | Same | Same | Same |

ıpply the credit rate to 50% of current QREs if the base amount is less than 50% of current QREs.

provides an immediate deduction for most research and experimentation expenditures. Taxpayers can also elect to es over 60 months, but in practice most firms immediately expense R&D. However, the IRC does not define R&D ;ulations have generally interpreted them to mean "R&D costs in the experimental or laboratory sense."

ł), the Senate Budget Committee's 2006 Tax Expenditures compendium and Thomas legislative summaries.

tion of Firms by Qualified Share of Total R&D Expenditures, Merged Sample of
S SOI Data

| ;ions | 0 | 0.00-0.20 | 0.20-0.40 | 0.40-0.60 | 0.60-0.80 | 0.80-0.90 | ≥ 0.90 |
|---|---|---|---|---|---|---|---|
| | 0.279 | 0.148 | 0.262 | 0.164 | 0.049 | 0.016 | 0.082 |
| | 0.343 | 0.014 | 0.057 | 0.186 | 0.200 | 0.029 | 0.171 |
| | 0.263 | 0.013 | 0.026 | 0.224 | 0.224 | 0.092 | 0.158 |
| | 0.360 | 0.013 | 0.053 | 0.227 | 0.213 | 0.040 | 0.093 |
| | 0.419 | 0.000 | 0.093 | 0.140 | 0.209 | 0.047 | 0.093 |
| | 0.533 | 0.013 | 0.013 | 0.147 | 0.160 | 0.040 | 0.093 |
| | 0.538 | 0.000 | 0.077 | 0.123 | 0.154 | 0.031 | 0.077 |
| | 0.525 | 0.000 | 0.082 | 0.098 | 0.131 | 0.016 | 0.148 |
| | 0.563 | 0.016 | 0.078 | 0.156 | 0.063 | 0.016 | 0.109 |
| | 0.458 | 0.017 | 0.102 | 0.169 | 0.119 | 0.017 | 0.119 |
| | 0.544 | 0.018 | 0.105 | 0.123 | 0.070 | 0.000 | 0.140 |
| | 0.435 | 0.023 | 0.082 | 0.163 | 0.147 | 0.033 | 0.118 |

·es are the ratio of qualified research expenditures (QREs) as reported in the firm's corporate tax return to the firm's ; reported in its financial filings. The firm's research credit and marginal research credit rate are determined by QREs. es as reported in financial statements includes foreign research spending and expenditures that do not satisfy the gical requirements of the R&D credit. The sample consists of all firms that can be successfully merged by Employer veen the Compustat and IRS datasets and report enough data to be included in later regression analysis.

Costs, Credit Recipiency Rates and Shares With Negative Credit Rates by Year, Compustat and IRS SOI Data

| | Compustat Data | | | | IRS SOI Data | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Observations | User Cost (Tax Price Component) | Fraction Receiving R&D Tax Credit | Fraction with Negative Marginal Credit Rates | Observations | User Cost (Tax Price Component) | Fraction Receiving R&D Tax Credit | Fraction with Negative Marginal Credit Rates |
| 1981 | 1,537 | 0.884 | 0.657 | 0.149 | 6,300 | 0.914 | 0.521 | 0.241 |
| 1982 | 1,371 | 0.907 | 0.636 | 0.182 | 6,056 | 0.849 | 0.540 | 0.083 |
| 1983 | 1,239 | 0.921 | 0.621 | 0.215 | 6,209 | 0.869 | 0.480 | 0.087 |
| 1984 | 1,238 | 0.906 | 0.613 | 0.191 | 6,166 | 0.878 | 0.441 | 0.076 |
| 1985 | 1,304 | 0.904 | 0.604 | 0.194 | 3,929 | 0.906 | 0.376 | 0.080 |
| 1986 | 1,317 | 0.942 | 0.568 | 0.209 | 6,048 | 0.940 | 0.329 | 0.086 |
| 1987 | 1,347 | 0.957 | 0.532 | 0.220 | 5,964 | 0.947 | 0.289 | 0.076 |
| 1988 | 1,466 | 0.933 | 0.564 | 0.158 | 5,789 | 0.949 | 0.299 | 0.076 |
| 1989 | 1,538 | 0.923 | 0.577 | 0.114 | 5,601 | 0.955 | 0.309 | 0.050 |
| 1990 | 1,821 | 0.918 | 0.459 | 0.000 | 5,467 | 0.961 | 0.283 | 0.000 |
| 1991 | 1,831 | 0.926 | 0.419 | 0.000 | 4,759 | 0.958 | 0.248 | 0.000 |
| | 16,009 | 0.920 | 0.561 | 0.138 | 62,288 | 0.919 | 0.379 | 0.081 |

of all firm-year observations that report sufficient data to be included in later regression analysis. The tax component beled $\lambda_t$ in the text, takes both expensing provisions and the research credit into account, in addition to reflecting any ie of tax advantages. In the Compustat sample firms receiving R&D tax credits are all firms that report current year their calculated base amounts. In the IRS sample all firms who report a tentative R&D tax credit are considered credit ıal credit rates arose for firms prior to the revamping of the credit in 1990 when they failed to qualify for a credit in the nt year spending increased base amounts for the subsequent three years when they did qualify for the credit.

'ser Costs, Credit Recipiency Rates and Shares With Negative Credit Rates by Year, mpustat and IRS SOI Data

| | | Compustat Data | | | IRS Data | | |
|---|---|---|---|---|---|---|---|
| | | User Cost (Tax Price Component) | Fraction Receiving R&D Tax Credit | Fraction with Negative Marginal Credit Rates | User Cost (Tax Price Component) | Fraction Receiving R&D Tax Credit | Fraction with Negative Marginal Credit Rates |
| 1981 | 67 | 0.880 | 0.821 | 0.104 | 1.025 | 0.657 | 0.433 |
| 1982 | 60 | 0.942 | 0.733 | 0.167 | 0.888 | 0.600 | 0.150 |
| 1983 | 58 | 0.945 | 0.759 | 0.224 | 0.864 | 0.638 | 0.138 |
| 1984 | 49 | 0.974 | 0.694 | 0.245 | 0.883 | 0.571 | 0.163 |
| 1985 | 31 | 0.980 | 0.677 | 0.226 | 0.919 | 0.516 | 0.161 |
| 1986 | 53 | 0.957 | 0.698 | 0.094 | 0.935 | 0.509 | 0.132 |
| 1987 | 45 | 1.000 | 0.622 | 0.289 | 0.926 | 0.422 | 0.133 |
| 1988 | 45 | 0.951 | 0.711 | 0.178 | 0.916 | 0.489 | 0.111 |
| 1989 | 45 | 0.944 | 0.667 | 0.178 | 0.940 | 0.444 | 0.067 |
| 1990 | 51 | 0.876 | 0.667 | 0.000 | 0.937 | 0.451 | 0.000 |
| 1991 | 49 | 0.902 | 0.551 | 0.000 | 0.929 | 0.388 | 0.000 |
| | 553 | 0.937 | 0.698 | 0.150 | 0.926 | 0.526 | 0.145 |

sists of all firms that can be successfully merged by Employer Identification Number between the Compustat and IRS . data to be included in later regression analysis. The tax component of the user cost formula, labeled $\lambda_t$ in the text, sions and the research credit into account, in addition to reflecting any losses that reduces the value of tax advantages. irms receiving R&D tax credits are all firms that report current year R&D expenses that exceed their calculated base le all firms who report a tentative R&D tax credit are considered credit recipients. Negative marginal credit rates arose aping of the credit in 1990 when they failed to qualify for a credit in the current year but their current year spending the subsequent three years when they did qualify for the credit.

tion of Firms by Tax Component of User Cost, Merged Sample of Compustat and

| tions | 0.75 | 0.75-0.80 | 0.80-0.875 | 0.875-0.95 | 0.95-1.00 | 1.00-1.25 | $\geq$ 1.25 |
|---|---|---|---|---|---|---|---|
| ) | 0.099 | 0.313 | 0.134 | 0.131 | 0.076 | 0.136 | 0.111 |
| 5 | 0.167 | 0.270 | 0.170 | 0.105 | 0.152 | 0.125 | 0.011 |
| 9 | 0.172 | 0.200 | 0.151 | 0.094 | 0.191 | 0.178 | 0.015 |
| 5 | 0.188 | 0.155 | 0.122 | 0.061 | 0.214 | 0.244 | 0.016 |
| 9 | 0.154 | 0.116 | 0.107 | 0.054 | 0.232 | 0.320 | 0.018 |
| 3 | 0.108 | 0.021 | 0.142 | 0.081 | 0.282 | 0.357 | 0.009 |
| 2 | 0.059 | 0.054 | 0.113 | 0.128 | 0.092 | 0.553 | 0.002 |
| 9 | 0.056 | 0.056 | 0.115 | 0.123 | 0.236 | 0.410 | 0.003 |
| 1 | 0.065 | 0.032 | 0.079 | 0.152 | 0.280 | 0.392 | 0.000 |
| 5 | 0.000 | 0.000 | 0.043 | 0.314 | 0.265 | 0.378 | 0.000 |
| 5 | 0.000 | 0.000 | 0.158 | 0.102 | 0.300 | 0.440 | 0.000 |
| 1 | 0.0989 | 0.1157 | 0.1222 | 0.1228 | 0.2068 | 0.3158 | 0.0177 |

nsists of all firm-year observations from the Compustat dataset that report sufficient data to be included in later ax component of the user cost formula, labeled $\lambda_t$ in the text, takes both expensing provisions and the research credit o reflecting any losses that reduces the value of tax advantages. Research credit rates are calculated using total R&D n financial statements.

son of Average Actual and Synthetic User Cost Tax-Adjustment Factors, Compustat and

| | | Compustat Data | | | IRS Data | | |
|---|---|---|---|---|---|---|---|
| | Year | Observations | Actual User Cost Tax-Adjustment Factor | Synthetic User Cost Tax-Adjustment Factor | Observations | Actual User Cost Tax-Adjustment Factor | Synthetic User Cost Tax-Adjustment Factor |
| | 1981 | 1,520 | 0.882 | 0.765 | - | - | - |
| | 1982 | 1,371 | 0.907 | 0.792 | 5,529 | 0.855 | 0.885 |
| ıte of wback | 1983 | 1,239 | 0.921 | 0.817 | 5,519 | 0.875 | 0.868 |
| | 1984 | 1,238 | 0.906 | 0.841 | 5,251 | 0.886 | 0.868 |
| | 1985 | 1,304 | 0.904 | 0.846 | 3,747 | 0.906 | 0.865 |
| | 1986 | 1,317 | 0.942 | 1.002 | 3,501 | 0.951 | 0.885 |
| ıte of wback | 1987 | 1,347 | 0.957 | 1.013 | 5,277 | 0.952 | 0.888 |
| | 1988 | 1,466 | 0.933 | 0.926 | 5,249 | 0.953 | 0.897 |
| ıte of wback | 1989 | 1,538 | 0.923 | 0.940 | 5,184 | 0.957 | 0.913 |
| ıte of | 1990 | 1,692 | 0.916 | 0.899 | 5,030 | 0.962 | 0.903 |
| | 1991 | 1,699 | 0.923 | 0.901 | 4,488 | 0.959 | 0.902 |
| | | 15,731 | 0.919 | 0.886 | 48,775 | 0.924 | 0.888 |

; tax-adjustment factors reflect both prevailing expensing and research credit provisions and contemporaneous research rates are calculated using contemporaneous total R&D spending in the case of Compustat data and qualified research f IRS SOI data. Synthetic user cost tax-adjustment factors are constructed using prevailing expensing and research rst lag of research spending (total R&D spending in Compustat data and QREs in the IRS SOI data).

x-Price Elasticity Estimates Using Compustat Data and Different ts

| | ag RHS Vars | Lag RHS Vars | Lag RHS Vars | Synthetic IVs | Synthetic IVs | Synthetic IVs |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | -0.844 | -0.822 | -0.734 | -0.449 | -0.459 | -0.453 |
| | (0.097) | (0.088) | (0.100) | (0.035) | (0.033) | (0.031) |
| | 0.003 | 0.002 | -0.001 | - | - | -0.042 |
| | (0.006) | (0.004) | (0.006) | - | - | (0.007) |
| | -0.006 | -0.004 | 0.000 | 0.007 | - | 0.042 |
| | (0.007) | (0.005) | (0.007) | (0.002) | - | (0.007) |
| | 1981-1991 | 1981-1991 | 1982, 1986-90 | 1982, 1986-90 | 1982, 1986-90 | 1982, 1986-90 |
| | anufacturing | All | All | All | All | All |
| | 5,615 | 6,398 | 3,131 | 6,339 | 6,348 | 6,207 |

ation in column 1 corresponds to my best effort to replicate the results of an earlier study, Hall (1994). That ted for all three regressors with their second and third lags as well as with lagged tax status and lagged growth s. It limited the analysis to only manufacturing firms but included observations from all years between 1981 and ng strategy based on synthetic tax-adjustment user cost factors, used in columns 4-7, is laid out in Section 2.2 and here the provisions of the tax credit were altered. The basic specification of columns 4-7 is:

$$+ \chi_t + \eta \log\left(\frac{Y_{it}}{Y_{it-1}}\right) + \varepsilon_{it}$$

le all firms, though the vast majority are manufacturing firms. Column 5 resestimates the specification of column 4 able, $\log S_{it-1}$. Column 6 adds a control for the first lag of R&D spending logged, $\log R_{it-1}$, instrumenting with the egressions include year fixed effects and a constant. Standard errors are clustered at the two-digit NAICS industry 'rice Elasticity Estimates Using Compustat Data, Robustness Checks

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| | -0.453 | -0.440 | -0.401 | -0.400 | -0.441 | -0.470 | -0.460 |
| | (0.031) | (0.057) | (0.059) | (0.058) | (0.067) | (0.038) | (0.065) |
| $R_{it}$. | | X | | | | | |
| | | | X | | | | |
| nd | | | | X | | | |
| | | | | | X | | |
| ırs | | | | | | X | |
| ɿ | | | | | | | X |
| | 6,207 | 6,207 | 6,207 | 6,207 | 6,207 | 3,360 | 3,305 |

is the baseline estimate and corresponds to column 6 of Table 1.7. The log-change in the tax-adjustment ith the synthetic change in the tax-adjustment factor, as explained in Section 1.2.2. The specification of

$$\cdot\Big) + \varepsilon_{it}$$

nd the first lag of log R&D spending, $\log R_{it-1}$. Additional terms are included in the specifications Column 2 adds a cubic in $\log R_{it-1}$ for each year. Column 3 includes industry fixed effects and column 4 ı NAICS two-digit industry. Column 5 adds a control function to correct for selection. Column 6 limits ;a for all five years. Column 7 limits the sample to firms wit December fiscal year ends. All regressions are clustered at the two-digit NAICS industry level.

Table 2.9: Impact on Total R&D Spending (COMPUSTAT Data Only)
Dependent Variable: (Δ Total R&D Exp./$\text{Sales}_{t-1}$)

| | OLS (1) | OLS (2) | IV (3) |
|---|---|---|---|
| Δ Tax Part of Usercost | -0.043 | -0.045 | -0.035 |
| | (0.010) | (0.010) | (0.008) |
| Sales Growth | 0.023 | 0.024 | 0.021 |
| | (0.012) | (0.012) | (0.013) |
| First Lag Total R&D | - | - | 3.18E-07 |
| | | | (8.79E-07) |
| Usercost Elasticity | -0.436 | -0.453 | -0.356 |
| | (0.101) | (0.104) | (0.078) |
| Impact of a 10% decrease | 13.182 | 13.705 | 10.749 |
| in usercost in $M R&D | (3.059) | (3.145) | (1.787) |
| Observations | 7,762 | 7,762 | 7,631 |

Note: All regressions include a constant. Column 1 presents estimates of the equation:

$$\left[\frac{R_{it}-R_{it-1}}{S_{it-1}}\right]=\alpha+\sigma\left[\lambda_{it}-\lambda_{it-1}\right]+\eta\left[\frac{S_{it}-S_{it-1}}{S_{it-1}}\right]+\gamma R_{it-1}+\chi_t+\varepsilon_{it}$$

Column 2 adds year fixed effects. Column 3 instruments for the endogenous change in the tax part of the usercost with the synthetic change described in Section 2.2.2, retaining year fixed effects. All data are inflated using the GDP index. Standard errors are clustered at the two-digit industry level according to NAICS codes from Compustat.

Table 2.10: Impact on Qualified R&D Spending (IRS Data Only)
Dependent Variable: ($\Delta$ Qualified R&D/Sales$_{t-1}$)

| | OLS (1) | OLS (2) | IV (3) |
|---|---|---|---|
| $\Delta$ Tax Part of Usercost | -0.041 | -0.040 | -0.020 |
| | (0.006) | (0.006) | (0.004) |
| Sales Growth | 0.026 | 0.026 | 0.029 |
| | (0.011) | (0.011) | (0.014) |
| First Lag Total R&D | - | - | 8.34E-07 |
| | | | (1.61E-06) |
| Usercost Elasticity | -3.424 | -3.316 | -1.673 |
| | (0.522) | (0.503) | (0.332) |
| Impact of a 10% decrease in usercost in $M R&D | 3.836 | 3.715 | 1.960 |
| | (0.585) | (0.564) | (0.389) |
| Observations | 28,371 | 28,371 | 18,691 |

Note: All regressions include a constant. Column 1 presents estimates of the equation:

$$\left[\frac{R_{it} - R_{it-1}}{S_{it-1}}\right] = \alpha + \sigma\left[\lambda_{it} - \lambda_{it-1}\right] + \eta\left[\frac{S_{it} - S_{it-1}}{S_{it-1}}\right] + \gamma R_{it-1} + \chi_t + \varepsilon_{it}$$

Column 2 adds year fixed effects. Column 3 instruments for the endogenous change in the tax part of the usercost with the synthetic change described in Section 2.2, retaining year fixed effects. All data are inflated using the GDP index. Standard errors are clustered at the two-digit industry level according to NAICS codes from Compustat.

Price Elasticity Estimates Using Compustat Data, R&D Spending Components

| | Wages & Sal. | Supplies | Equip. Rental | Contracted | University |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| | -0.016 | -0.005 | -5.42E-04 | -9.11E-04 | -9.67E-04 |
| | (0.004) | (0.001) | (4.78E-04) | (9.49E-04) | (6.09E-04) |
| | 5.34E-07 | -3.13E-07 | -1.14E-07 | 8.96E-07 | 1.66E-07 |
| | (2.23E-06) | (5.12E-07) | (7.20E-08) | (3.52E-07) | (2.58E-07) |
| | 0.025 | 0.005 | 0.000 | 0.002 | 1.99E-05 |
| | (0.013) | (0.003) | (0.000) | (0.001) | (1.48E-05) |
| | -1.655 | -1.926 | -6.300 | -1.069 | 1.17E-04 |
| y | (0.449) | (0.454) | (5.560) | (1.114) | (1.17E-04) |
| lecrease | 1.431 | 0.417 | 0.049 | 0.083 | 0.088 |
| R&D | (0.389) | (0.098) | (0.044) | (0.087) | (0.056) |
| | 14,394 | 14,394 | 14,394 | 14,394 | 2,882 |

ıclude a constant and year fixed effects. Columns 1 through 5 present estimates of the equation:

$$+ \chi_t + \eta \log\left(\frac{Y_{it}}{Y_{it-1}}\right) + \varepsilon_{it}$$

the tax part of the usercost in instrumented with the synthetic change described in Section 2.2, retaining year fixed ed using the GDP index. Standard errors are clustered at the two-digit industry level according to NAICS codes from

Table 2.12: Impact on Total R&D Spending (Merged Data)

| Dependent Variable: | (Δ Total R&D Exp./Sales$_{t-1}$ | | (Δ Qualified R&D/Sales$_{t-1}$) | |
|---|---|---|---|---|
| | OLS | IV | OLS | IV |
| | (1) | (2) | (3) | (4) |
| Δ Tax Part of Usercost | 0.002 | -0.013 | -0.047 | -0.087 |
| | (0.010) | (0.011) | (0.014) | (0.040) |
| Sales growth | -0.003 | -0.002 | 0.027 | 0.022 |
| | (0.001) | (0.001) | (0.013) | (0.020) |
| First Lag R&D | - | 1.47E-05 | - | -1.79E-06 |
| | | (1.23E-05) | | (1.57E-05) |
| Usercost Elasticity | 0.043 | -0.315 | -2.330 | -5.312 |
| | 0.211 | 0.254 | (0.700) | (2.435) |
| Impact of a 10% decrease in | -0.330 | 2.168 | 8.156 | 15.669 |
| usercost in $M R&D | (1.614) | (1.743) | (2.451) | (7.182) |
| Observations | 314 | 217 | 314 | 216 |

Note: All regressions include a constant and year fixed effects. Columns 1 and 3 present estimates of the equation:

$$\left[\frac{R_{it} - R_{it-1}}{S_{it-1}}\right] = \alpha + \sigma[\lambda_{it} - \lambda_{it-1}] + \eta\left[\frac{S_{it} - S_{it-1}}{S_{it-1}}\right] + \gamma R_{it-1} + \chi_t + \varepsilon_{it}$$

Columns 2 and 4 instrument for the endogenous change in the tax part of the usercost with the synthetic change described in Section 2.2, retaining year fixed effects. All data are inflated using the GDP index. Standard errors are clustered at the two-digit industry level according to NAICS codes from Compustat.

# Appendix

Several variables used to calculate a firm's marginal R&D tax credit rate are not reported directly and must instead be inferred from other variables. These variables, and their instrument analogue were calculated as follows:

$j_{it}$: the number of years the firm will carry forward any earned R&D tax credits

If a firm does not pay federal taxes, it is assumed to not have taxable income and must therefore carry-back (then carry-forward) its R&D tax credit. The R&D tax credit can be carried back up to 3 years and carried forward up to 15 years. The analysis presented here only calculates up to 6 carry-forward years; firms who would carry the credit forward more than 6 years are assigned a six-year carry-forward period. The firm will first offset taxes paid (Compustat Data63) three years prior. If its taxes paid three years prior are insufficient to offset the credit, it will offset taxes paid two years prior, then one year prior. Any remaining R&D tax credit will then be carried forward.

To construct the synthetic tax rate, $j_{it}$ is replaced by a constant (0.5) for all firms in all years.

$k_{it}$: the number of years until any tax losses will be exhausted

Compustat reports a firm's stock of net operating loss carry-forwards (Data 52) but not their time to expiration. Net operating losses (NOLs) can be carried forward up to 20 years. All NOL carry-forwards are assumed to be used before they expire. NOLs are first used to offset the following year's pre-tax income (Data272). If next year's pre-tax income is insufficient to offset all NOL carry-forwards, the remaining NOL carry-forwards are offset against the second leading year's pre-tax income and so on. The analysis presented here only calculates up six years of tax losses; firm who may have more than six years of tax losses are assigned a tax loss period of six years.

To construct the synthetic tax rate, $k_{it}$ is replaced by a constant (0.5) for all firms in all years.

# Chapter 3

# Deferred Tax Positions and Incentives for Corporate Behavior Around Corporate Tax Changes

Joint with James M. Poterba and Jeri K. Seidman

## 3.1 Introduction

Conventional wisdom holds that corporate executives support lower statutory corporate tax rates, because after-tax corporate earnings would be higher if tax rates were lower. While for most firms this statement is an accurate long-run characterization, the short-run effects of a corporate rate reduction can differ across firms. Disparities in the tax circumstances of different firms can lead to important cross-firm differences in the short-run effect of changes in statutory tax rates, and potentially in the firms' support for rate reduction.

For example, when corporate tax reform was debated by Congress in 2004, survey evidence suggested that executives at a majority of firms supported corporate tax rate reduction, and that they preferred rate reduction to other tax reform options. Yet some large firms with substantial deferred tax assets that would be subject to revaluation if the statutory corporate rate changed lobbied successfully against a corporate tax rate cut, in part because a rate cut would have reduced the value of these assets. Hanna (2009) explains that "a corporate tax rate cut would cause a small group of manufacturing companies, on behalf of which the representatives were lobbying, to take an immediate charge or "hit" to earnings—thereby reporting lower quarterly net income and lower earnings per share." In part as a result of their efforts, the American Jobs Creation Act of 2004 (AJCA) included a complex domestic activities production deduction that had the approximate effect of a rate cut without requiring firms to write down their deferred assets and liabilities. This episode illustrates how deferred tax assets, and the incentives they create for firms for whom they are significant, can play an important role in the analysis of corporate tax transitions.

This paper aims to better understand the potential effect of deferred tax positions on corporate behavior. It also explores how these positions may affect managerial preferences regarding corporate tax reform. Deferred tax asset or liability positions recognize the estimated future tax effects attributable to past temporary differences between book and tax income.[1] How a corporate tax reform will affect a firm's reported earnings in the year of its enactment, and how the firm may choose to react to the tax reform, depend in part on the sign and magnitude of its net deferred tax position. We collect data on, and then describe, the amounts and components of deferred tax assets and liabilities for the largest public U.S. corporations between 1993 and 2004. The sample of firms that we study account for nearly forty percent of the aggregate market capitalization of the U.S. corporate sector in 2004.

The presence of deferred tax assets and liabilities is important for understanding the transitional impact of statutory tax rate changes on different firms. It also complicates the task of estimating the revenue impact of a corporate tax change. Deferred tax positions generate incentives for firms to re-time their recognition of income around tax changes. The resulting changes in reported corporate earnings may

[1]The difference between reported pre-tax income, and estimated taxable income, is comprised of temporary, permanent and other differences. Temporary differences result from discrepancies in the timing of income and expense recognition for book and tax purposes. Temporary differences affect a firm's cash flow both when they arise and when they reverse; this future effect gives rise to the recorded deferred tax position.

affect the revenue raised by the tax system. When tax rates are scheduled to decline, firms with large deferred tax assets have an incentive to shift income into the present to utilize deferred tax benefits at a currently high tax rate, just the opposite of the standard prediction that when tax rates decline income will be deferred until the low-tax regime takes effect. In contrast, for firms with large deferred tax liabilities, the incentive to defer income to the anticipated low-tax regime is even stronger than for firms without such liabilities, since by shifting income into the future these firms can discharge their deferred liabilities at the lower rate. Scholes, Wilson and Wolfson (1992) and Guenther (1994) study the Tax Reform Act of 1986 (TRA86), which reduced corporate rates. They find that firms delayed reporting of income so that this income would be taxed at the new, lower tax rate. Maydew (1997) finds that firms generating Net Operating Losses in the years immediately following TRA86 delayed income recognition or accelerated deduction recognition to increase the loss, thereby moving the refunds from the carryback into a tax year with a high statutory rate. These results support the view that firms attempt to shift income across time periods when there are pre-announced changes in statutory corporate tax rates, and that the way they make such shifts depends on their particular tax position.

When the statutory corporate tax rate changes, firms must revalue their deferred tax positions; this revaluation flows through current period net income. As the size of the deferred tax positions of U.S. corporations increases, the potential for revaluation of these balances to materially affect net income, and to affect the way managers and shareholders view corporate tax reform, increases. McChesney (1997) provides examples of how industry lobbying influenced the Tax Reform Act of 1986; understanding deferred tax asset and liability positions may more generally offer insights into firm lobbying incentives regarding corporate tax reform. Mills (2006) and Neubig (2006), among others, suggest that concerns about the changes in reported income that are associated with such revaluations may be an important determinant of whether corporate executives support potential corporate tax reform.

This study explores the influence that deferred tax positions may have on the way firms respond to tax changes, and on the incentives managers may face when they lobby with regard to tax policy. While we do not examine the political actions of firms, we suggest that a political economy perspective on firm behavior might offer useful insights on the support for, and opposition to, various corporate tax reforms from the corporate sector.[2] We construct and describe components of deferred tax assets and liabilities for large corporations. We identify all public firms that are Fortune 50 members between 1995 and 2004 and carefully construct comparable entities for the period 1993 to 2004 by combining merged companies prior to the merger and divested companies after the divestiture. For this set of 81 "super-firms," we then catalog the components of their deferred tax positions so we can investigate changes within category and in total for each firm. Hand-collection is necessary because the available machine-readable balance sheet data has historically encoded only the long-term deferred tax liability disclosed on the balance sheet rather than the net deferred tax position and components disclosed in the tax footnote. While the most recent Compustat data includes net deferred tax positions, is not complete. This data field is populated for only 50.9 percent of the firm-years in our sample. The machine-readable data therefore does not permit analysis of short-term deferred tax liabilities or any deferred tax assets. This makes it impossible for researchers to measure the magnitude of deferred tax assets that are likely to influence the amount of lobbying against a proposed rate cut or the extent of income shifting that might take place as firms try to utilize NOLs when faced with a statutory tax rate reduction.

The aim of our study is to calculate the size of net deferred tax asset and liability positions in order to allow policy-makers to better understand the incentives facing large U.S. corporations. We also provide evidence on how changes in temporary differences—both aggregate temporary differences and specific types of temporary differences—are linked with the recent rise in the difference between reported pre-tax book income and estimated taxable income (the book-tax gap).

Our analysis has three parts. First, we measure both the total book-tax gap and

[2]We focus on temporary differences, rather than permanent differences, because permanent differences do not accumulate over time in the form of deferred tax assets or liabilities, so they do not create incentives with regard to tax policy transitions in the way that temporary differences do. The full impact of a permanent difference is recognized in the period when the underlying income-generating activity takes place.

the portion of the gap attributable to temporary differences. Our hand-collected firm-level data set enables us to overcome missing-data problems that are common in the standard data source, Compustat, in order to accurately calculate these figures.[3] Our findings suggest that temporary differences account for a substantial share of the book-tax gap. When we stratify our data by year, we find that in every year, more than half of the book-tax gap for the median firm in our sample is attributable to temporary differences.[4] Additionally, both the fraction of firms in our sample with a net deferred tax liability and the size of the average net deferred tax liability rise substantially during our sample. Thus, growth in temporary differences appears to contribute to the widening of the book-tax gap. As a firm's deferred tax position rises relative to its non-tax assets and liabilities, the firm is likely to be more sensitive to proposed changes in statutory tax rates.

Second, we disaggregate deferred tax positions into categories in order to understand whether the recent growth in the book-tax gap attributable to temporary differences is observed over most of the components that contribute to temporary differences, or is driven by a few specific types of temporary differences. This disaggregation provides the first detailed analysis of the components of deferred tax positions for a significant and relatively constant sample of firms over an extended period of time.[5] Key contributors to the increase in the book-tax income gap include mark-to-market adjustments; property, including leases and both tangible and intangible property; and valuation allowances. The overall growth of the book-tax

[3]We use current tax expense to calculate the book-tax income gap and deferred tax expense to calculate temporary differences. Using hand-collected data, current tax expense (deferred tax expense) is non-missing and non-zero for 92.4 percent (91.2 percent) of the firm-year observations in our sample. Compustat current tax expense, calculated as the sum of TXFED, TXFO and TXS, (Compustat deferred tax expense, calculated as the sum of TXDFED, TXDFO and TXDS) is non-missing and non-zero for 74.8 percent (62.6 percent) of the firm-years in our sample.

[4]The residual (Book Income less [(Current plus Deferred Tax Expense)/0.35]) should be attributed to permanent and other differences as well as to measurement error. Tax expense not clearly disclosed as current or deferred (for example, tax expense due to Discontinued Operations or disclosed only by jurisdiction) will be included in this residual measure.

[5]Amir, Kirschenheiter, and Willard (1997) collect similar data on the size and components of deferred tax positions but only study the period 1992-1994. Phillips, Pincus, Rego, and Wan (2004) study a longer period, 1994-2000, but study a random sample of firm-years in this period. We collect data for a relatively constant set of firms over a long period, which allows us to make across-time comparisons.

gap is smaller than the growth in some of the items noted above, however, because some accounting items that reduce the book-tax gap, such as NOL and tax credit carryforwards, also increased during our sample period.

Finally, we interpret the data we collect on deferred tax assets and liabilities in the context of the behavioral and political economy incentives surrounding a tax rate change. We find that a pre-announced reduction in the corporate tax rate would give a third of the firms in our sample a strong incentive to accelerate income to the high-tax period. Moreover, many of these firms seem to have the capacity to make such a shift. While we are unable to estimate how much income would be shifted in response to such incentives, and the magnitude would depend on the size of the rate change, the nontrivial share of firms affected by such an incentive and the rise in the size of loss carryfowards, suggests that policy-makers should consider the revenue impact of rate-change-motivated income shifting when they estimate the short-run revenue effect of a change in the statutory corporate tax rate.

We also estimate the net income impact of a statutory rate change to demonstrate how this aspect of a corporate rate cut might influence the incentives firms have to lobby for or against specific tax changes. For the average firm in our sample, reducing the statutory federal corporate income tax rate from 35 to 30 percent would result in a $328 million increase in reported net income as a result of revaluation of deferred tax positions. There is, however, substantial heterogeneity across firms. More sample firms would report an increase than a decrease in net income from revaluations associated with a reduction in the statutory corporate tax rate. Among those that would report an increase, the average impact of a rate reduction to 30 percent would be $677 million. For firms with a net deferred tax asset, however, the rate reduction would induce an average reduction of $315 million in net income. Our results quantify a potentially important transitional effect of corporate tax reform on net income—the revaluation effect of deferred tax positions—that policy-makers may want to consider as they try to target transition relief in prospective tax legislation to the various types of firms that may be affected by policy changes.

We divide our analysis of temporary book-tax differences into five sections. The next section—section 3.2—explains how temporary differences generate deferred tax assets and liabilities. This background is particularly important for non-accountants. Section 3.3 describes the data set that we have assembled from a sample of SEC filings, identifies a number of potential data limitations and presents summary statistics. Section 3.4 disaggregates the book-tax gap, both to estimate the importance of temporary differences within our sample and to provide details on the most significant components of temporary differences. Section 3.5 examines how the sum of past temporary differences can affect net income when tax policy changes induce revaluations. A brief conclusion in section 3.6 explores implications of our findings for tax policy and suggests future research.

## 3.2 Temporary Differences Between Book and Tax Earnings

Statement of Financial Accounting Standards 109 (SFAS 109), *Accounting for Income Taxes*, which took effect for fiscal years beginning after December 15, 1992, provides guidance for the calculation of tax expense. SFAS 109 uses a balance sheet approach to determine provision for income taxes. Deferred tax expense is calculated as the change in the firm's net deferred tax position. To calculate the end-of-period deferred tax position, temporary differences are cumulated over time and multiplied by the statutory corporate tax rate that the firm expects to be in effect, under enacted laws, when the temporary difference reverses. Temporary book-tax differences are the result of disparities in the *timing* of an income component's inclusion in book and tax earnings. When expected tax rates are constant through time, a firm's deferred tax expense equals the current statutory tax rate times temporary book-tax differences that arise or reverse in the current period.[6] When tax rates change, the balance sheet approach adopted in SFAS 109 requires revaluing net deferred tax positions. The revaluation of the deferred tax asset or liability is then included in net income

[6]Under SFAS 109, temporary differences are recorded at their full tax-effect and are not discounted to reflect any timing considerations.

through the deferred tax expense or benefit.[7]

While the balance sheet approach of SFAS 109 may appear relatively complicated, in most instances the following simplification yields approximately the same result.[8] Total tax expense, which measures the taxes that will be due at some point in time on current period income, equals the statutory corporate tax rate times taxable book income, less tax credits and other rate adjustments.[9] Taxable book income equals pretax book income less permanent differences between book and tax income. Permanent differences arise when a component of income enters one earnings measure but not the other. The exclusion of tax-exempt interest from taxable income but inclusion of tax-exempt interest in pretax book income is an example of a permanent difference. The effect of permanent differences on the firm's net income, taxable income, and cash flow is fully reflected in the year when these differences occur.[10]

While temporary differences do not affect total tax expense, they do affect taxable income. Temporary book-tax differences arise when book and tax rules differ not on the treatment of an income component but on the timing of its inclusion in book and tax earnings. For example, the difference between book and tax depreciation is a temporary difference. Temporary differences affect the partition of total tax expense between current and deferred tax expense. In the absence of revaluation, temporary differences do not affect net income.

$$\text{Total Tax Expense} = \text{Current Tax Expense} + \text{ Deferred Tax Expense} \qquad (3.1)$$

[7]Revaluation of the deferred tax balance flows through net income regardless of whether or not the creation of the deferred tax balance affected net income. For example, deferred tax positions associated with unrealized gains and losses on available for sale securities affect other comprehensive income rather than net income but revaluation of these positions would affect net income.

[8]This simplification does not hold when the statutory rate changes, merger activity occurs, or in certain other settings.

[9]We refer to tax credits and other rate adjustments that affect current tax expense but not taxable income as other differences. These other differences confound our estimate of taxable income.

[10]When permanent or other differences are not able to be utilized in the period in which they arise (for example, excess charitable contributions or R&D credits), a deferred tax asset will be created to record the expected benefit from using this permanent or other difference in the future. In these cases, permanent and other differences may affect net income, taxable income, and cash flow in additional years. In general, deferred tax assets related to permanent and other differences are small relative to those related to temporary differences.

Temporary differences generate a disparity between current-period pretax book and tax income, but they also generate a future, *opposite-signed* effect on taxable income. Temporary differences also affect cash flow twice—both in the period in which they arise and defer a tax payment or receipt and in the period in which they reverse and generate the deferred tax payment or benefit.

Deferred tax positions equal the current statutory corporate tax rate times the sum of differences that will reverse in the future, which equals the historical sum of the firm's temporary differences. Firms with a positive sum of temporary differences have a net deferred tax liability (DTL): they have accelerated tax deductions relative to accounting expenses or have recorded income for accounting purposes that has not been recognized yet for tax and they will owe tax when this difference reverses. Firms for which taxable income has exceeded pretax book income, in contrast, have a deferred tax asset (DTA); they are entitled to future tax relief either because they have already paid additional taxes relative to their tax expense, either on taxable income that has not yet been reported for accounting purposes or on accelerated expenses relative to tax deductions, or because they have a tax benefit (a tax credit or NOL) they have not yet been able to use.

For a firm in steady state, with constant nominal-dollar investment flows and other balance sheet items, temporary differences should not affect pretax book income relative to taxable income. For example, the reductions in taxable income relative to pretax book income generated by recently-acquired assets subject to accelerated depreciation should just offset the increases in taxable income relative to pretax book income on older assets that have already been completely depreciated for tax purposes. When the firm experiences swings in investment from year to year, however, or is growing, temporary differences associated with different vintages of investment will not be of equal magnitude so they may affect book relative to taxable income. Similar patterns could emerge as a result of variation over time in other temporary components.

We study temporary differences by analyzing reported deferred tax positions. Three features of SFAS 109 that affect these reports are particularly significant for our study. First, firms must report both deferred tax assets and liabilities, not just a net deferred tax position. Deferred tax positions are presented on the balance sheet based on a current/non-current classification, as determined by the current/non-current status of the underlying asset or liability that gave rise to the deferred tax position. Second, firms must adjust their reported DTAs and DTLs when laws change. Changes in statutory corporate tax rates, in particular, must be reflected. For many firms, and for many but not all components of deferred taxes, a reduction in the statutory corporate tax rate would reduce DTLs (DTAs) and thereby have a positive (negative) effect on reported earnings. Third, firms must report a valuation allowance that reflects the probability of realizing deferred tax assets.[11] This permits an assessment of the potential tax benefit associated with a deferred tax asset.

Disaggregating deferred tax assets and liabilities makes it possible to study many aspects of these deferred tax positions, but we are aware of only four studies that have moved beyond machine-readable data to focus on the components of the deferred tax account.[12] Phillips, Pincus, Rego and Wan (2004) disaggregate changes in deferred tax positions to explore which types of deferred tax positions reveal aggressive financial reporting. They find that changes in deferred tax positions related to revenue and expense accruals and reserves are particularly likely to signal aggressive financial reporting. Givoly and Hayn (1992) study how share prices of firms with deferred tax liabilities reacted to the corporate tax rate reduction in the 1986 Tax Reform Act. They find that the decline in corporate rates had a favorable effect on the market value of firms with deferred tax liabilities, after controlling for the other effects of tax reform on these firms. Chen and Schoderbek (2000) distinguish changes in deferred tax positions that were triggered by the 1993 corporate tax rate increase from other changes to deferred tax positions. They find that analysts reacted in roughly the same way to both types of changes, even though the persistence and predictive power

[11] A valuation allowance is a contra-asset account that reflects the value of deferred tax assets that are not likely to be recognized. The deferred tax asset is netted with the valuation allowance to assess the firm's expected future tax benefit.

[12] Several studies analyze a portion of the deferred taxes. For example, Miller and Skinner (1998) and Bauman, Bauman, and Halsey (2001) study the valuation allowance related to deferred tax assets.

of the two are likely to differ. Finally, Amir, Kirschenheiter, and Willard (1997) disaggregate deferred taxes and find some evidence that market participants consider the source of deferred tax positions in valuation. We follow these studies in disaggregating deferred tax balances, but we focus on how temporary differences change over time and on how they affect the income statement rather than market values.

## 3.3 Data Collection

Machine-readable data, such as the deferred tax liability balance recorded by Compustat, measure firms' deferred tax positions with substantial noise. Until recently, Compustat reported long-term deferred tax liabilities as shown on the balance sheet, but it omitted deferred tax positions reported as assets or as short-term liabilities, thereby preventing researchers from identifying firms with net deferred tax assets or from accurately measuring the position of firms with net liabilities.[13] Compustat's Fundamentals database, introduced in 2007, collects data on net deferred tax positions as well as the balance of short-term and long-term deferred tax assets and liabilities.[14] This dramatically improves the ability of researchers to measure the net deferred tax positions of firms. However, the Fundamentals dataset does not yet contain data for all firms for all years.[15] Our dataset has many advantages over Legacy Compustat. Relative to Fundamentals Compustat, its primary advantage is its completeness.

A second limitation of machine-readable data is that it does not allow detailed

[13]For example, the 2005 balance sheet for Kimberly-Clark reports a current deferred tax asset of $223.4 million and a long-term deferred tax liability of $572.9 million. Legacy Compustat only collects the liability disclosed on the balance sheet of $572.9 million. Even if Compustat had also collected the balance-sheet-disclosed current asset of $223.4 million, the user would not have been able to tie to the footnote-disclosed net deferred tax liability position of $121.4 million because of deferred tax positions included in other assets on the balance sheet.

[14]Returning to the example in the footnote above, for 2005 Kimberly-Clark, Fundamentals Compustat collects $223.4 million for short-term deferred tax assets, $228.1 million for non-current deferred tax assets, and $572.9 million for long-term deferred tax liability as well as the net deferred tax liability position of ($121.4) million.

[15]Fundamentals Compustat has backfilled tax data for a number of firms and continues to backfill fairly rapidly (nearly 30 percent of our sample has become populated in the last 6 months.) However, only 50.9 percent of the valid observations during our period have a non-missing value for Net Deferred Tax Balance. Researchers will find comfort in the fact that 96.9 percent of the Net Deferred Tax Balances collected by Compustat are approximately equal to the Net Deferred Tax Balances we hand-collected.

component-based analysis of deferred tax asset and liability positions. As part of our study, we endeavor to provide evidence about which types of differences have contributed to the rise in the book-tax gap. A second benefit of our dataset over both Fundamentals and Legacy Compustat is that it is includes information on the type of temporary difference which created the deferred tax position.

To overcome the limitations of existing data sets, we collect data from the tax footnote in 10-K filings for FORTUNE 50 firms for fiscal years between 1993 and 2004. Our sample begins in FY 1993 because it is the first year when all firms' financial statements were prepared in accordance with SFAS 109. FORTUNE ranks firms by gross revenue.[16] Our sample includes both financial and non-financial firms. Since we are interested in tracking deferred tax positions over time, we use the annual FORTUNE 50 lists to construct a panel data set. For any firm in the FORTUNE 50 in any of our sample years, we collect data for the entire sample period. There is moderate turnover in the FORTUNE 50. Only 25 of the firms in the 1995 FORTUNE 50 were in the 2004 FORTUNE 50. Nine of the 50 firms on the 1995 list were acquired between 1995 and 2004. In a typical year, five firms leave the FORTUNE 50 for various reasons. One hundred firms appear in the FORTUNE 50 at least once between 1995 and 2004. We drop four firms from this group: State Farm Insurance and TIAA-CREF, which are private companies that do not need to file 10-Ks, and Fannie Mae and Freddie Mac, which are government-sponsored enterprises. This leaves a sample of ninety-six firms.

Corporate control transactions complicate the problem of tracking FORTUNE 50 firms through time. Sample firms acquire other firms, or in some cases are themselves acquired. When this occurs we collect data on the acquired or acquiring firm for years prior to the acquisition. To preserve data comparability over time, we create "super-firms" by combining the distinct accounts of the two firms that subsequently consolidated. This process is designed to minimize discrete changes in deferred tax positions that are due to acquisitions. However, no methodology we know of will

[16]Prior to 1995, FORTUNE rankings included only manufacturing firms. To avoid including firms that are only in the FORTUNE 50 due to the exclusion of non-manufacturing firms, we formed our sample using the FORTUNE rankings from 1995-2004.

completely eliminate these changes because the merger itself can create deferred tax assets and liabilities.[17]

Because most of the companies acquired by FORTUNE 50 firms are companies that are not part of the FORTUNE 50, constructing super-firms involves data collection on many small companies. This increases the number of firms in our sample in at least one year to 420; these firms combine to create 81 super-firms. Due both to limited availability of electronic filings in the early years of our sample and to the non-traded nature of some firms, the number of super-firms in our sample rises from 71 in the first year (1993) to 78 in the final year (2004). Appendix A lists the individual firms in our sample. Our analysis relies on super-firms rather than individual companies as our units of observation to preserve comparability across years. SFAS 109 mandates: (i) an income tax summary, which details the significant components of income tax expense; (ii) a rate reconciliation, which reconciles reported income tax expense with the amount that would result from applying the domestic federal statutory rate to pretax income; and (iii) a schedule of deferred tax positions, which provides information about DTAs and DTLs. Firms also are expected to disclose information regarding the amounts and expiration dates of loss and credit carry-forwards, the division of tax expense between continuing operations and all other items, the composition between domestic and foreign earnings before income taxes, and temporary differences for which the firm has not recorded a deferred tax liability, including permanently reinvested foreign earnings.

We match each firm-year observation with Compustat using both firm name and year, and validate the match using total assets and net income.[18] We collect the

[17]Our super-firm methodology will minimize differences due to non-taxable mergers accounted for as a pooling-of-interest. However, a non-taxable merger accounted for as a purchase will result in stepped-up basis for book but not tax, increasing deferred tax liability positions. While our methodology (taking the change between the merged firm and the sum of the target and the acquiring firm) will usually reduce the change relative to considering a change between the merged firm and the acquiring firm only, our methodology does not always eliminate the change caused by the merger.

[18]We collected tax information from the first 10-K or annual report filing for each fiscal year. Restatements may cause differences between the total assets and net income entries in the 10-K and those reported in Compustat. We hand-checked the 48 firm-years where neither AT nor NI corresponded to our hand-collected total assets and net income numbers. The majority of differences were due to small restatements. We dropped 17 firm-years, 15 for which Compustat did not have any data and two where a stub year or merger caused a mismatch.

tax summary, rate reconciliation, and the schedule of deferred tax positions from tax footnotes. There is substantial variation across firms in the level of detail presented in the tax footnote, although most firms follow a fairly stable reporting policy from year to year. Appendix B describes our procedure for disaggregating DTAs and DTLs into their component parts.

There are several data limitations inherent in our categorized data. First, our ability to categorize deferred tax assets and liabilities is dictated by the level of disclosure provided in the 10-K. Firms who disclose relatively few line items or use vague language hamper our categorization efforts. Second, SFAS 109 is a world-wide consolidated firm disclosure. Most firms are taxed in multiple jurisdictions, but they do not make jurisdiction-specific income tax disclosures. Rather than allocating DTAs and DTLs across jurisdictions in an arbitrary fashion, we assume that all DTAs and DTLs relate to federal temporary differences. Finally, there may be heterogeneity across firms in the auxiliary assumptions that are used to compute and present the value of DTAs and DTLs. We do not have any information regarding the detailed calculations underlying the tax footnotes, so we are unable to address such potential heterogeneity and its effects on our estimates.

## 3.4 Summary Findings

We begin our analysis by reporting summary statistics. Table 3.1 reports aggregate and median values of the estimated book-tax income gap, temporary differences, and the share of the book-tax income gap attributable to temporary differences for our super-firm sample. We define the book-tax income gap on a world-wide basis as Pretax Income less estimated Taxable Income, where Taxable Income is defined as Current Tax Expense divided by the maximum U.S. corporate statutory tax rate (35 percent throughout our sample). We calculate temporary differences as Deferred Tax Expense divided by 0.35. We present and discuss two alternative calculation approaches in Appendix C. The share measure equals the book-tax gap due to temporary differences divided by the total book-tax gap. While Compustat in principle collects the data necessary for both of these calculation, we find that Current Tax Expense in Compustat, which we calculate as the sum of TXFED, TXFO and TXS, is missing or zero for 25.2 percent of the firm-year observations. By comparison, Current Tax Expense is only missing or zero for 7.6 percent in the comparable set of firm-years in our hand-collected data. Deferred Tax Expense in Compustat, which we calculate as the sum of TXDFED, TXDFO and TXDS is missing or zero for 37.4 percent if the firm-year observations; it is missing or zero for 8.8 percent of the firm-year observations in the comparable component of our dataset. In light of these discrepancies, we use hand-collected data for the calculations throughout the paper.

The third through fifth columns of Table 3.1 present medians. The median share attributable to temporary differences is the median of the ratio estimated temporary differences/estimated total book-tax gap, calculated at the super-firm level. For the median firm in our sample, there is variation across years in the share of the imputed book-tax difference attributable to temporary differences, ranging from 61.3 percent in 1994 to 93.2 percent in 1999. In every year, however, estimated temporary differences comprise the majority of the estimated book-tax gap for the median super-firm in our sample.

In columns six through eight of Table 3.1, we report aggregate statistics. The aggregate share attributable to temporary differences is calculated as the sum of temporary differences across super-firms divided by the sum of the book-tax gap across super-firms. This measure offers further insight into the distribution of temporary differences. For example, in 2001 the median super-firm reports a positive book-tax gap and positive temporary differences but the aggregate figures are both negative. Just slightly less than half of the sample—43.6 percent—reports a negative book-tax gap in 2001 and it is on average significantly larger at ($2.942) billion than the average positive book-tax gap of $1.814 billion. The difference between the median and the aggregate (or the mean) arises because firms with large book-tax gaps or large temporary differences are more influential in the computation of the aggregate measure than in the computation of the median. For instance, the very large aggregate share attributable to temporary differences in 2002 is driven by AOL Time Warner

Inc., which reports a book-tax gap of ($46.254) billion but temporary differences of only ($1.42) billion.[19] Even though the aggregate ratio is less stable than the median ratio, both measures yield a similar inference: temporary differences are the largest component of the book-tax gap for the firms in our sample.

Table 3.2 presents additional information on the total market value and assets for the firms in our sample. Market Value of Equity is calculated as Compustat Common Shares Outstanding (CSHO) multiplied by fiscal year-end price (PRCC_F); all other variables are hand-collected. With regard to market value of equity (assets), our sample represents 39.2 percent (41.9 percent) of the Compustat universe in 2004 and averages 41.2 percent (40.3 percent) over our whole sample period.

The last four columns in Table 3.2 show the number of firms in each sample-year that report net deferred tax assets, the number that report net deferred tax liabilities, and the total value of these net deferred tax positions. The data demonstrate the heterogeneity in firm tax positions, as well as the evolution of these positions through time. In 1993, 31 of 72 super-firms report net deferred tax assets that total $52.2 billion, while the remaining 41 report net deferred tax liabilities totaling $79.7 billion. The proportion of net DTL firms increases through our sample period, and in 2004, 27 of 78 super-firms report net DTAs. While Neubig (2006) cites a recent survey that suggests that the majority of surveyed firms prefer a lower corporate tax rate to other incremental or fundamental tax reforms, Table 3.2 suggests that there is a significant minority of firms that would experience at least one adverse effect of such a rate reduction—a decline in the value of their DTAs.

Table 3.2 suggests a rising share of firms with net DTLs during our sample period. A net DTL, indicating cumulative book income higher than taxable income, could be due to a number of factors, including but not limited to aggressive financial reporting which raises pretax book income and aggressive tax reporting which lowers taxable income. In addition to showing an increase in the proportion of firms with a net DTL,

[19]There is not a lone culprit for the negative share attributable to temporary differences in 1998 but rather three super-firms that report large negative book-tax differences and either a small negative or a positive book-tax gap: Citigroup Inc., International Business Machines, and Johnson & Johnson. Removing these three super-firms results in an aggregate book-tax gap of $9.588 billion, 28.4 percent of which is attributable to temporary differences.

the table also shows that firms with a net DTL have larger deferred tax positions than firms with a net DTA. In 1993, the average net DTL is $2.0 billion while the average net DTA is $1.7 billion. The average net DTL increases by 122 percent during our sample period, to $4.4 billion in 2004, while the average net DTA increases by only 42 percent. This is consistent with the increase in DTLs over our sample period that was evident in Table 3.1.

Tables 3.3 and 3.4 explore the increases in temporary differences that have contributed to the rise in the book-tax income gap and present detailed information on the composition of deferred tax positions. Table 3.3 disaggregates deferred tax positions into their constituent components, and indicates the sources of the most important temporary book-tax differences. Table 3.4 separates DTA positions from DTL positions for components that do not consist almost exclusively of either assets or liabilities. We report means of these disaggregate measures to facilitate comparison across years with different sample sizes.

The results in Table 3.3 suggest some variation over time in the key sources of deferred tax positions within our sample. The most important source of deferred tax liabilities is Property. Early in the sample, the most important source is Benefits, which includes benefits related to current employees as well as retiree health benefits and pensions. This is not a surprise, because our sample begins in 1993 shortly after SFAS 106, *Accounting for Other Postretirement Benefits*, required firms to record liabilities for unfunded retiree medical costs. In the following decade, many companies eliminated or scaled back such coverage, thereby decreasing the DTA values associated with Benefits. By the end of the sample in 2004, Credits and Carryforwards replaces Benefits as the most significant deferred tax asset, although Benefits remains a major contributor. Although the economy had substantially recovered by 2004, many firms likely still have unused loss and credit carryforwards from the economic downturn of 2001.

While the overall ranking of various components of deferred tax assets does not change dramatically between 1993 and 2004, the magnitude of certain categories does. For example, deferred tax positions related to mark-to-market adjustments rise and fall with the general equity market. NOL Carryforwards increase 248 percent while Other Tax Credits and Carryforwards increase 148 percent, consistent with the extension of the carryforward period under the Taxpayer Relief Act of 1997. Deferred tax liabilities related to Property, Plant and Equipment (PPE) increase 45 percent. Possible explanations for the rise in PPE include special "bonus tax depreciation" that took effect in 2001 as well as the implementation of SFAS 142, which removed book amortization of intangible assets. Liabilities related to Intangible Assets and Leases rise 113 percent and 77 percent, respectively. Intangible Assets includes goodwill and is likely a result of substantial merger activity recently. Some fraction of the rise in leasing-related deferred tax components may reflect a rise in either, or both, of aggressive financial and tax reporting using leased assets. Table 3.3 also shows that book revenues rose relative to tax revenues during the 1990s, a result consistent with Plesko's (2004) study. The data in Table 3.3 suggests that the increase in temporary differences that contributed to the rise in the book-tax income gap was not driven by a single source, but was instead the result of increases in many deferred tax liabilities including Property, Subsidiary-Related Items and Valuation Allowance (the latter being a contra-asset).

In addition to describing which categories have contributed most to the rise in temporary differences, Tables 3.3 and 3.4 offers insight into the deferred tax positions that are more likely to be manipulated if managers foresee changes in statutory tax rates. Between 1993 and 2004, the stock of deferred tax assets related to total loss and credit carryforwards increased nearly 200 percent. While much of this increase was offset through increases in Valuation Allowances, the rise in loss- and credit carryforward-related deferred tax positions still suggests in the event of a pre-announced decline in the corporate tax rate, there would be strong incentives to accelerate the recognition of income, and thereby to utilize carryforwards at a higher tax rate than will prevail in the future. Table 3.4 separates deferred tax assets from deferred tax liabilities for sub-categories that include substantial assets as well as liabilities. Some categories, such as Revenue-Related, appear relatively small in Table 3.3 when the net deferred tax positions are presented, but represent a significant deferred tax asset for some firms and a significant deferred tax liability for others. For example, a firm that receives cash but has not yet provided the service may have to pay income tax on that cash but does not record revenue until the associated goods or services are delivered, and so will record an unearned revenue liability and a corresponding deferred tax asset. A firm with installment sales, for which it recognizes a gain for book purposes when the sale closes but recognizes the gain for tax purposes as the payments are received, will have a deferred tax liability. Disaggregating into the asset and liability positions for certain categories also allows us to see the effect of changes to book or tax calculation of these items.

SAB 101, published in late 1999, tightened guidelines regarding how companies can recognize revenue; SAB 104, published in late 2003, further curtailed aggressive financial recognition of revenue. Evidence in Table 3.4 is consistent with both of these pronouncements—the upward trend in the DTL for Revenue-Related slows beginning in 1999 and even reverses beginning in 2002.[20] Table 3.4 presents additional detailed information that may be helpful in understanding the contribution of temporary differences to the increase in the book-tax income gap.

The foregoing tables suggest that temporary differences are a significant portion of the book-tax income gap and provide evidence on the components of these temporary differences. We now explore the size of deferred tax positions relative to assets. This normalization is helpful for judging the importance of DTAs and DTLs relative to firm value. Table 3.5 reports the distribution of net DTAs and DTLs as a share of firm assets for each super-firm and for each individual firm. The net deferred tax balance is substantial for many firms. In 2002, for example, 35 percent of both super-firms and individual firms reported a net deferred tax position in excess of five percent of assets. Although the table does not show it, almost ten percent of both individual firms and super-firms had a net deferred tax position exceeding ten percent of assets. For super-firms, the maximum (minimum) net deferred tax position as a function of assets occurred in 2004 (1995) and was 14.5 percent (-31.9 percent). Overall, Table

[20]An alternative explanation for the observed trend in Revenue-Related deferred tax positions that we cannot rule out is the slowing economy.

3.5 suggests that while the majority of firms have a small deferred tax position relative to total assets, a nontrivial number have a more significant position.

Table 3.6 presents information similar to that in Table 3.5, but it distinguishes financial and non-financial firms. We have not separated these two groups in our earlier tables because we did not find a significant difference between them in the average (unscaled) size of the deferred balance positions or in the percent of the book-tax gap attributable to temporary differences. However, in Table 3.6, we separate financial and non-financial firms; their balance sheets appear to be affected differently by deferred tax positions.

Financial firms have relatively smaller deferred tax positions than non-financial firms, largely because their base of financial assets is so large. In every sample year, more than three-quarters of the financial firms in our sample have a net deferred tax position, either positive or negative, that represents less than three percent of total assets. About half of non-financial firms, in contrast, have deferred tax positions in this range. The extreme values of the ratio of deferred tax positions to firm assets are also smaller for financial than for non-financial firms. The maximum (minimum) Net Deferred Tax Position/Assets for a financial firm occurred in 1994 (1997) and was 16.2 percent (-18.5 percent) while the maximum (minimum) Net Deferred Tax Position/Assets for a non-financial firm occurred in 2001 (1995) and was 48.0 percent (-46.3 percent). For financial firms, the net deferred tax positions as a percentage of assets are distributed more tightly around zero than are the comparable positions for non-financial firms.

## 3.5 Temporary Differences and Firm Behavior

The presence of deferred tax positions on a corporation's balance sheet may affect several aspects of firm performance and create a range of incentives that may influence firm behavior. In this section, we describe several consequences of the presence of temporary differences. To focus attention on a concrete policy setting, we consider a situation in which the statutory corporate rate is expected to decline.

### 3.5.1 Income Re-Timing Incentives

Firms with deferred tax assets and liabilities face incentives to alter the timing of reported income in the periods immediately surrounding a tax rate cut. In the period prior to the rate cut, absent deferred tax considerations firms will want to shift current period income into the future to pay tax on that income at the lower future rate.[21] The presence of deferred tax liabilities should exacerbate this incentive—firms will also want to delay the reversal of deferred tax liabilities so the liability is settled at a lower rate than currently recorded. Firms with deferred tax assets, however, will want to receive the deferred benefits at the higher tax rate and so have an incentive to shift income into the current period.

Many firms hold deferred tax positions related to NOL carryforwards—they have carried the NOL as far back as is allowed and some NOL remains to offset taxable profit in future periods. In 2004, 37 percent of the individual firms in our sample had a beginning-of-year, NOL carryforward-related DTA that would likely be affected by a federal rate cut.[22] While firms with deferred tax assets related to NOL carryforwards have a strong incentive to create income in the final higher-tax-rate period in order to receive the benefit of the NOL carryforward at the higher rate, not all firms with a net NOL carryforward may be able to shift income. We assume that firms reporting taxable income have more scope to accelerate income than do firms currently in a tax loss position. In 2004, three of the firms with a net NOL carryforward are estimated to be in a tax loss positions, leaving 26 of the 78 firms with both a beginning-of-year net NOL Carryforward and positive estimated taxable income. This brief analysis indicates that nearly one third of our sample would have an incentive to accelerate income, as well as some capacity to do this. We are unable to extend this analysis to estimate the dollars of income these firms are likely to shift. However,

[21]Guenther (1994) discusses nontax costs that limit this type of tax rate arbitrage, including the cost of reporting lower financial income for debt covenants and management compensation. We acknowledge these constraints but do not measure them. Our estimates of the percent of firms who are likely to shift for NOL CF purposes may be considered an upper bound for the percentage of firms who are likely to undertake income shifting into the higher tax regime.

[22]In this calculation, we exclude disclosed state and foreign NOL carryforwards as well as carryforwards disclosed together with a tax credit (i.e., Credit and Loss Carryforwards.) The latter exclusion may cause us to understate the percentage of firms with a federal NOL carryforward.

based on Maydew's (1997) finding that the average firm in his sample shifts $11.2 million of income, or 1.5 percent of Net Sales, in response to a 12 percent decrease in the corporate income tax rate, we believe that the re-timing of corporate income associated with a change in statutory tax rates could be substantial. This suggests that revenue estimators should consider rate-motivated income shifting into their estimates of the short-run revenue effects of a change in the statutory corporate tax rate.

### 3.5.2 Preference for Tax Rate Change

Temporary differences generally do not affect net income but only affect cash flow. Both when they arise and when they reverse, temporary differences affect the allocation between current and deferred tax expense and therefore affect cash paid for taxes. Generally, the effect when the difference is recorded and when it reverses are equal and opposite. For example, when taxable depreciation exceeds book depreciation, cash outflow for taxes decreases, increasing cash flow relative to a situation in which book and taxable depreciation are equal. When this temporary difference reverses, book depreciation exceeds taxable depreciation and cash outflow for taxes increases. In both the period in which the temporary difference arises and the period in which it reverses, the temporary difference does not affect net income but does shift cash flow.

However, when tax rates change, the firm must revalue its deferred tax asset or liability, which in turn affects net income. Neubig (2006) and Mills (2006) argue that firms are very sensitive to the impact of tax reform on their reported earnings and recognize the potential income effect through revaluation of DTAs and DTLs. Managers who will report lower earnings as a result of these revaluations may be particularly concerned that analysts may inadvertently assume that these one-time effects are persistent. Chen and Schoderbek (2000) suggest that analysts did not understand the transitory nature of deferred tax revaluations around the 1993 tax rate change—a concern that might heighten managerial concern.

We illustrate the potential net income impact of deferred tax position revaluations with a counterfactual example in which the federal corporate income tax rate drops by five percentage points in 2004.[23] Using the data in Tables 3.1 and 3.2, we estimate the revaluation of beginning-of-year deferred tax positions.[24] We limit the sample to just those firms that report federal income tax separately. This limited sample includes 80.8 percent of our firm-year observations, representing 81.8 percent of sample adjusted net deferred tax positions. The revaluation calculations exclude deferred tax positions related to tax credits, including foreign tax credits. Because credits directly offset tax liability, rather than taxable income, a rate change will not affect their valuation.

Our results are presented in Table 3.7. A lower tax rate reduces federal tax expense on current period income and increases the period's net income; we refer to this as its "direct effect." This is a persistent and long-lived effect of the rate reduction. If the 2004 corporate tax rate had been reduced to 30 percent, the direct effect would have reduced federal tax expense by $147 million for the average super-firm. The average super-firm's net income in 2004 was $3,625 million, so this reduction in tax expense represents an increase in net income of 4.1 percent.

In the year of the rate change, net income reflects both the direct effect and the revaluation effect. While we might expect the deferred tax revaluation to be second-order, for many firms it is considerably larger than the direct effect. Our estimates in Table 3.7 suggest that for the average super-firm, the revaluation of 2003 deferred tax positions would have increased 2004 net income by $328 million, or 9.0 percent.[25] Our average super-firm would experience a 13.1 percent increase in net income—two-thirds of which is attributable to the revaluation effect. This effect, not surprisingly, differs across firms. For firms with net DTAs, the write-down of net DTA decreases net income, offsetting the positive net income effect of the reduction in the current

[23]While many other changes in the business environment, including changes in Generally Accepted Accounting Principles, also affect deferred tax positions, we consider a statutory rate change because it is broadly applicable and its impact is relatively easy to estimate.

[24]We assume no rate-change-motivated income shifting because we cannot estimate the effect of the income shifting.

[25]In results that are not reported here, we found that the median revaluation effect in 2004 would have increased net income by 2.1 percent. While the median effect is considerably lower than the mean effect of 9.0 percent, it is still substantial.

period's tax expense. For net DTL firms, on the other hand, the revaluation reduces the value of a balance sheet liability, which increases their net income. Net DTA super-firms in our sample would on average experience a $315 million revaluation decrease in net DTA and net income.[26] The lower tax rate would have decreased these firms' current tax expense and increased their net income by $103 million. On net, these firms would report a $212 million earnings decrease due to the rate change, a 7.7 percent decrease in their average net income of $2,755 million. Firms in our sample with a net DTL would experience, on average, a $677 million dollar revaluation decrease in their net DTL, and a matching net income increase.[27] They would also report $171 million less in taxes on income generated in the current period. DTL firms average $4,097 million of net income in 2004. For net DTL firms the revaluation effect reinforces the direct tax expense effect. Net income rises, on average, by 20.7 percent for our sample firms with a net DTL.

Although our estimates of DTAs and DTLs provide some guidance on the effects of statutory rate changes, there are several reasons for caution in evaluating our estimates. First, our assumption that all DTAs and DTLs relate to federal temporary differences may lead to some overstatement of the effect of U.S. federal income tax rate changes. Second, not all DTAs and DTLs are affected by statutory rate changes. Tax credit carry-forwards, for example, are not, because they are applied after the tax rate. We address this concern by removing credits from base deferred tax positions where possible when we estimate the revaluation effect of a tax rate change. We make the conservative assumption that any disclosure which includes credits, such as "Net Operating Loss and Credit Carry-forwards," is comprised entirely of credits.

### 3.5.3 Deferred Taxes and Corporate Tax Reform

A change in the corporate tax rate would affect firms through many channels. Our analysis highlights one aspect of corporate tax reform that is often overlooked: changes

[26]The median revaluation effect in 2004 for Net DTA firms would have decreased net income by 4.2 percent.

[27]The median revaluation effect in 2004 for Net DTL firms would have increased net income by 6.3 percent.

statutory rates will affect firms by requiring revaluation of their deferred tax assets and liabilities. This "temporary differences" channel will have divergent effects on firms with net deferred tax assets and those with net deferred tax liabilities, and it may lead their respective managers to have different reactions to tax reform and to pursue different strategies to shift income from the old to the new regime. Managers appear to be sensitive to the impact of tax reform on reported earnings. Chen and Schoderbek (2000) provide evidence that the market does not fully understand the impact of tax reform on reported earnings, providing some support for this concern. Our findings suggest that for some firms, the effects of some corporate tax reforms on the value of deferred tax assets and liabilities can be substantial. Managers at firms with significant net deferred tax assets may lobby against statutory corporate tax rate cuts, for example, if they are primarily concerned with the short-term effect of such policy changes on reported after-tax income.

The political history of tax policy changes is replete with examples of corporate groups with closely-aligned incentives affecting policy design. Hanna (2009) describes the policy debate surrounding corporate tax reform in 2003 and 2004. In that episode, corporate pressure from firms with accumulated net operating losses was one factor in Congress' decision to replace the extraterritorial income export incentive with a "qualified production activities" deduction, as part of AJCA, rather than a reduction in corporate tax rates. For firms with large net deferred tax assets positions, a rate cut would have generated substantial tax expense. Less than two months after the passage of AJCA, the Financial Accounting Standards Board (FASB) published its interpretation of the qualified production activities deduction as a special deduction, rather than a tax rate reduction, under SFAS 109. While firms with deferred tax liabilities would have preferred FASB treat the new qualified production activities deduction as a tax rate reduction, FASB's treatment is additional evidence that firms are concerned about the financial statement impact of tax rate changes.

In a different context, Neubig (2006) notes that one concern some firms may have about expanding investment incentives by adopting expensing is that expensing creates deferred tax liabilities that could be subject to revaluation if the corporate tax rate changes in the future. In the event of a corporate rate increase, this would reduce current earnings—an event that some managers may seek to avoid.

Ohio's recent corporate tax reform, described in *State and Local Tax Alert* (2005), illustrates how firms with substantial deferred tax positions may affect the tax legislative process. The reform legislation included three distinct forms of transition relief for firms that would lose deferred tax assets when the corporate income tax was replaced by a gross receipts tax. First, firms operating in Ohio under the income tax regime were encouraged to schedule the reversal of their temporary differences during the phase-out of the corporate income tax. To the extent that any temporary items would not reverse by the end of the phase-out, an adjustment for the estimated deferred tax position at the end of the transition period was recognized in income in the period in which the phase-out began. Second, certain deferred tax assets, primarily research and development tax credits, were retained as credits under the new activity tax regime. These credits are not recorded as assets on the financial books of the firm, however, because SFAS 109 applies only to taxes on income. Finally, there was special transition tax relief aimed at those firms with large NOL carryforwards, which would lose the ability to use these assets under the new tax regime. These policies provide transition relief to firms that were 'owed' tax relief under the income tax regime and that lost this prospective tax relief as a result of the tax reform.

## 3.6 Conclusions and Future Directions

This paper explores the role of temporary differences in contributing to the disparity between reported pretax book and estimated tax earnings for large U.S. corporations. Temporary differences comprise a substantial fraction of the book-tax income gap. Temporary differences that increase the book-tax income gap are larger than those that decrease it in our data sample. More than half of the firms in our sample have a net deferred tax liability, which reflects the accumulation of past excesses of book income over taxable income. Additionally, the average net deferred tax liability position is greater than the average net deferred tax asset position.

Firms exhibit substantial heterogeneity in their deferred tax positions. In 2004, more than forty percent of the firms in our sample of FORTUNE 50 companies reported a net deferred tax position valued at more than five percent of corporate assets. The observed heterogeneity suggests that firms may be affected in different ways by tax and accounting reforms. We estimate that roughly one third of the firms in our sample have strong incentives to shift income forward to maximize their use of NOL Carryforwards in response to a pre-announced reduction in the statutory corporate tax rate, while a large part of the sample likely has the opposite income shifting incentives. This heterogeneity also affects the net income impact of a statutory rate cut. If the corporate tax rate had been reduced by five percentage points in 2004, then the average firm in our sample would have experienced a $328 million increase in net income due to the revaluation of its deferred tax positions. The average revaluation effect for a firm with a net deferred tax asset position is a $315 million *decrease* in net income while the average revaluation effect for a firm with a net deferred tax liability position is a $677 million *increase*. Understanding the disparate incentives created by deferred tax asset and liability positions is important for crafting transitional relief associated with changes in the structure of the corporate income tax.

The prospective importance of deferred tax assets and liabilities in affecting firm behavior and firm incentives is possibly even greater than the findings from our sample suggest. Many corporations are likely to experience growing deferred tax assets as a result of the recession that began in 2007. While the recently-extended NOL carryback period will enable some firms to draw down their deferred tax assets, the new tax provisions will not affect all firms.[28] Moreover, as new financial products provide firms with potentially greater control over the timing of income recognition, the magnitude of their behavioral response to transitory tax incentives associated with deferred tax assets and liabilities may increase.

Our descriptive findings suggest a number of possibilities for future research. The

[28]The Worker, Homeownership, and Business Assistance Act, passed in November 2009, allows five-year NOL carryback for NOLs incurred in 2008 or 2009. This is only useful for firms with a tax loss in 2008 or 2009 who paid tax in 2003, 2004 or 2005, the newly accessible period that was not accessible under the prior two-year carryback rules.

detailed information on deferred tax positions that we have collected may provide a starting point for studying the interplay between financial accounting for taxes and various aspects of corporate behavior. One particularly interesting question is how managers respond to the incentives created by deferred tax assets and liabilities. Their responses might involve political action in support of, or opposition to, policies that would be beneficial to, or costly for, their firms, or might involve changes in the investment or financing policies that are designed to take advantage of opportunities, or minimize burdens, associated with deferred tax positions. It may, for example, be possible to investigate whether firms that are large contributors to the campaigns of legislators who serve on tax-writing committees are particularly sensitive to the nature of tax reform insofar as they have large deferred tax positions. Data such as that collected for the current project provides a much richer description of the potential heterogeneous effect of tax policies created by cross-firm differences than does the more aggregate data reported in machine-readable databases, and it consequently makes it possible to test more refined hypotheses about firm behavior.

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'ax Income Gap and Share Attributable to Temporary Differences

| of ms | Median Super-Firm Book-Tax Income Gap ($M) | Median Super-Firm Temporary Differences ($M) | Median Share Attributable to Temporary Differences | Aggregate Super-Firm Book-Tax Income Gap ($M) | Aggregate Super-Firm Temporary Differences ($M) | Aggregate Share Attributable to Temporary Differences |
|---|---|---|---|---|---|---|
| | $25.0 | ($2.5) | 67.08% | ($7,987.5) | ($14,368.0) | 179.9% |
| | 96.3 | 72.0 | 61.34 | 29,488.4 | 20,371.7 | 69.08 |
| | 115.9 | 47.4 | 64.10 | 31,022.9 | 22,762.2 | 73.37 |
| | 134.6 | 155.4 | 71.36 | 41,440.6 | 29,578.7 | 71.38 |
| | 117.5 | 136.2 | 67.69 | 33,839.3 | 19,123.2 | 56.51 |
| | 10.8 | 10.1 | 63.17 | 9,870.7 | (2,534.0) | -25.67 |
| | 251.0 | 245.7 | 93.20 | 83,660.6 | 67,123.7 | 80.23 |
| | 219.7 | 238.9 | 80.97 | 67,715.3 | 63,341.0 | 93.54 |
| | 180.8 | 142.0 | 82.22 | (20,192.0) | (26,220.9) | 129.86 |
| | 302.3 | 144.1 | 71.24 | 2,246.1 | 42,485.6 | 1,891.52 |
| | 736.0 | 477.1 | 75.62 | 139,877.3 | 68,004.2 | 48.62 |
| | 607.4 | 296.6 | 66.63 | 89,942.7 | 18,694.0 | 20.78 |

nd-collected. Sample includes firms ranked in the Fortune 50 from 1995-2004. To standardize firms across time, firms
;ion, or divestiture activity with the Fortune 50 ranked firm are included with the Fortune 50 ranked firm to create a
: Income gap is calculated as Pretax Book Income less Taxable Income, where Taxable Income is calculated as Current
he maximum corporate statutory rate of 35% in all periods. Temporary differences are calculated as Deferred Tax
Median Share Attributable to Temporary Differences is the median value of (Temporary Differences/Book-tax Income
:r-firm level. Aggregate measures are computed by summing all firms' book-tax gaps and temporary differences.

'haracteristics by Year

| Aggregate Market Capitalization of Super-Firms ($B) | Aggregate Total Assets of Super-Firms ($B) | Cross-sectional Standard Deviation of Net DTA ($B) | Super-Firms with Net DTA | | Super-Firms with Net DTL | |
|---|---|---|---|---|---|---|
| | | | Number | Aggregate Value ($B) | Number | Aggregate Value ($B) |
| 1,718 | 5,202 | 3.5 | 31 | 52.2 | 40 | -79.7 |
| 1,804 | 6,328 | 3.3 | 35 | 52.7 | 41 | -81.2 |
| 2,484 | 4,918 | 3.2 | 32 | 41.5 | 44 | -83.7 |
| 3,199 | 5,719 | 3.4 | 31 | 43.8 | 47 | -97.4 |
| 4,311 | 6,768 | 3.8 | 29 | 48.2 | 49 | -110.5 |
| 5,764 | 7,295 | 4.0 | 33 | 56.9 | 44 | -108.2 |
| 6,651 | 8,305 | 5.4 | 33 | 52.0 | 44 | -148.0 |
| 6,468 | 9,340 | 6.2 | 31 | 58.3 | 47 | -166.5 |
| 5,938 | 10,229 | 6.6 | 33 | 69.1 | 45 | -181.6 |
| 4,543 | 10,625 | 7.3 | 33 | 94.1 | 45 | -186.9 |
| 5,466 | 11,757 | 7.5 | 29 | 68.4 | 49 | -226.9 |
| 5,800 | 13,302 | 7.0 | 27 | 65.4 | 51 | -226.6 |

.nd-collected except as noted. Sample includes firms ranked in the Fortune 50 from 1995-2004. To standardize firms in merger, acquisition, or divestiture activity with the Fortune 50 ranked firm are included with the Fortune 50 ranked ı." Market capitalization is calculated as Common Shares Outstanding (Compustat CSHO) multiplied by Fiscal Year-ϽC_F).

s of Net Deferred Tax Positions ($M), Average per Super-Firm, 1993-2004

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ounts | 206 | 193 | 206 | 226 | 239 | 264 | 250 | 212 | 283 | 287 | 255 | 244 |
| | 242 | 241 | 235 | 312 | 380 | 441 | 459 | 452 | 514 | 655 | 434 | 482 |
| benefits | 519 | 522 | 526 | 481 | 432 | 365 | 348 | 328 | 335 | 395 | 377 | 318 |
| | -25 | -65 | -73 | -103 | -105 | -82 | -120 | -129 | -172 | -117 | -152 | -207 |
| | 165 | 168 | 161 | 174 | 174 | 214 | 265 | 310 | 369 | 509 | 524 | 575 |
| forwards | 18 | 22 | 18 | 1 | 2 | 4 | 9 | 11 | 5 | 5 | 5 | 11 |
| ryforwards | 182 | 190 | 183 | 176 | 197 | 186 | 214 | 215 | 241 | 379 | 435 | 452 |
| ed | 6 | 4 | 6 | 4 | 22 | 24 | 34 | 44 | 37 | 48 | -31 | -75 |
| | 15 | 16 | 18 | 9 | 13 | 15 | 12 | 17 | 8 | 5 | 2 | -5 |
| cquisition | 205 | 141 | 113 | 80 | 45 | 43 | 13 | -37 | 34 | 23 | 2 | 41 |
| | 23 | 22 | 27 | 17 | 11 | 4 | 4 | -9 | 1 | 11 | 25 | 28 |
| | 5 | 5 | 6 | 4 | 3 | 5 | 5 | 5 | 60 | 84 | 90 | 102 |
| | 454 | 451 | 463 | 456 | 489 | 548 | 556 | 628 | 398 | 517 | 413 | 545 |
| | -248 | -268 | -257 | -243 | -248 | -186 | -234 | -255 | -245 | -615 | -578 | -688 |
| | -40 | -55 | -55 | -48 | -36 | -39 | -65 | -75 | -97 | -129 | -169 | -197 |
| ts | -117 | -15 | -193 | -186 | -276 | -300 | -361 | -275 | -286 | -345 | -451 | -484 |
| | -148 | -142 | -143 | -179 | -166 | -152 | -327 | -385 | -394 | -142 | -351 | -315 |
| | -208 | -217 | -227 | -256 | -280 | -266 | -293 | -328 | -333 | -376 | -365 | -369 |
| ment | -1,479 | -1,448 | -1,416 | -1,450 | -1,500 | -1,468 | -1,584 | -1,600 | -1,707 | -1,989 | -2,057 | -2,148 |
| errals | -17 | -20 | -21 | -22 | -29 | -25 | -32 | -36 | -35 | -40 | -43 | -45 |
| | -139 | -113 | -114 | -125 | -132 | -205 | -220 | -210 | -219 | -197 | -178 | -93 |
| | 5 | 2 | -2 | -4 | -9 | -17 | -20 | -10 | -6 | -3 | -1 | 1 |
| | -13 | -9 | -17 | -14 | -23 | -41 | -161 | -260 | -237 | -153 | -219 | -240 |
| n Sample | 71 | 76 | 76 | 78 | 78 | 77 | 77 | 78 | 78 | 78 | 78 | 78 |
| e | 201 | 223 | 233 | 285 | 268 | 236 | 193 | 170 | 149 | 134 | 126 | 120 |

deferred tax positions are hand collected from income tax disclosures in 10-K and Annual Report filings and assigned based on frequency and monetary significance of disclosure items. Amounts presented here are annual averages per s defined in Table 3.1 and in the text.

t Components of Net Deferred Tax Positions ($M), Average per Super-Firm, 1993-2004

| | | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DTA | 269 | 276 | 303 | 391 | 452 | 501 | 542 | 536 | 534 | 681 | 572 | 633 |
| | DTL | -27 | -35 | -68 | -79 | -72 | -60 | -83 | -84 | -20 | -26 | -137 | -151 |
| enefits | DTA | 537 | 539 | 553 | 511 | 462 | 409 | 395 | 380 | 395 | 429 | 426 | 368 |
| | DTL | -18 | -16 | -27 | -29 | -30 | -43 | -46 | -52 | -60 | -34 | -48 | -50 |
| | DTA | 51 | 35 | 43 | 29 | 34 | 42 | 18 | 1 | 9 | 39 | 40 | 36 |
| | DTL | -76 | -99 | -115 | -133 | -139 | -123 | -138 | -130 | -181 | -156 | -192 | -243 |
| | DTA | 5 | 6 | 9 | 24 | 28 | 36 | 32 | 53 | 54 | 44 | 48 | 48 |
| | DTL | -45 | -61 | -63 | -72 | -64 | -75 | -97 | -128 | -151 | -173 | -217 | -246 |
| | DTA | 24 | 33 | 35 | 43 | 60 | 76 | 90 | 99 | 118 | 137 | 118 | 111 |
| | DTL | -18 | -29 | -29 | -39 | -39 | -52 | -56 | -55 | -80 | -89 | -150 | -186 |
| | DTA | 32 | 38 | 39 | 36 | 36 | 43 | 48 | 52 | 50 | 53 | 53 | 44 |
| | DTL | -17 | -22 | -21 | -27 | -24 | -28 | -36 | -35 | -41 | -49 | -52 | -49 |
| | DTA | 11 | 72 | 7 | 7 | 5 | 7 | 50 | 34 | 83 | 163 | 167 | 135 |
| | DTL | -127 | -87 | -200 | -193 | -281 | -307 | -411 | -309 | -369 | -508 | -617 | -619 |
| uisition | DTA | 210 | 143 | 118 | 86 | 62 | 59 | 27 | 28 | 58 | 49 | 28 | 73 |
| | DTL | -5 | -2 | -5 | -5 | -17 | -16 | -14 | -66 | -24 | -26 | -25 | -32 |
| | DTA | 35 | 33 | 35 | 30 | 27 | 18 | 16 | 18 | 22 | 25 | 40 | 44 |
| | DTL | -13 | -11 | -8 | -13 | -16 | -15 | -12 | -27 | -20 | -14 | -15 | -16 |
| | DTA | 44 | 46 | 46 | 44 | 54 | 61 | 47 | 36 | 50 | 116 | 131 | 136 |
| | DTL | -191 | -188 | -190 | -223 | -220 | -213 | -373 | -422 | -444 | -257 | -483 | -451 |
| :als | DTA | 22 | 16 | 18 | 18 | 15 | 17 | 7 | 6 | 8 | 2 | 2 | 2 |
| | DTL | -39 | -36 | -39 | -39 | -44 | -42 | -39 | -43 | -43 | -42 | -44 | -47 |
| | DTA | 50 | 49 | 53 | 75 | 85 | 91 | 96 | 118 | 135 | 152 | 157 | 164 |
| | DTL | -189 | -162 | -167 | -199 | -217 | -296 | -316 | -328 | -354 | -349 | -335 | -257 |
| | DTA | 7 | 5 | 3 | 2 | 2 | 2 | 7 | 5 | 7 | 7 | 8 | 10 |
| | DTL | -2 | -2 | -4 | -5 | -11 | -19 | -26 | -15 | -13 | -10 | -9 | -9 |

deferred tax positions are hand collected from income tax disclosures in 10-K and Annual Report filings and assigned based on frequency and monetary significance of disclosure items. Amounts presented are annual averages per super-ıents, which are primarily DTA or DTL, we do not present the DTA and DTL detail here.

Table 3.5: Distribution of Net Deferred Tax Positions as a Share of Firm Assets, 1993-2004

Super-Firm Sample

| Year | Sample Size | Firms with Net Deferred Tax Liabilities | | | Firms with Net Deferred Tax Assets | | |
|---|---|---|---|---|---|---|---|
| | | ≤ -5 % | -5 to -3 % | -3 to 0 % | 0 to 3 % | 3 to 5 % | ≥ 5 % |
| 1993 | 71 | 25.4% | 5.6% | 25.4% | 31.0% | 2.8% | 9.9% |
| 1994 | 76 | 27.6 | 5.3 | 21.1 | 35.5 | 6.6 | 3.9 |
| 1995 | 76 | 21.1 | 13.2 | 23.7 | 31.6 | 5.3 | 5.3 |
| 1996 | 78 | 23.1 | 6.4 | 30.8 | 25.6 | 10.3 | 3.8 |
| 1997 | 78 | 23.1 | 7.7 | 32.1 | 25.6 | 7.7 | 3.8 |
| 1998 | 77 | 22.1 | 9.1 | 26.0 | 28.6 | 7.8 | 6.5 |
| 1999 | 77 | 27.3 | 5.2 | 24.7 | 31.2 | 6.5 | 5.2 |
| 2000 | 78 | 25.6 | 5.1 | 29.5 | 28.2 | 5.1 | 6.4 |
| 2001 | 78 | 24.4 | 5.1 | 28.2 | 25.6 | 10.3 | 6.4 |
| 2002 | 78 | 23.1 | 7.7 | 26.9 | 26.9 | 2.6 | 12.8 |
| 2003 | 78 | 26.9 | 3.8 | 32.1 | 21.8 | 6.4 | 9.0 |
| 2004 | 78 | 25.6 | 9.0 | 30.8 | 19.2 | 7.7 | 7.7 |

Individual Firm Sample

| Year | Sample Size | Firms with Net Deferred Tax Liabilities | | | Firms with Net Deferred Tax Assets | | |
|---|---|---|---|---|---|---|---|
| | | ≤ -5 % | -5 to -3 % | -3 to 0 % | 0 to 3 % | 3 to 5 % | ≥ 5 % |
| 1993 | 201 | 21.9% | 6.5% | 21.4% | 38.8% | 4.0% | 7.5% |
| 1994 | 223 | 20.6 | 6.7 | 22.9 | 34.5 | 9.9 | 5.4 |
| 1995 | 233 | 17.2 | 8.6 | 27.0 | 32.6 | 7.3 | 7.3 |
| 1996 | 285 | 17.5 | 7.4 | 25.3 | 34.7 | 6.7 | 8.4 |
| 1997 | 268 | 16.8 | 7.1 | 20.1 | 36.9 | 9.0 | 10.1 |
| 1998 | 236 | 16.9 | 7.2 | 19.5 | 36.0 | 9.3 | 11.0 |
| 1999 | 193 | 20.2 | 5.7 | 18.7 | 38.3 | 7.3 | 9.8 |
| 2000 | 170 | 18.8 | 7.1 | 21.8 | 35.3 | 8.8 | 8.2 |
| 2001 | 149 | 18.8 | 5.4 | 22.8 | 32.9 | 7.4 | 12.8 |
| 2002 | 134 | 17.9 | 6.0 | 26.1 | 29.9 | 3.0 | 17.2 |
| 2003 | 126 | 22.2 | 6.3 | 27.0 | 23.0 | 10.3 | 11.1 |
| 2004 | 120 | 21.7 | 9.2 | 28.3 | 23.3 | 6.7 | 10.8 |

Note: All data are hand-collected. The distribution in the upper panel is calculated at the super-firm level; the distribution in the lower panel is calculated with each individual firm as its own observation.

Table 3.6: Distribution of Net Deferred Tax Positions as a Share of Firm Assets: Financial and Non-Financial Firms, 1993-2004

| Year | Sample Size | Firms with Net Deferred Tax Liabilities | | | Firms with Net Deferred Tax Assets | | |
|---|---|---|---|---|---|---|---|
| Financial Firms | | | | | | | |
| | | ≤ -5 % | -5 to -3 % | -3 to 0 % | 0 to 3 % | 3 to 5 % | ≥ 5 % |
| 1993 | 34 | 2.9% | 0.0% | 23.5% | 70.6% | 0.0% | 2.9% |
| 1994 | 34 | 2.9 | 0.0 | 29.4 | 50.0 | 11.8 | 5.9 |
| 1995 | 32 | 3.1 | 3.1 | 40.6 | 43.8 | 0.0 | 9.4 |
| 1996 | 36 | 5.6 | 2.8 | 44.4 | 36.1 | 2.8 | 8.3 |
| 1997 | 35 | 2.9 | 2.9 | 51.4 | 37.1 | 0.0 | 5.7 |
| 1998 | 33 | 6.1 | 3.0 | 48.5 | 36.4 | 3.0 | 3.0 |
| 1999 | 28 | 3.6 | 3.6 | 35.7 | 53.6 | 3.6 | 0.0 |
| 2000 | 24 | 8.3 | 4.2 | 37.5 | 50.0 | 0.0 | 0.0 |
| 2001 | 24 | 0.0 | 8.3 | 41.7 | 37.5 | 8.3 | 4.2 |
| 2002 | 23 | 4.3 | 4.3 | 43.5 | 43.5 | 4.3 | 0.0 |
| 2003 | 21 | 0.0 | 0.0 | 47.6 | 47.6 | 4.8 | 0.0 |
| 2004 | 18 | 0.0 | 0.0 | 50.0 | 50.0 | 0.0 | 0.0 |
| Non-Financial Firms | | | | | | | |
| Year | Sample Size | Firms with Net Deferred Tax Liabilities | | | Firms with Net Deferred Tax Assets | | |
| | | ≤ -5 % | -5 to -3 % | -3 to 0 % | 0 to 3 % | 3 to 5 % | ≥ 5 % |
| 1993 | 167 | 25.7% | 7.8% | 21.0% | 32.3% | 4.8% | 8.4% |
| 1994 | 189 | 23.8 | 7.9 | 21.7 | 31.7 | 9.5 | 5.3 |
| 1995 | 201 | 19.4 | 9.5 | 24.9 | 30.8 | 8.5 | 7.0 |
| 1996 | 249 | 19.3 | 8.0 | 22.5 | 34.5 | 7.2 | 8.4 |
| 1997 | 233 | 18.9 | 7.7 | 15.5 | 36.9 | 10.3 | 10.7 |
| 1998 | 203 | 18.7 | 7.9 | 14.8 | 36.0 | 10.3 | 12.3 |
| 1999 | 165 | 23.0 | 6.1 | 15.8 | 35.8 | 7.9 | 11.5 |
| 2000 | 146 | 20.5 | 7.5 | 19.2 | 32.9 | 10.3 | 9.6 |
| 2001 | 125 | 22.4 | 4.8 | 19.2 | 32.0 | 7.2 | 14.4 |
| 2002 | 111 | 20.7 | 6.3 | 22.5 | 27.0 | 2.7 | 20.7 |
| 2003 | 105 | 26.7 | 7.6 | 22.9 | 18.1 | 11.4 | 13.3 |
| 2004 | 102 | 25.5 | 10.8 | 24.5 | 18.6 | 7.8 | 12.7 |

Note: All data are hand-collected except as noted. The distributions are calculated with each individual firm as its own observation. The sample parallels that of the individual firm analysis in the lower panel of Table 3.5. Industry is determined using SIC codes obtained from Compustat; financial

Table 3.7: Mean Impact of Federal Statutory Rate Decrease to 30% ($M)

| Year | Number of Super-Firms | Mean Pre-tax Income | Mean Net Income | Beginning of Period Adjusted Net DTA | Revaluation Effect on NI | Current Period Federal Tax Expense | Direct Effect on NI | Total Effect on NI |
|---|---|---|---|---|---|---|---|---|
| **Panel A: All Super-Firms** | | | | | | | | |
| 1994 | 66 | 2,597 | 4,841 | -486 | 69 | 569 | 81 | 150 |
| 1995 | 69 | 2,897 | 1,629 | -463 | 66 | 615 | 88 | 154 |
| 1996 | 69 | 3,536 | 2,243 | -516 | 74 | 763 | 109 | 183 |
| 1997 | 72 | 3,608 | 2,530 | -574 | 82 | 769 | 110 | 192 |
| 1998 | 69 | 3,469 | 2,884 | -690 | 99 | 787 | 112 | 211 |
| 1999 | 69 | 4,562 | 3,012 | -580 | 83 | 1,121 | 160 | 243 |
| 2000 | 69 | 5,135 | 3,253 | -1,241 | 177 | 1,219 | 174 | 351 |
| 2001 | 71 | 3,049 | 1,933 | -1,466 | 209 | 578 | 83 | 292 |
| 2002 | 72 | 2,785 | 140 | -1,615 | 231 | 759 | 108 | 339 |
| 2003 | 73 | 4,520 | 3,100 | -1,438 | 205 | 876 | 125 | 330 |
| 2004 | 74 | 5,302 | 3,625 | -2,298 | 328 | 1,029 | 147 | 475 |
| **Panel B: Super-Firms with Beginning of Period Net DTA** | | | | | | | | |
| 1994 | 29 | 3,079 | 7,234 | 1,514 | -216 | 656 | 94 | -122 |
| 1995 | 31 | 3,820 | 2,448 | 1,414 | -202 | 778 | 111 | -91 |
| 1996 | 29 | 3,625 | 2,337 | 1,152 | -165 | 683 | 98 | -67 |
| 1997 | 30 | 3,859 | 2,552 | 1,280 | -183 | 658 | 94 | -89 |
| 1998 | 28 | 3,145 | 2,677 | 1,569 | -224 | 589 | 84 | -140 |
| 1999 | 32 | 4,089 | 2,645 | 1,590 | -227 | 881 | 126 | -101 |
| 2000 | 31 | 4,601 | 2,920 | 1,430 | -204 | 952 | 136 | -68 |
| 2001 | 26 | 3,749 | 2,459 | 1,857 | -265 | 608 | 87 | -178 |
| 2002 | 32 | 2,994 | 1,808 | 1,720 | -246 | 537 | 77 | -169 |
| 2003 | 28 | 3,623 | 2,493 | 2,865 | -409 | 629 | 90 | -319 |
| 2004 | 26 | 4,065 | 2,755 | 2,203 | -315 | 721 | 103 | -212 |
| **Panel C: Super-Firms with Beginning of Period Net DTL** | | | | | | | | |
| 1994 | 37 | 2,219 | 2,965 | -2,054 | 293 | 501 | 72 | 365 |
| 1995 | 38 | 2,145 | 960 | -1,995 | 285 | 482 | 69 | 354 |
| 1996 | 40 | 3,471 | 2,174 | -1,724 | 246 | 820 | 117 | 363 |
| 1997 | 42 | 3,428 | 2,514 | -1,898 | 271 | 849 | 121 | 392 |
| 1998 | 41 | 3,690 | 3,025 | -2,232 | 319 | 922 | 132 | 451 |
| 1999 | 37 | 4,971 | 3,329 | -2,457 | 351 | 1,329 | 190 | 541 |
| 2000 | 38 | 5,570 | 3,526 | -3,421 | 489 | 1,437 | 205 | 694 |
| 2001 | 45 | 2,644 | 1,629 | -3,387 | 484 | 560 | 80 | 564 |
| 2002 | 40 | 2,618 | -1,194 | -4,283 | 612 | 937 | 134 | 746 |
| 2003 | 45 | 5,079 | 3,478 | -4,116 | 588 | 1,029 | 147 | 735 |
| 2004 | 48 | 5,973 | 4,097 | -4,737 | 677 | 1,195 | 171 | 848 |

Note: All data are hand-collected. The sample is limited to firms who separately report Federal Tax Expense. We adjust Beginning of Period Net DTA for Credits as discussed in Section 3.4. All effects are calculated assuming a 30% Federal Statutory Tax Rate rather than the actual rate 35%.

# Appendix 3A: Sample Firms and Years in Sample

Our sample was constructed based on FORTUNE magazine's annual sales-based ranking of U.S. firms. The top 50 firms for each year from 1995 until 2004 were included in the sample. To mitigate the effects of changes in firm size in the net deferred tax analysis, the tax notes for all firms acquired or sold by FORTUNE 50 firms during the sample period were also included. For example, Berkshire Hathaway acquired General Re Corp in 1998, so the tax note information for General Re Corp was added to Berkshire Hathaway for years 1993–1997. Similarly, AMR Corp spun off Sabre in 2000, so going forward, tax note details for Sabre were added to AMR Corp for years 2000–2004. We use online firm histories and 10-Ks to research merger and acquisition activity. Four FORTUNE 50 firms were dropped due to insufficient disclosures: Fannie Mae, Freddie Mac, State Farm, and TIAA-CREF.

For the net deferred tax descriptive analysis, the main FORTUNE 50 firm and all of its acquired and divested components were combined into a singe aggregate firm observation, summing over the deferred tax and liability categories as well as total assets and market values.

The following 81 FORTUNE 50 super-firms are included in our sample: Aetna Inc, Allstate Corp., Albertsons Inc, Altria Group, American Electric Power Co., American International Group Inc, AmerisourceBergen Corp., Amoco, AMR Corp, AOL Time Warner Inc, Aquila Inc, AT&T Corp, Bank of America Corp, BellSouth Corp, Berkshire Hathaway Inc, Cardinal Health, CenterPoint Energy Inc, Chevron Texaco Corp., Cigna Corp, Citigroup Inc, Chrysler, Coca-Cola Co, Columbia/HCA Health, ConAgra Foods Inc, ConocoPhillips, Costco Wholesale Corp., Dell Computer Corp, Dow Chemical Co, Duke Energy Co, Dynegy Inc, Eastman Kodak, El Paso Corp., Enron Corp, Exxon Mobil Corp, Ford Motor Co, General Electric Co, General Motors Corp, Goldman Sachs Group Inc., Hewlett Packard Co., Home Depot Inc., Ingram Micro Inc., Intel Corp, International Paper Co, International Business Machines, ITT Industries Inc, J C Penney Corp Inc, J P Morgan Chase & Co, Johnson & Johnson, Kmart Holding Corp., Kroger Co., Lockheed Martin Corp, Loews Corp., Lowe's, Marathon

Oil Corp, MCI Worldcom, McKesson Corp, Merck & Co Inc, Merrill Lynch & Co Inc, MetLife Inc, Microsoft Corp, Morgan Stanley, Motorola Inc, PepsiCo Inc, Pfizer Inc, Procter and Gamble Co, Prudential Financial Inc, Safeway Inc, Sara Lee Corp, SBC Communications Inc, Sears Roebuck Co, Supervalu Inc, Target Corp., The Boeing Co., United Parcel Service Inc, United Technologies, Valero Energy Corp, Verizon Communications Inc, Walgreen Co, Walmart, Wells Fargo & Co, Xerox Corp.

The following 15 FORTUNE 50 firms are included in our sample as part of another super-firm: American Stores, included with Albertsons Inc; Bank One, included with J.P. Morgan Chase & Co; BankAmerica, included with Bank of America Corp; Bell Atlantic, included with Verizon Communications Inc; Chase Manhattan Corp, included with J.P. Morgan Chase & Co; Citicorp, included with Citigroup Inc; Compaq Computer, included with Hewlett Packard Co.; Conoco, included with ConocoPhillips; DuPont E I De Nemours & Co, included with ConocoPhillips; GTE, included with Verizon Communications Inc; Lucent, included with AT&T Corp.; Medco Health, included with Merck & Co Inc; Mobil, included with ExxonMobil Corp; Prudential Insurance, included with Prudential Financial Inc; Texaco, included with Chevron Texaco Corp.

# Appendix 3B: Classification of Deferred Tax Assets and Liabilities

Each deferred tax asset or liability category listed in a firms 10-K tax footnote is classified into one of the following aggregate categories:

- Allowances for doubtful accounts
- Employee benefits
- Other (non-pension) post-employment benefits
- Pensions
- NOL carryforwards
- Foreign tax credit carryforwards
- Other tax credits and carryforwards
- International activity-related
- Inventory
- Restructuring, merger & acquisition
- Oil & Gas, environmental
- Warranties
- Valuation allowances
- Expense-related
- Mark-to-market adjustments
- Intangible assets
- Leases
- Property, plant & equipment
- Regulated accruals and deferrals
- Revenue-related
- U.S. State-related
- Subsidiary-related

Items that were too vague to categorize (e.g., 'other adjustments'), included multiple categories (e.g., 'A/R and inventory reserves') or too unusual to warrant a category (e.g., 'Bond Premiums') were classified as 'Other'.

# Appendix 3C: Example of Calculations using the 2004 10-K of Coca Cola Co.

Baseline calculations, corresponding to entries in our dataset and tables:

Pre-tax book income =$6222 Taxable income =current tax expense/0.35 =$1213/0.35 =$3466 Book-tax income gap =$6222 - $3466 =$2756 Temporary differences =deferred tax expense/0.35 =$162/0.35 =$463 Permanent and other differences =book-tax gap less temporary differences =$2756 -$463 =$2293

While we believe the deferred tax method of calculating temporary differences suffers from fewer confounding factors than any other method, we present two alternative methods below. They, like our deferred tax method, contain noise, not bias.

Alternative Method I One alternative method of calculating temporary differences uses the rate reconciliation to calculate permanent and other differences, and then defines temporary differences as the resulting residual. Reconciling items total 12.9% of pre-tax income. This translates to $803 tax dollars of permanent and other differences (12.9% x pre-tax income of $6222) or $2294 of permanent and other differences ($803/0.35) for Coca Cola Co. in 2004. When the firm discloses the current/deferred break down for their total tax provision (i.e. current tax expense plus deferred tax expense equals total tax provision), this alternative method results in the same figures as calculated using the first method. However, jurisdiction-specific disclosures and the tax effect of non-recurring items often do not include current/deferred specifics. These disclosures confound this relationship and results in over- or under-stated temporary differences relative to the deferred tax expense method.

Alternative Method II A third method of calculating temporary differences uses the change in the net deferred tax position, divided by the tax rate. For example, for Coca

Cola, this would equal ($671-$235)/0.35. This alternative method results in a higher number than is calculated using the deferred tax expense. Text in the 10-K suggests that the discrepancy is due to a valuation allowance booked against foreign deferred tax assets. There are a number of other reasons why the change in deferred tax assets may not equal the deferred tax expense, including mergers and acquisitions, change in accounting standards and change in tax law or tax rates. As such, this method may also result in over- or understated temporary differences relative to the deferred tax method.

## CONSOLIDATED STATEMENTS OF INCOME

*The Coca-Cola Company and Subsidiaries*

| Year Ended December 31, | 2004 | 2003 | 2002 |
|---|---|---|---|
| **INCOME BEFORE INCOME TAXES AND CUMULATIVE EFFECT OF ACCOUNTING CHANGE** | **6,222** | 5,495 | 5,499 |
| Income taxes | **1,375** | 1,148 | 1,523 |
| **NET INCOME BEFORE CUMULATIVE EFFECT OF ACCOUNTING CHANGE** | **4,847** | 4,347 | 3,976 |
| Cumulative effect of SFAS No. 142, net of income taxes: | | | |
| Company operations | — | — | (367) |
| Equity investees | — | — | (559) |
| **NET INCOME** | **$ 4,847** | $ 4,347 | $ 3,050 |

Income tax expense (benefit) consists of the following (in millions):

| Year Ended December 31, | United States | State and Local | International | Total |
|---|---|---|---|---|
| **2004** | | | | |
| Current | **$ 350** | **$ 64** | **$ 799** | **$ 1,213** |
| Deferred | **209** | **29** | **(76)** | **162** |

A reconciliation of the statutory U.S. federal rate and effective rates is as follows:

| Year Ended December 31, | 2004 | 2003 | 2002 |
|---|---|---|---|
| Statutory U.S. federal rate | **35.0 %** | 35.0 % | 35.0 % |
| State income taxes—net of federal benefit | **1.0** | 0.9 | 0.9 |
| Earnings in jurisdictions taxed at rates different from the statutory U.S. federal rate | **(9.4)**[1,2] | (10.6)[7] | (6.0) |
| Equity income or loss | **(3.1)**[3,4] | (2.4)[8] | (2.0)[10] |
| Other operating charges | **(0.9)**[5] | (1.1)[9] | — |
| Write-down/sale of certain bottling investments | — | — | 0.7 [11] |
| Other—net | **(0.5)**[6] | (0.9) | (0.9) |
| Effective rates | **22.1 %** | 20.9 % | 27.7 % |

The tax effects of temporary differences and carryforwards that give rise to deferred tax assets and liabilities consist of the following (in millions):

| December 31, | 2004 | 2003 |
|---|---|---|
| Deferred tax assets: | | |
| Property, plant and equipment | **$ 71** | $ 87 |
| Trademarks and other intangible assets | **65** | 68 |

| | | |
|---|---|---|
| Equity method investments (including translation adjustment) | **530** | 485 |
| Other liabilities | **149** | 242 |
| Benefit plans | **594** | 669 |
| Net operating/capital loss carryforwards | **856** | 711 |
| Other | **257** | 195 |
| Gross deferred tax assets | **2,522** | 2,457 |
| Valuation allowance | **(854)** | (630) |
| Total deferred tax assets[1] | **$ 1,668** | $ 1,827 |
| Deferred tax liabilities: | | |
| Property, plant and equipment | **$ (684)** | $ (737) |
| Trademarks and other intangible assets | **(247)** | (247) |
| Equity method investments (including translation adjustment) | **(612)** | (468) |
| Other liabilities | **(71)** | (55) |
| Other | **(180)** | (211) |
| Total deferred tax liabilities | **$ (1,794)** | $ (1,718) |
| Net deferred tax assets (liabilities) | **$ (126)** | $ 109 |