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**Working Paper**

## Corporate Taxation, Capital Formation, and the Substitution Elasticity between Labor and Capital

CESifo Working Paper, No. 707

**Provided in Cooperation with:**

Ifo Institute – Leibniz Institute for Economic Research at the University of Munich

*Suggested Citation:* Chirinko, Robert S. (2002) : Corporate Taxation, Capital Formation, and the Substitution Elasticity between Labor and Capital, CESifo Working Paper, No. 707, Center for Economic Studies and ifo Institute (CESifo), Munich

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# Working Papers

## CORPORATE TAXATION, CAPITAL FORMATION, AND THE SUBSTITUTION ELASTICITY BETWEEN LABOR AND CAPITAL

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CESifo Working Paper No. 707 (1)

April 2002

Category 1: Public Finance

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ISSN 1617-9595



An electronic version of the paper may be downloaded

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# CORPORATE TAXATION, CAPITAL FORMATION, AND THE SUBSTITUTION ELASTICITY BETWEEN LABOR AND CAPITAL

## Abstract

This study provides some perspective on analyzing the effects of corporate taxation on capital formation. Our framework translates tax policy legislation into real outcomes, and identifies three parameters that play a central role in determining the impact on policy. The remainder of the paper focuses on the substitution elasticity between labor and capital. Several of the prominent studies representing the major contours of this research area over the past 40 years are examined. Our review of five general equilibrium studies indicates that alternative values of this elasticity matter a great deal for the welfare changes following from proposed tax reforms. The paper concludes with two lessons for tax policy analysis and some suggestions for future research.

JEL Classification: H25, H32.

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# **Corporate Taxation, Capital Formation, And The Substitution Elasticity Between Labor And Capital**

## **INTRODUCTION**

When discussing economic policy issues with President Harry Truman, Dr. Edwin Nourse (the first chairman of the U.S. Council of Economic Advisers) remarked "On the one hand...but then on the other hand..." After Dr. Nourse left the office, a somewhat frustrated Truman supposedly asked his assistant, John Steelman, "John, do you think you could find me a one-armed economist?"<sup>1</sup>

Analyzing corporate taxation and capital formation is two-handed economics. The economics literature has been reasonably successful in developing analytic frameworks and identifying the key parameters that determine the impact of tax policy on business capital formation. Less success has been achieved reaching consensus on the actual values of these key parameters. Consequently definitive judgments are elusive, and tax policy analyses need to be conditioned on a range of values.

This study provides some perspective on analyzing the effects of corporate taxation on capital formation. The second section begins by presenting a framework that translates tax policy legislation into real outcomes, and identifies three parameters -- the price elasticity of saving ( $\phi$ ), the capital elasticity of output ( $\alpha$ ), and the substitution elasticity between labor and capital ( $\sigma$ ) -- that play a central role in determining the impact of policy.

The remaining part of the paper focuses on the latter parameter, the substitution elasticity between labor and capital. The third section reviews several

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<sup>1</sup> I thank Liz Safly of the Harry Truman Library for her assistance in documenting this exchange.

empirical studies and approaches, and concludes that no consensus value exists. This range of plausible values would not matter for tax policy evaluation if the welfare changes following from tax reforms were relatively insensitive to alternative values of  $\sigma$ . The fourth section documents why the value of  $\sigma$  matters. Two lessons for tax policy analysis to be drawn from this study, as well as some thoughts for future research, are discussed in the concluding section.

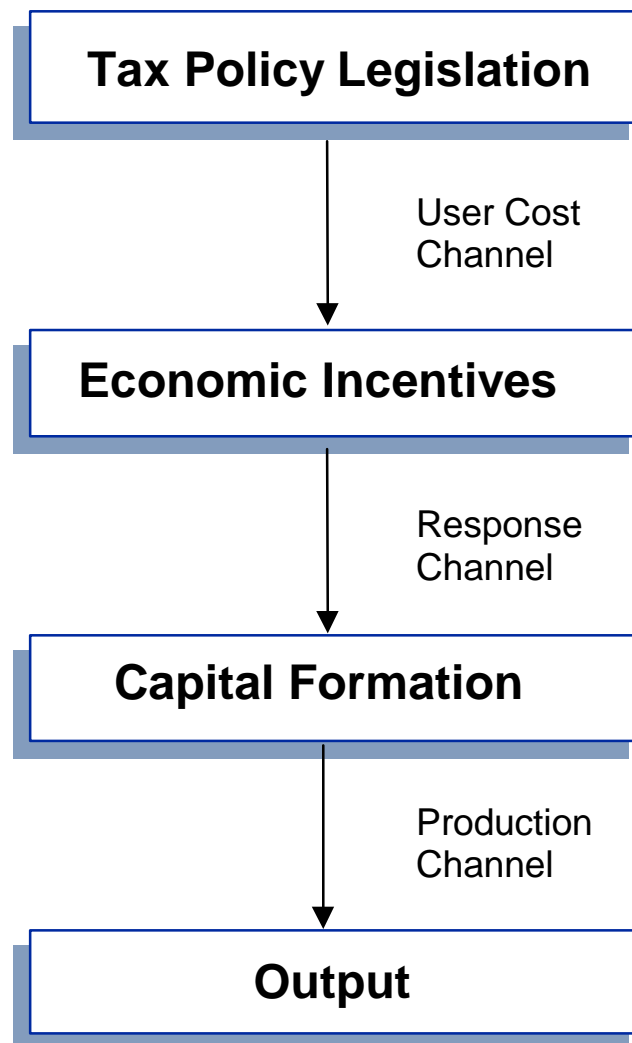
## **A FRAMEWORK FOR ANALYZING TAX POLICY**

This section presents a framework that traces the effects of tax policies affecting capital income from the initial legislation to changes in capital formation and output. Three key parameters determining the magnitude of the ultimate impact are highlighted. Tax policy affects real outcomes through the user cost, response, and production channels displayed in Figure 1. Each channel is discussed in the following three subsections.

### **The User Cost Channel: From Tax Policy To The User Cost**

The fundamental concept for quantifying the effects of tax legislation is the user cost of capital. This concept was introduced by Jorgenson (1963), was developed further by Coen (1969), Hall and Jorgenson (1971), and Jorgenson and Yun (2001), among others, and is based on the equivalence between renting and owning a piece of durable capital. With this insight, durable capital can be assigned a rental price (or user cost) that is easy to measure and easy to analyze with the standard tools of price theory. Furthermore, several tax policy instruments -- investment credits, depreciation allowances, and income taxes -- can also be quantified. The user cost provides an enormously convenient framework for translating the effects of legislated tax changes into numerical estimates useful in quantitative policy analysis.

**Figure 1**  
**A Framework For Tax Policy Analysis**



In its simplest form, the user cost of capital ( $C$ ) is the financial cost of capital or the opportunity cost of funds,  $R$ , as measured by the nominal interest rate ( $r$ ) less the expected rate of inflation ( $\pi$ ).<sup>2</sup> The definition of  $C$  needs to be broadened to incorporate economic depreciation, relative prices, and taxes. Economic depreciation can be viewed as a "nonrefundable security deposit" reflecting that only a fraction of the rented capital good will be returned because of depreciation. In the standard user cost formula, capital is assumed to depreciate geometrically at rate  $\delta$ , a representation equivalent to calculating the present value of a stream of deductions for a capital good depreciating according to a declining-balance pattern at rate  $\delta$ .<sup>3</sup> As with any microeconomic price variable, the user cost must be defined as a relative price. The numerator is the price of new investment goods ( $P^I$ ), and the denominator depends on an additional assumption about the benefit to the firm from the new unit of capital. For a profit-maximizing firm, the relevant benefit is the incremental output, and the price of output appears in the denominator.<sup>4</sup>

A variety of taxes can be reflected in the user cost formula. Policymakers have frequently stimulated capital formation by granting investment tax credits ( $k$ ) on the purchase of new capital goods. These credits are reductions in tax liabilities determined as a percentage of the price of a purchased asset. Additionally, since capital is durable,

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<sup>2</sup> The expected rate of inflation is frequently stated in terms of output prices. However, to be consistent with the theoretical derivation of the user cost, the inflation correction should be stated in terms of the price of new investment. The (largely anticipated) fall in the price of computing and related equipment suggests that inflation, stated in terms of capital goods prices, may have a substantial impact on estimated user costs for some assets.

<sup>3</sup> Even if capital depreciates according to some other pattern, long-run replacement requirements tend to a geometric pattern (Jorgenson, 1974).

<sup>4</sup> For the cost-minimizing firm producing a given level of output, the additional unit of capital allows the firm to use less labor, and the price of labor would appear in the denominator.

the purchase price is deducted as a business expense gradually over the life of the asset. The present value of this stream of current and future tax depreciation deductions ( $z$ ) is multiplied by the rate of income taxation ( $u$ ), and the combined expression enters the user cost formula as an adjustment to the purchase price. Income taxes also enter the model by lowering the price of output in the denominator and perhaps the financial cost of capital if nominal interest payments are tax deductible. Based on these considerations, the user cost of capital can be written as follows,

$$[1] \quad C = (R + \delta) (P^I / P^Y) (1 - k - u * z) / (1 - u),$$

where  $R = (1 - u)r - \pi$ . Equation [1] summarizes the incentives that a profit-maximizing firm faces when evaluating the acquisition of the marginal piece of capital.

This discussion of the user cost highlights a few of the points relevant to the construction of the user cost, and the reader is referred to the other symposium article by Mackie (this volume, especially Section 2) for further discussion.<sup>5</sup> The remainder of this sub-section highlights several key caveats that should be kept in mind in using equation [1] to assess tax policy. First, the user cost formula may not capture all aspects of tax legislation. For example, Ballentine (1986) estimates that only 8.1 percent of the dollar volume of corporate tax increases in the 1986 Tax Act (over a five year period) are reflected in the variables entering the standard user cost.

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<sup>5</sup> Note that Mackie analyzes effective tax rates, while this study focuses on the user cost of capital. Although closely related (see Mackie for details), it is the user cost concept that is relevant for the econometric analysis of capital formation.



Second, an important assumption is that the firm has sufficient profits to pay taxes. Absent this condition, tax credits and deductions are not immediately useful, and the calculation of tax incentives becomes complicated.<sup>6</sup>

Third, the specification of the financial cost of capital is more involved than indicated in [1]. This opportunity cost equals the real cost of the marginal source of funds -- retained earnings (internal equity), external debt, or external equity.<sup>7</sup>

Determining the marginal source of funds is important because the costs may differ among sources. For example, the Pecking Order model of Myers and Majluf (1984) indicates that asymmetric information between firms and investors leads to a hierarchy of financing costs increasing from internal equity to external debt to external equity. Additionally, the tax treatment of funding sources differs by the identity of the investor. Here we restrict our attention to differences in the gross-of-tax nominal costs of internal equity ( $r^{IE}$ ), external debt ( $r^{ED}$ ), and external equity ( $r^{EE}$ ), and write the opportunity cost of funds as follows,

$$[2] \quad R = w^{IE} r^{IE} + w^{ED} r^{ED} + w^{EE} r^{EE} - \pi$$

where the  $w$ 's are weights that sum to unity and  $r^{ED}$  will be multiplied by  $(1-u)$  if interest expenses are tax deductible.

With alternative weights, equation [2] can capture various specifications of  $R$  appearing in the literature. Equation [1] was based on the assumption that external debt

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<sup>6</sup> See Auerbach and Poterba (1987), Mintz (1988), and Altshuler and Auerbach (1990) for further discussion of tax incentives and tax law asymmetries.

<sup>7</sup> See Sinn (1991) for a taxonomy of different funding sources and the associated taxes, Auerbach (1983) for the relations between taxes and corporate financial decisions, and Harris and Raviv (1991) for a survey of capital structure theories.

was the marginal source of finance ( $w^{ED} = 1, w^{IE} = w^{EE} = 0$ ). The Pecking Order model implies an alternative specification in which the marginal source of finance changes over time, and hence the source of finance receiving a weight of unity would differ for a given firm in a given year. The financial cost of capital has also been constructed by weighting all three sources by stock weights (reflecting the return on a portfolio of the firm's securities) or flow weights (reflecting financing from the sources of funds statement). Which of these specifications of  $R$  is correct depends on the identity of the marginal investor.<sup>8</sup>

Fourth, related to the specification of  $R$ , firms whose cost of external finance exceeds that for internal funds receive two benefits from a tax cut. Changing internal finance affects the behavior of these financially constrained firms over and above the incentive represented by variations in  $C$ . A higher investment tax credit, for example, may have standard incentive effects on the demand for capital but, for financially constrained firms, the resulting increase in cash flow raises capital formation further than if the firm did not face finance constraints. This additional cash flow effect is unlikely to affect long-run capital formation, as most models of finance constraints imply that the constraint impacts capital accumulation only in the short-run.

Notwithstanding these caveats, the user cost defined by [1] and [2] provides a solid foundation for translating tax legislation into price incentives, and is an enormously useful device for capturing the incentive effects of taxation.

### **The Response Channel: From The User Cost To Capital Formation**

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<sup>8</sup> There has been a lively debate about the extent to which the corporate income tax distorts economic decisions that turns on, among other issues, whether the marginal source of finance is from debt (Stiglitz, 1973) or a weighted average of debt and equity defined by balance sheet weights (Harberger, 1962).

The second channel through which tax policy affects real outcomes quantifies the responses of demanders and suppliers of capital to price incentives. This response behavior is crucial. For example, consider a perfectly inelastic demand schedule in the market for business fixed capital. In this extreme case, firms have no margin along which to substitute, and tax policy via price incentives is unable to increase the capital stock.

Estimating the slopes of these schedules has been the focus of much research. For firms, the price elasticity of the demand for capital can be related to production function characteristics. If production is represented by a Constant Elasticity Of Substitution specification, then the price elasticity is identical to the substitution elasticity between labor and capital, which is represented as a parameter,  $\sigma$ .<sup>9</sup> The third section examines prior estimates of this parameter, and the fourth section documents the sensitivity of the impact of tax reform proposals to alternative values of  $\sigma$ .<sup>10</sup>

The elasticity of the supply schedule, which is denoted by  $\phi$ , is the other key parameter, and depends on two unsettled questions. First, how freely does capital flow

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<sup>9</sup> This equality does not hold for all production functions (e.g., the Translog or Generalized Leontief). See Berndt (1991, Section 9.4) for further discussion and elasticity formulas. When production is represented by a function strongly separable in the factors of production (e.g., Cobb-Douglas or Constant Elasticity), price and substitution elasticities are equal.

<sup>10</sup> It should be kept in mind that the response of the long-run capital stock to a change in tax policy depends on both a substitution effect via the user cost and a scale effect via the level of long-run production. This paper focuses on the substitution between capital and other factors of production, thus holding fixed the scale of operations. For a fall in the user cost, the scale effect is the sum of the higher production following from reduced operating costs and lower production due to compensating changes required to balance the revenue loss from the tax policy (absent Laffer curve effects). Additionally, with heterogeneous assets, the distribution of user cost changes can affect the scale of operation. Macroeconometric and computational general equilibrium models have been constructed to analyze these effects. Nonetheless, the substitution elasticity remains a key element to understanding the response of capital formation to price incentives (cf. Fox and Fullerton, 1991).

between countries? If capital is freely mobile among countries, then the supply schedule is flat, and domestic saving is unimportant for domestic capital formation. Feldstein and Horioka (1980) proposed an ingenious test -- if capital is mobile internationally, then the correlation between domestic investment and saving should be zero. In their original paper, Feldstein and Horioka find a correlation near unity; further tests have sustained this result, though the correlation has fallen over time.<sup>11</sup> If capital is less than perfectly mobile (as suggested by the Feldstein and Horioka test), then a second question arises: what is the sensitivity of domestic savings to changes in relative prices?

No consensus exists on the size of  $\phi$ , and the relevant evidence is too voluminous to be reviewed here. An appealing argument is that  $\phi$  is very large because capital markets have become increasingly open over the past few years and, at the margin, capital flows freely across countries in pursuit of the highest return. However, the free flow of capital internationally may be restricted by various frictions -- risk aversion and ignorance (Feldstein, 1994) or transactions costs (Obstfeld and Rogoff, 2000). While these frictions are surely important for many investors, it is not clear that they have a measurable impact on the marginal international investor. If these frictions or other factors impede the flow of international capital, then the price sensitivity of domestic saving becomes important for determining  $\phi$ . Estimates of the domestic saving elasticity have generally been quite low, though substantial elasticities have been reported in some studies.<sup>12</sup> However, this evidence is not directly relevant to the intranational market for business capital. This market absorbs only part of the flow of domestic

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<sup>11</sup> The Feldstein-Horioka test has been controversial. See Obstfeld (1995) for a review of this test and its implications for capital mobility.

capital, and is thus likely to have a very flat supply schedule. Thus, for several reasons, it would appear that the supply schedule is relatively flat ( $\phi$  is very large) and that saving does not constrain the impact of tax policy.

### **The Production Channel: From Capital Formation To Output**

The third channel connects capital to output. At the firm-level, the impact of capital is noncontroversial, and is determined by a production function exhibiting a declining marginal product of capital (MPK). If this property of the MPK carries over to the aggregate production function, then, along with some additional assumptions about saving, population growth, and resource utilization, we obtain the theory of economic growth pioneered by Robert Solow. In the face of declining returns, increments to the capital stock lead to ever smaller increments to output. In the long-run, the additional capital formation just covers the additional replacement needs of the capital stock, and no further growth of per capita output occurs unless it is driven by exogenous technical change. Thus, long-run growth is exogenous in the Solow model, and unaffected by policies aimed at raising capital formation.

New theories of growth have emerged in recent years in response to the apparent inconsistency of the aggregate empirical evidence with the Solow model. In these “endogenous growth” models, long-run growth can be increased permanently by government policy. The critical feature of these new theories is that the MPK for the aggregate economy does not decline because capital is assumed to have a direct effect on an individual firm's output and an indirect effect on the output of other firms. As in the Solow model, the direct effect of capital on a firm's output exhibits declining returns. Additionally, increases in a firm's capital also indirectly affect the output of other firms in the economy by increasing such factors as the stock of knowledge and the education

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<sup>12</sup> See the recent survey by Bernheim (2002) for a review of the empirical evidence.

of the work force. For example, investment by a handful of firms in personal computer technology produces knowledge that allowed many other firms to manufacture personal computers. As long as the indirect effect is sufficiently strong, the MPK for the economy as a whole does not decline. Without a declining MPK, policies aimed at spurring capital formation can raise growth in the long run.<sup>13</sup>

This debate between exogenous vs. endogenous growth models has been set in terms of the aggregate per capita production function, in particular, the exponent on capital,  $\alpha$ , in the Cobb-Douglas specification. (We note with concern the assumption of  $\sigma = 1.00$  implicit in this specification.) The  $\alpha$  parameter influences the critical MPK (holding labor constant). In the exogenous growth case,  $\alpha$  is the share of factor income (approximately 0.33 for the United States), and the MPK depends positively on  $\alpha$  and negatively on the capital stock. This parameter is nearly doubled if “capital” is broadened to include human capital (Mankiw, Romer, and Weil, 1992). In this case, capital has a more important role to play in production, but does not affect long-run growth rates. In the endogenous growth case,  $\alpha = 1.00$ , and the MPK is constant and independent of capital.

Discussing the evidence pertinent to the exogenous vs. endogenous growth model debate is beyond the scope of this paper. See Plosser (1992), Barro and Sala-i-Martin (1995), and Aghion and Howitt (1998) for reviews of exogenous and endogenous growth models and their policy implications, and Mankiw (1995) and Romer (1995) for an exchange concerning the appropriate model characterizing

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<sup>13</sup> There are alternative models for generating endogenous growth. The “AK model” generates a constant MPK by assuming that there exists a core subset of capital goods produced with a constant returns to scale production technology that depends only on reproducible factors (Rebelo, 1991). (Note that “AK” represents the productivity index (A) and capital stock (K), not the “Auerbach/Kotlikoff” model familiar to many public finance economists.) Endogenous growth can also occur if  $\sigma > 1$  (Pitchford, 1960; Barro and Sala-i-Martin, 1995).

long-run growth.<sup>14</sup> The author's reading of the evidence suggests that  $\alpha$  is very far below unity and hence that the exogenous growth model offers the most appropriate theoretical perspective on the long-run development of the economy.

### **Summary**

The translation of tax policy into real output depends on the three channels presented in Figure 1. This framework does not cover all of the tax code, nor all incentives impinging on firms, nor all factors affecting production. Furthermore, this framework abstracts from general equilibrium effects. However, it does focus on three key elasticities -- the demand for capital ( $\sigma$ ), the supply of capital ( $\phi$ ), and capital's role in aggregate production ( $\alpha$ ) -- determining the potency of tax policy. If demanders and supplies are very price sensitive ( $\sigma$  or  $\phi$  are large) or endogenous growth theory is appropriate ( $\alpha$  equal to unity), then tax policy has significant effects on output. Alternatively, if capital market participants are price insensitive ( $\sigma$  or  $\phi$  are small), then tax policy has a modest impact on capital formation and subsequently on output.

## **ESTIMATES OF THE SUBSTITUTION ELASTICITY**

Estimating  $\sigma$  has been an active area of research for many decades. Some of the prominent studies representing the major contours of this research area are displayed in Table 1 (which emphasizes recent work).<sup>15</sup> These elasticity estimates

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<sup>14</sup> A concern with endogenous growth models is that they are based on a knife-edge condition (what Solow has dubbed the "generalized Domar problem"). If the MPK is slightly greater than one, growth is explosive. If the MPK is slightly less than one, growth ceases in the long-run. No obvious mechanisms exist to keep the MPK at unity.

<sup>15</sup> See Chirinko (1993a, 1993b) for a more detailed review of prior studies.

are set into three different categories depending on whether the dependent variable is defined by aggregate investment, panel investment, or capital stock data. Table 1 clearly documents the wide range of  $\sigma$ 's estimated on U.S. data.

The earliest work by Jorgenson (1963) and Hall and Jorgenson (1967, 1971) was based on a Cobb-Douglas production function, and hence  $\sigma$  equals 1.00 by assumption. Eisner and Nadiri (1968) estimated  $\sigma$  freely, and found that the responsiveness of capital to its user cost was between 0.16 and 0.33. The gap has not been closed by subsequent research using aggregate investment data. A summary by Chirinko (1993a) found the elasticity estimates varied widely, but were generally small and less than 0.30.

Aggregate data have several drawbacks. There is a limited amount of variation relative to industry or firm-level datasets, and thus parameters may be imprecisely estimated. Furthermore, problems of simultaneity, capital market frictions, or firm heterogeneity may bias the estimated elasticities. Simultaneity bias arises because a positive shock to investment demand will raise interest rates (embedded in the user cost) either because the supply of saving is upward sloping or the monetary authorities attempt to moderate fluctuations. In either event, the regression error term and user cost variable will be positively correlated, and the estimated elasticity biased toward zero. Capital market frictions affecting different classes of firms (e.g., those that are highly leveraged) and their sensitivity to price incentives have been documented in many studies (see Fazzari, Hubbard, and Petersen, 1988, and the survey by Hubbard, 1998).

To address these concerns, recent research has explored the price sensitivity of capital with large panel datasets (in some cases containing approximately 25,000 firm/year observations). Cummins and Hassett (1992) and Cummins, Hassett, and



Hubbard (1994, 1996) estimate capital's responsiveness by focusing on those periods with major tax reforms in order to reduce measurement error in the user cost. They report somewhat large  $\sigma$ 's (but see footnote 1 to Table 1 for an alternative interpretation that lowers these estimates). Peter Clark (1993) uses a smaller panel for 15 classes of equipment assets, and reports  $\sigma$ 's ranging from 0.25 to his preferred estimate of 0.40. These estimates translate into  $\sigma$ 's for total capital of roughly 0.18 to 0.28.<sup>16</sup> With a large panel of firm specific data, Chirinko, Fazzari, and Meyer (1999) relate investment to current and lagged values of the user cost and sales (both expressed as percentage changes) and cash flow. They obtain a precisely estimated but small value for  $\sigma$  of 0.25.

Elasticity estimates from regressions with investment as the dependent variable may be biased for several reasons. If much of the variation in the data reflects transitory rather than permanent changes and firms respond less to transitory than permanent variation, an elasticity estimated with time-series data at quarterly or annual frequencies will tend to be lower than the "true" long-run elasticity. A further source of bias may occur because the dynamics of investment are difficult to formulate, and hence investment equations may contain specification error. Moreover, estimates based on investment data will be biased toward zero because they do not generally account for the effects of an upward-sloping supply curve for capital goods (Goolsbee, 1998).<sup>17</sup>

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<sup>16</sup> See footnote 2 in Table 1 for the computation of the total capital elasticity from the reported equipment elasticity.

<sup>17</sup> See Chirinko, Fazzari, and Meyer (2001) for further discussion of these biases.

**Table 1****Estimates Of The Elasticity Of Substitution**

	$\sigma$	Characteristics Of The Study
<u>A. Investment Data -- Aggregate</u>		
Jorgenson (1963)	1.00	Cobb-Douglas Production Function
Hall And Jorgenson (1967, 1971)	1.00	Cobb-Douglas Production Function
Eisner And Nadiri (1968)	0.16 to 0.33	CES Production Function
Chirinko (1993a)	0.00 to 0.30	Survey Of Econometric Estimates
<u>B. Investment Data -- Panel</u>		
Cummins And Hassett (1992)		Years Of Major Tax Reforms
Equipment	0.93 [0.23 <sup>1</sup> ]	
Structures	0.28 [0.07 <sup>1</sup> ]	
Cummins, Hassett, And Hubbard (1994, 1996)	0.67 [0.17 <sup>1</sup> ]	Years Of Major Tax Reforms
Clark (1993)	0.18 to 0.28 <sup>2</sup>	Fifteen Asset Classes
Chirinko, Fazzari, And Meyer (1999)	0.25	Variety Of Estimators
<u>C. Capital Stock Data</u>		
Lucas (1969)	0.30 to 0.50	Variety Of Specifications
Berndt (1976)	0.00 to 1.24	Variety Of Specifications
Berndt (1991)	0.97	Translog System

**Table 1 (continued)****Estimates Of The Elasticity Of Substitution**

	$\sigma$	Characteristics Of The Study
<b><u>C. Capital Stock Data</u></b>		
Jorgenson and Yun (2001)		Translog System
Corporate	0.50	
Noncorporate	0.70	
Caballero (1994)	0.28 to 0.65 <sup>2</sup>	Cointegration Relation
Caballero, Engel And Haltiwanger (1995)	0.70 <sup>2</sup>	Cointegration Relation
Chirinko, Fazzari, And Meyer (2001)	0.40	Averages In The Time Dimension
<b><u>D. Joint Committee On Taxation</u></b>		
Several Studies	0.20 to 1.00	Survey Of Simulation Models

<sup>1</sup> Chirinko, Fazzari, and Meyer (1999, Section 5) offer a different interpretation of this estimate that lowers this estimate to  $\sigma = 0.17$  because Cummins, et. al.'s econometric equation contains the level (rather than the percentage change) in user cost.

<sup>2</sup> The cited study presents elasticity estimates for equipment capital that are translated into a total capital elasticity by multiplying the reported elasticity by 0.70. This adjustment factor is obtained from the following calculation. Cummins and Hassett (1992) estimate separate elasticities for equipment and structures capital, and find that the equipment elasticity is larger by a factor of three. (An identical ratio is obtained by Pindyck and Rotemberg, 1983.) Assuming that equipment and structures have (stock) weights of 0.55 and 0.45, respectively, the elasticity for equipment and structures is computed from the equipment estimate (0.40 in this example) as follows,  $0.55 * 0.40 + 0.45 * 0.40 / 3 = 0.40 * 0.70 = 0.28$ .

A third class of studies is less susceptible to the problems of transitory variation and equation specification that plague models with investment data, and focuses on long-run relations between the capital stock and its determinants. One strand examines the direct relations between factors of production and relative prices, and estimates one or more of these first-order conditions in a system of equations. Lucas (1969) adjusts for various biases, and concludes that the most reasonable estimates of  $\sigma$  range from 0.30 to 0.50. Berndt (1976) presents a large number of estimates differing by equation specification, variable definitions, and estimation technique. Estimates of  $\sigma$  vary from 0.00 to 1.24, though the range is narrowed considerably to slightly above unity when better data are used. His preferred value of  $\sigma$  is obtained from a system of equations based on a translog technology and estimated with manufacturing sector data, and equals 0.97 (Berndt, 1991). The most recent estimates of a system of first-order conditions and other equations describing optimal firm behavior (based on a translog technology) have been computed by Jorgenson and Yun (2001). Their data cover the entire economy, and they obtain estimates of  $\sigma$  of 0.50 and 0.70 for corporate and noncorporate capital, respectively.

These estimates are based on the assumption that adjustment occurs rapidly and that the observed stocks of factors are reasonably accurate estimates of the long-run desired stocks.<sup>18</sup> Other studies using capital stock data attempt to account for the possibly distorting effects from sluggish adjustment. Caballero (1994) exploits the innovative idea that the user cost elasticity can be estimated in a

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<sup>18</sup> Pindyck and Rotemberg (1983) present a system of equations based on the translog technology that allows explicitly for dynamic adjustment. They obtain price elasticities for equipment and structures of -0.52 and -0.16, respectively. Note that in a translog system, these price elasticities do not equal the substitution elasticity between capital and labor.

cointegrating equation that includes the capital/output ratio and the user cost. Because cointegration is an asymptotic property, this estimate can be biased downward in finite samples. Using aggregate quarterly data for equipment capital and the Stock-Watson (1993) correction to adjust the estimates for the effects of transitory variation, Caballero obtains a range of elasticity estimates, from 0.40 to 0.93, depending on the number of lags used in the correction.<sup>19</sup> These elasticities approximately correspond to 0.28 to 0.65 for total capital. Caballero, Engel, and Haltiwanger (1995) estimate a model similar to Caballero (1994) with plant-level equipment stocks. They obtain a range of elasticities across two-digit industries from 0.01 to 2.00, with an unweighted average of approximately unity; the user cost elasticity for total capital is approximately 0.70. Chirinko, Fazzari, and Meyer (2001) addresses the issue of adjustment dynamics by averaging firm-level panel data over two separate intervals of years to measure the long-run values of the variables entering the first-order condition. The averaged data are differenced to eliminate possible distortions due to productivity growth and other factors, and then estimated as a cross-section. Their estimated value of  $\sigma$  for total business capital is 0.40.

The wide range of estimates of  $\sigma$  displayed in the first three panels of Table 1 remain in evidence in a recent study of tax modeling organized by The Joint Committee On Taxation (1997: Table 6). In this study, nine research groups participated in a common simulation exercise. As reported in Panel D, their elasticity estimates varied from 0.20 to 1.00. While recent advances in data and technique have narrowed the

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<sup>19</sup> For Japan, Kiyotaki and West (1996) specify a model that includes deviations of the desired from the actual capital stock. With quarterly aggregate data, they find that the short-run and long-run user cost elasticities are 0.05 and 0.07, respectively. The authors attribute these very small responses to transitory variation in the user cost series as represented by a pronounced tendency for mean reversion.

range of estimates somewhat, substantial ambiguity remains concerning the strength of the substitution channel for the demand for capital.

## WHY $\sigma$ MATTERS

The above discussion indicates the difficulty of reaching a consensus concerning the value of  $\sigma$ . This sizeable variation may be of little consequence if alternative values of  $\sigma$  have only a modest impact on policy evaluations. This section reviews why  $\sigma$  matters for tax policy, as well as for several macroeconomic issues.

### **Tax Policy**

The response of the capital stock to a tax policy change that is captured by the user cost depends fundamentally on  $\sigma$ . If saving is perfectly elastic, general equilibrium effects are absent, and production depends on a Constant Elasticity Of Substitution specification,  $\sigma$  is the sole determinant of the impact on the capital stock for a given change in the user cost. However, tax policies are usually evaluated in general equilibrium models that allow for more complicated responses with more complicated production technologies. Five general equilibrium studies using alternative values of  $\sigma$  are discussed in this sub-section.

Table 2 presents welfare changes due to various tax reforms relative to the distorted baseline specific to each study.<sup>20</sup> Row 1 reports computations from the original analysis by Harberger (1959) replacing the existing corporate income tax with a “neutral” capital tax, that is, equalizing capital income taxation on all firms in both the corporate and noncorporate sectors. The distortions from the existing

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<sup>20</sup> It should be noted with a combination of seriousness and amusement about the difficulty of building and simulating these general equilibrium models. The five papers discussed here average 3.2 authors.

corporate tax aggregated across industries amount to 1.66 percent of total capital income when  $\sigma = 0.5$ . This figure rises markedly to 2.48 percent if  $\sigma = 1.0$ . To quantify the sensitivity of these welfare changes to the substitution elasticity, we compute an elasticity,  $\zeta$ , equal to the percentage change in the welfare increment (due to the tax reform) based on different values of  $\sigma$  divided by the percentage change in  $\sigma$ . The  $\zeta$  elasticity isolates the contribution of a change in  $\sigma$  on the welfare increment following from a given tax reform. For the Harberger analysis,  $\zeta$  equals 0.50.

Four other sets of results reviewed in Table 2 are based on more recent and elaborate simulation models than used by Harberger, and alternative values of  $\sigma$  matter a great deal for most of these studies. In a simplified version of the Ballard, Fullerton, Shoven, and Whalley (1985) computational general equilibrium (CGE) model, national income rises by 6.78 percent when capital tax rates are equalized across industries (as in Harberger's study) and the production function depends on a  $\sigma$  of 0.50. This increase becomes 11.48 percent and 16.89 percent when  $\sigma$  equals 1.00 or 1.50, respectively. The  $\zeta$ 's associated with the successively higher values of  $\sigma$  are 0.69 and 0.94, respectively. Engen, Gravelle, and Smetters (1997) show that, when a comprehensive income tax is replaced by a consumption tax, the increase in steady-state net output is 3.80 percent, 6.80 percent, and 9.50 percent higher than the benchmark for  $\sigma$  equal to 0.50, 1.00, or 1.50, respectively. The value of  $\zeta$  is identical for either change at 0.79. Results from the two-country model of Roeger, Veld, and Woehrmann (2000) are also sensitive to whether  $\sigma$  is 0.50 or 1.00; a one percentage point cut in one country's corporate tax rate generates a  $\zeta$  of 0.71 for this increase in  $\sigma$ . Contrasting results are obtained with the overlapping generations model of Altig, Auerbach, Kotlikoff, Smetters, and Walliser (2001).

They report that national income rises by 4.3 percent when the current tax system is replaced by a flat tax and  $\sigma$  equals 0.8. When  $\sigma$  equals 1.0, the response of national income rises modestly to 4.5 percent. The associated  $\zeta$  is only 0.19.<sup>21</sup>

Two conclusions emerge from our review of these simulation studies. First,  $\sigma$  is a crucial element in the implied welfare changes following from proposed tax policies in four of the five studies reviewed in Table 2. A second and unexpected finding for the four studies sensitive to the substitution elasticity is that the impact of alternative values of  $\sigma$  have similar impacts on the estimated welfare changes. This sensitivity is measured by  $\zeta$ , which ranges between 0.50 to 0.94. The models seemingly have quite different structures, and the narrow range of  $\zeta$ 's is thus surprising. This similarity may be related to the results generated by Fox and Fullerton (1991), who find that, in CGE models, estimated welfare gains from tax reforms depend much more on  $\sigma$  than on the complex features and detailed disaggregation found in many simulation models.

### **Macroeconomic Policy**

While the primary focus of this article is on tax policy, this sub-section notes that  $\sigma$  also plays a large role in several macroeconomic debates. The price sensitivity of capital is important in the long-standing controversy about how

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<sup>21</sup> Why  $\zeta$  is so much lower in the Altig, et. al. study is not immediately apparent. One conjecture is that the more complicated tax modeling in Altig et. al. reduces the role of substitution in production. This muted response occurs because, prior to the tax reform, agents had several margins to attenuate distortions. Under this interpretation, the degree of substitutability becomes less important in a complicated tax environment. Important differences may also arise because of the adjustments made to the models when changing  $\sigma$ . Simulation models are calibrated to a benchmark steady-state and, when a parameter is altered, some offsets must be undertaken to restore the benchmark.



**Table 2**  
**Sensitivity Of Welfare Changes To The Substitution Elasticity**

Welfare Measure		Welfare Changes (Percent Relative To The Baseline)		
		$\sigma = 0.5$	$\sigma = 1.0$	$\sigma = 1.5$
1. Harberger	Total Capital Income	1.66 [ $\zeta=0.50$ ]	2.48	N.A.
2. Ballard, et. al.	National Income	6.78 [ $\zeta=0.69$ ]	11.48 [ $\zeta=0.94$ ]	16.89
3. Engen, et. al.	Net Output	3.80 [ $\zeta=0.79$ ]	6.80 [ $\zeta=0.79$ ]	9.50
4. Roeger, et. al.	Consumption In Two Countries	1.78 [ $\zeta=0.71$ ]	3.04	N.A.
		<del><math>\sigma = 0.8</math>   <math>\sigma = 1.0</math></del>		
5. Altig, et. al.	National Income Per Effective Labor Unit	4.30	4.50 [ $\zeta=0.19$ ]	

N.A., Not Available. The entries (not in [brackets]) are the percentage changes in welfare due to various tax reforms relative to the pre-reform baseline,  $\sigma$  is the elasticity of substitution between labor and capital, and  $\zeta$  is the elasticity defined as the percentage change in the welfare increment (due to the policy reform) based on different values of  $\sigma$  divided by the percentage change in  $\sigma$  (using the lower value of  $\sigma$  as the base). Sources and simulations: Row 1, Harberger (1959, pp. 241 and 243), the entry for  $\sigma = 0.5$  is interpolated linearly from the published figures for  $\sigma = 0.0$  and  $\sigma = 1.0$ ; simulation: equalize capital tax rates across industries. Row 2, Ballard, Fullerton, Shoven, and Whalley (1985), as reported in Fox and Fullerton (1991, Table 1, Row 1); simulation: equalize capital tax rates across industries. Row 3, Engen, Gravelle, and Smetters (1997, Table 5); simulation: replace a comprehensive income tax by a consumption tax. Row 4, Roeger, Veld, and Woehrmann (August 2000, Table 2); simulation: reduce the corporate income tax rate in one country. Row 5, Altig, Auerbach, Kotlikoff, Smetters, and Walliser (2001, Tables 4 and 5); simulation: institute a flat tax.

monetary policy impacts real variables. The “interest rate channel” maintains that monetary policy affects real activity by altering bank reserves, changing short-term interest rates and, through the term structure, changing long-term interest rates. With a large  $\sigma$  and the implied large price elasticity, monetary policy can have an important effect on business investment spending. However, if  $\sigma$  is small, it is difficult to appeal to the interest rate channel to explain why money affects the aggregate economy via business capital formation. As a consequence, some researchers favor a “credit channel” that assigns a large role to firm-specific characteristics in understanding the transmission of monetary policy into real outcomes (e.g., Bernanke and Gertler, 1995).

Implicit assumptions about  $\sigma$  play a key role in real business cycle models. Most production function specifications in this class of models are Cobb-Douglas, and hence assume  $\sigma$  equals 1.0. Thus, the ability of RBC models to reproduce certain features of macroeconomic data is based in part on capital formation (defined in terms of foregone consumption) being quite responsive to variations in its price. Such a substantial response is not supported by the econometric evidence reviewed in Table 1.

The substitution elasticity is also central to the analysis of long-run growth. The relative contributions of technological change and factor accumulation in accounting for long-run growth depend on  $\sigma$  (Acemoglu, 2001), which has further implications for the importance of biased technological change. Even if technological progress is absent, long-run growth is possible if  $\sigma$  exceeds one (Pitchford, 1960; Barro and Sala-i-Martin, 1995). In the Solow growth model,

Klump and Preissler (2000) show that  $\sigma$  is negatively related to the speed of convergence toward the steady-state (if the economy has overaccumulated capital) and positively related to steady-state per capita output. However, the latter result is not robust; in a Diamond overlapping generations model, Miyagiwa and Papageorgiou (forthcoming) show that  $\sigma$  and steady-state per capita output are negatively related (provided  $\sigma$  is sufficiently large). Based on the Solow model, Mankiw (1995, p. 287) presents a formula for computing the impact of  $\sigma$  on the difference in rates of return on capital between rich and poor countries. When  $\sigma = 4.0$ , the rate of return difference is only 3 percentage points (assuming a return of 10 percent in the rich country and a capital elasticity in production of  $2/3$ ). However, as  $\sigma$  is lowered to 1.0 or 0.5, the differences become implausibly large, rising to 32 and 100 percentage points, respectively. If  $\sigma$  is near or below one, then serious doubts exist about the validity of the Solow growth model as conventionally formulated.

### **CONCLUSIONS FOR TAX POLICY ANALYSIS AND DIRECTIONS FOR FUTURE RESEARCH**

For the tax policy analyst, two general lessons emerge from this study of corporate taxation and capital formation. First, there is a reasonably well developed framework for translating tax policy legislation into real outcomes. Key to this framework is the user cost of capital, which transforms tax policy into a relative price that is amenable to the standard tools of economic analysis. Three parameters -- the price elasticity of saving ( $\phi$ ), the capital elasticity of output ( $\alpha$ ), and the substitution elasticity between labor and capital ( $\sigma$ ) -- largely determine the magnitude of the response.

The second lesson is that tax policy analysis must be undertaken with a range of parameter values. Our review of the empirical evidence bearing on  $\sigma$  suggested that no consensus exists for estimates of this parameter (Table 1) and that welfare implications depend on alternative values (Table 2). Similar uncertainty and sensitivity exist for the other two parameters. Consequently, there is a need for sensitivity analysis in the evaluation of tax policy. Such an analysis might use  $\sigma = 0.40$  as the benchmark value, and offer alternative simulations with  $\sigma$ 's of 0.20 and 0.60 as lower and upper bounds, respectively. There is little support for using the Cobb-Douglas value of  $\sigma = 1.00$ . Given the current state of knowledge, analyzing corporate taxation and capital formation remains two-handed economics.

How might future research best be directed to improve tax policy analysis? First, analysts need a better understanding of the fundamental factors driving tax-induced welfare changes in CGE models. Increases in the sophistication of solution algorithms, the power of computers, and the ingenuity of researchers has led to larger, more complicated models. What are the key factors driving these models? Which core relations and the associated parameters largely determine the results? "Simple" analyses in the spirit of Fox and Fullerton (1991) would be welcome.

Second, better measures of the user cost of capital are needed. This concept is fundamental to tax policy analysis because it translates the intricacies of the tax code into a single price variable. However, there are many complexities not easily represented in the standard user cost; some have been mentioned here and many others are discussed by Mackie (this volume). Developing and computing user cost variables that go beyond the standard formulation is key to understanding existing distortions and the benefits of tax policy reform.

A third and related suggestion concerns estimates of the key parameters. As indicated by the framework presented in Figure 1, movements in the user cost are only part of the story of any tax reform. The response and output channels translate these policy-induced user cost changes into real outcomes. Regarding  $\sigma$ , the recent models focusing on capital stocks (Table 1, Panel C) overcome several important econometric problems, and offer much promise. That promise can only be fulfilled with firm-specific user cost data that varies through time and accurately represent the price incentives faced by firms.

### ACKNOWLEDGEMENT

The author gratefully acknowledges helpful comments from Dale Jorgenson, Jay Mackie, and Kent Smetters and especially careful and useful suggestions from the editor, Rosanne Altshuler. Parts of this paper are drawn from Chirinko (2001) and Chirinko, Fazzari, and Meyer (1999, 2001). All errors, omissions, and conclusions remain the sole responsibility of the author.

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