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Irreversible Investment and Endogenous Financing: An Evaluation of the Corporate Tax Effects

by

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Abstract

We evaluate the effects of corporate taxation on firms' investment and financing choices. We focus on how the asymmetry of the corporate tax, imperfect loss carry-overs, endogenous financing with credit constraints, and different degrees of investment irreversibility affect both incremental investment and entry decisions. We find that, as long as capital can be financed with debt at the margin, the tax distortions on the marginal investment decision are small. This is particularly so if the technology is flexible. In contrast, the tax distortions on the entry decision are substantial. The ability of firms to carry over their losses and choose their financial structure endogenously are important for reducing both types of distortions.

JEL classification codes: E2, G3, H2.

Key words: Irreversible investment, corporate finance, asymmetric taxation.

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I. Introduction

It has been nearly seven decades since the corporate tax was first introduced in the United States. Since then, the effects of this tax have remained an important policy debate because of its influence over investment, efficiency, and government revenue. It is well-known that if the corporate tax base were economic profits, then i) the corporate tax system would be neutral, ii) firms' investment decisions would be efficient, and iii) the government would raise revenue if and only if average economic profits were positive. However, the U.S. corporate tax, as in most countries, is not a simple tax on economic profits, and a number of issues complicate the assessment of its effects. First, the government does not allow firms to deduct the entire opportunity cost of their capital. The cost of capital financed with equity, for example, is not deductible while the cost of capital financed with debt, the interest expense, is. Therefore, the extent to which the opportunity cost of the firms' capital is tax-deductible depends on the firms' choice of financing instruments,[1] governed in part by their ability to borrow. Second, the corporate tax system is asymmetric, in the sense that taxes are payable immediately if taxable income is positive, whereas losses are not refundable at the full corporate tax rate. Instead, losses can be carried back to offset previously taxed income, or carried forward to offset future income. Because there are limitations[2] on carry-backs and carry-forwards, these provisions partly correct, but do not eliminate the asymmetry of the

[1] In this paper, we do not consider the difference between true economic depreciation and capital cost allowance.

[2] Losses can be carried back for three years in the U.S. and in Canada. Losses can be carried forward for fifteen years in the U.S. and for seven years in Canada. Most European countries have less generous provisions. No interest is paid on carry-backs or carry-forwards.

corporate tax system. And third, capital takes time to build, and once built, most costs cannot be recovered, so firms may be "stuck" with more capital than they later desire. With uncertainty, such investment irreversibility increases the opportunity cost of capital. And the presence of a corporate tax further exacerbates this effect because the cost of capital inflexibility is not a deductible expense.

The objective of this paper is to evaluate the effects of the corporate tax on firms' investment and financing decisions in a model that replicates some of the main features of this tax in the United States: the tax system is asymmetric, although losses can be carried back or carried forward with limitations. Further, firms' financing choices are endogenous, but they face a credit constraint, namely, the amount of debt in each firm cannot exceed the value of the firm's capital stock (or a certain portion of this value). Also, firms operate in an uncertain environment, where the output price is not known at the time decisions are made. Lastly, firms' investment is subject to an irreversibility constraint. In the remaining section, we explain why each of these features matters.

An asymmetric corporate tax system is one in which the government does not treat firms' gains and losses equally. When taxable income is positive, taxes have to be paid immediately. When taxable income is negative, however, firms are not entitled to a refund at the full corporate tax rate. Rather, as explained above, the government allows a partial carry-over of losses. This asymmetry discourages risky investment in the corporate sector, as the government does not share firms' downside risks and the expected return on capital is

lowered as a result (Domar and Musgrave [1944] and Stiglitz [1969]).[3] Obviously, partial carry-over of losses mitigates, but does not eliminate this disincentive. Nonetheless, the ability to carry back or carry forward losses *is* an important consideration because it creates a link in the firms' investment choices across periods. For instance, firms maybe more willing to risk a loss this year if they expect that this loss could be used to shelter a profit next year.

Corporate taxes affect both firms' investment and financing decisions, and they make these decisions interdependent (Cooper and Franks [1983], Mayer [1986], Dammon and Senbet [1988], Mauer and Triantis [1994]). Corporate taxes affect firms' financing decisions because of the differential tax treatment of the opportunity cost of capital financed with debt and equity (Modigliani and Miller [1963], Miller [1977], DeAngelo and Masulis [1980], and Keen and Schiantarelli [1991]). Because of this differential tax treatment of debt and equity, the after-tax opportunity cost of capital and hence, investment, depend on firms' financing decisions. Real distortions caused by the tax system are often exaggerated in previous research because firms' financing decisions are not taken into account. When the latter is endogenous, it may cushion some of the adverse effects of the corporate tax asymmetry and uncertainty on investment (Mayer [1986]). At the same time, as a result of the corporate tax asymmetry and uncertainty, investment has an important influence on firms' financing decisions. For example, a change in investment-related expenses such as depreciation will affect the expected value of the firms' debt tax shield (DeAngelo and Masulis [1980] and

[3] Other papers that study the effects of limited loss offset on investment include: Auerbach (1983), (1986), Green and Talmor (1985), Mayer (1986), Fane (1987), Mintz (1988), Altshuler and Auerbach (1990), Devereux, Keen and Schiantarelli (1994), and Shum (1994).

Dammon and Senbet [1988]). One of the goals of this paper is to investigate how an endogenous financing decision and borrowing constraints affect investment, and how this effect varies with different degrees of investment irreversibility.

The interaction of irreversibility and uncertainty has been shown to be quantitatively important for investment decisions, even in the absence of corporate taxation (see Dixit and Pindyck [1994] for a general survey of the literature, and Bertola [1988], Pindyck [1988], Bertola and Caballero [1993], and Abel and Eberly [1996] for studies that consider an incremental investment decision as we do here). In quite different contexts from ours, Mackie-Mason (1990), McKenzie (1994), and Mauer and Triantis (1994)[4] argue that corporate taxation interacts with the dynamic effects caused by investment irreversibility and uncertainty in a non-trivial fashion. An important impact of investment irreversibility for our purposes is the slow adjustment of capital that it induces. Firms with irreversible investment face long periods of positive or negative profits due to their reluctance to increase their capital stock which would constrain future capital choices, or their inability to downsize their capital stock without cost. The long periods of positive or negative profits enhance the relevance of the corporate tax asymmetry, especially with imperfect carry-over of losses. In addition, the presence of sunk entry costs implies that the marginal firm - the firm that is indifferent between entering or not- expects positive economic profits upon entry. Therefore, even if firms can deduct the full opportunity cost of capital from their income, the

[4] Mackie-Mason (1990) and Mauer and Triantis (1994) focus on a single investment project with fixed output. McKenzie (1994) studies incremental investment as we do in this paper, but under a symmetric corporate tax system with full loss offset. Mackie-Mason and McKenzie assume an all-equity financed firm. All three papers abstract from carry-back and carry-forward of losses, personal taxes, and explicit financial constraints.

government will be able to collect a positive (and quantitatively large) corporate tax revenue.

The main findings of this paper are summarized as follows. The asymmetry of the corporate tax system leads to noticeable effects on firms' investment choices. These effects distort both the incremental investment decision on the size of the firm, and the entry decision involving sunk costs. Using numerical simulations, we show that quantitatively, as long as firms can finance a large portion of the cost of their capital with debt, the welfare costs from the incremental investment decision are small. This is particularly so if the investment technology is flexible. In contrast, the welfare costs from the entry decision involving sunk costs are large even if firms can fully finance their capital with debt and the investment technology is flexible. In addition, the ability of firms to carry over their losses and choose their financial structure endogenously are important for the reduction of these welfare costs.

The rest of this paper is organized as follows. In section II, we explain the general framework and analyze the financing and investment policies of a representative firm. In section III, we present some preliminary results that set the stage for the examination of the corporate tax effects. In section IV, we evaluate the corporate tax system by focusing on its impact on the desired capital stock of an active firm, the willingness of a new firm to incur sunk entry costs, and the welfare costs associated with these effects. A summary section concludes the paper.

II. The model

Consider a firm with a single input: capital. At the beginning of each period, the firm must make its investment and financing decisions before the output price is revealed. At the end of the period, once the price is realized and the output is sold, the firm pays taxes to the

government, interest to its bondholders, and dividends to its shareholders.[5] The objective of the firm is to maximize its joint value to bondholders and shareholders:[6]

$$V = \max_{\{k,b\}} \mathrm{E}[\pi(p,k) - t(p,k,b) + \beta V'] \tag{1}$$

where

V = value of the firm (after distributing past earnings to shareholders and before the output price is revealed).

V' = value of the firm in the next period.

π = economic profit of the firm.

t = total corporate and personal tax liability net of opportunity cost.

p = output price.

k = capital stock.

b = debt (one-period bonds).

β = after-tax discount factor, $\beta \in (0,1)$.

The firm's economic profit is defined as:

$$\pi = F(k,p) - \delta k - rk - g. \tag{2}$$

where

[5] To focus on the main issues, we abstract from the firm's dividend policy and adopt the usual assumption that at the end of each period, the firm distributes *all* of its earnings (after tax and interest) to shareholders as dividends.

[6] For ease of exposition, we assume that investors are risk-neutral. However, it is well-known that there is no loss of generality with this assumption if markets are complete. That is, the probabilities used in the model should be interpreted as having been corrected for the contingent value of wealth in different states of nature.

F = revenue function net of (variable) operating costs.

δ = depreciation rate.

r = interest rate.

g = fixed operating costs and/or revenues from other investments that are independent of k.

The price of capital is normalized to one. The rate of interest rate, r, is the rate of return that shareholders can earn in an alternative investment. The revenue function $F{:}K\text{x}P \rightarrow \mathbb{R}$ is continuously differentiable, bounded, and concave with respect to k. As functions of p, both $F(k,\cdot)$ and $\partial_k F(k,\cdot)$ are increasing. Finally, for all $p \in P$, $F(0,p) = 0$, $\lim_{k\rightarrow 0} \partial_k F(k,p) = \infty$, and there exists a $\bar{k} \in K$ such that $\partial_k F(k,p) \leq \delta$ for all $p \in P$ and all $k \geq \bar{k}$. For the most part, we assume that the firm is competitive, so it takes the output price, p, as given. However, as in Bertola (1988), Bertola and Caballero (1994), and McKenzie (1994), one can interpret the firm as a monopolist, with p being a shift parameter in its output's demand curve.

The output price, p, is modeled as a continuous random variable which follows a Markov process, and takes on values within a bounded interval $P = [\underline{p}, \bar{p}] \subset \mathbb{R}_+$. If the price in the last period is p_0, then the distribution of p is determined by the transition function $Q(p_0,\text{d}p)$, where Q has the Feller property (i.e., if v is bounded and continuous in P, then $\int v(p)Q(p_0,\text{d}p)$ is bounded and continuous for all $p_0 \in P$), and is monotone (i.e., if v is non-decreasing in P, then $\int v(p)Q(p_0,\text{d}p)$ is non-decreasing for all $p_0 \in P$). This monotone property implies that the stochastic process of p is persistent: the probability of a high p increases with p_0.

We now turn to discuss the firm's tax liability. The total personal and corporate tax

liability of the firm net of opportunity cost, *t*, is:

$$t = \tau_b r(b - k) + \tau_c S(c) - \tau_c S(x_0) \quad \textbf{(3)}$$

where

$c =$ $\pi + r(k - b) + x_0$, the firm's taxable income.

$x_0 =$ cumulated profits (losses) carried over from the previous period.

$\tau_c =$ combined tax rate on corporate income and dividends.

$\tau_b =$ personal tax rate on interest income.

$\rho =$ depreciation factor for carry-forward and carry-back.

$S =$ truncation function for values lower than zero; that is, *S* maps a positive number onto itself, and a non-positive number onto zero.

In an opportunity cost sense, the personal tax liability on interest income is $\tau_b r(b-k)$. This liability is the difference between the personal tax payable by bondholders on the interest they receive, $\tau_b rb$, and the personal tax that would have been payable on an alternative investment, $\tau_b rk$, where rk represents the interest cost of capital. This difference is negative as long as part of the firm's capital is financed with equity, because shareholders pay tax on corporate income and dividend, instead of interest income. Note that the interest cost of capital, rk, is subtracted from the firm's economic profit, π. Since it is not tax-deductible (only rb is), it has to be added back in the taxable income term, c.

The asymmetric corporate tax liability is $\tau_c S(c) - \tau_c S(x_0)$. To see this, let us consider all of the possible values of x_0 and c. First, if x_0 is negative, it represents a cumulated loss which is a tax deduction to the firm in the current period. In this case, corporate taxes are $\tau_c c$ if $c \geq 0$, and zero otherwise. Second, if x_0 is positive, it represents a cumulated profit, and

the firm is able to carry back any losses that it may incur in the current period. In this case, the firm gets a refund equal to $\tau_c x_0$ if current losses exceed x_0 (so that $c < 0$), it gets a refund equal to $\tau_c(x_0 - c)$ if current losses do not exceed x_0 (so that $c \geq 0$), and it pays taxes equal to $\tau_c(c - x_0)$ if the firm earns a profit.

In the United States and in most other countries, losses carried over to other periods do not accrue interest and have a time limit. For tractability, we capture this partial carry-over of losses by assuming that cumulated profits and losses depreciate as time passes. We assume for the moment that both carry-backs and carry-forwards have the same depreciation factor, ρ; hence, the cumulated profit (loss) from the current period to be carried over to the next period is $x = \rho c$. In the numerical simulations, we will take into account that carry-backs and carry-forwards have different time limits, and employ two different depreciation factors: one for cumulated profits (carry-backs), and one for cumulated losses (carry-forwards).

The firm's financing decision faces the constraint that the amount of debt cannot exceed a portion, θ, of the value of its capital:

$$b \leq \theta k. \tag{4}$$

We do not impose a lower bound for debt. A negative b simply means that the firm invests in bonds rather than issuing them.

The firm's investment decision is subject to the following irreversibility constraint:

$$k \geq k_0^S. \tag{5}$$

where k_0^S is the stock of capital that survives from the previous period. We define k_0^S to be a fraction, μ (the survival rate), of the previous period's capital stock. This specification

accommodates flexible investment technologies with a zero μ, as well as irreversible investment technologies with a positive μ. With irreversible technologies, one would expect μ to be one minus the depreciation rate, δ. Our model allows for this possibility, and it also allows μ to be determined by other considerations such as maintenance costs, partial flexibility, or the aggregation of several types of capital.[7]

The value of the firm, V, is a function of the three state variables k_0^S, x_0 and p_0. V includes the value of x_0 (this value is non-negative), and the value of the firm's commitment to a minimum capital stock of k_0^S in the following period due to the irreversibility constraint. If the firm owns the capital it employs, its market value at the beginning of the period is $k_0^S + V$. The value function in the next period, V', is endogenous to the model. If the investment horizon is finite, V' can be easily obtained by solving the firm's maximization problem backward from the last period to the first. If the horizon is infinite however, V' must be obtained using limiting arguments (or numerical calculations). In any case, for a given V', the firm's financing and incremental investment decisions can be characterized using standard calculus.

The first-order condition for the optimal debt level is that either the marginal cost of debt is equal to its marginal benefit, or the marginal cost of debt is less than its marginal benefit. The latter would be the case when the firm's debt reaches its credit constraint and cannot be increased any further. In algebraic terms:

7As explained in Faig (1997), the aggregate survival rate may be much higher than one minus the average depreciation rate if the different types of capital are complementary.

$$\tau_b \le \tau_c \Pr(c \ge 0) - \beta\rho E(\partial_x V'), \qquad \text{with equality if } b < \theta k. \tag{6}$$

where Pr© ≥ 0) is the probability that the firm will be tax-paying in the current period. To understand (6), consider a marginal increase in debt financing. On the marginal cost side, an additional dollar of debt interest, *rb*, raises the bondholders' tax liability by τ_b. On the marginal benefit side, an extra dollar of debt interest reduces the firm's current tax liability by $\tau_c \Pr(\tau_c \ge 0)$, and decreases the firm's expected future value (through a lower cumulated profit) by $\beta\rho E(\partial_x V')$. Thus, the marginal benefit of debt increases with the probability that the firm will be tax-paying in the current period through a larger $\Pr(\tau_c \ge 0)$, or in the future through a smaller $E(\partial_x V')$.

The first-order condition for the firm's optimal capital stock is that either the marginal benefit of capital is equal to its marginal cost, or the marginal benefit of capital falls short of its marginal cost. The latter would be the case if the firm's capital reaches its irreversibility constraint and cannot be lowered any further. In algebraic terms:

$$E(R\partial_k F) + \theta r[1 - \tau_b - E(R)] \le \delta E(R) + r(1 - \tau_b) - \beta\mu E(\partial_k V'), \text{ with equality if } k > k_0^S. \tag{7}$$

To simplify notation, we use *R* to denote the marginal retention rate of the firm's profit; that is, *R* equals one minus the marginal effective tax rate: $R = 1 - \tau_c L(c \ge 0) + \beta\rho\partial_x V'$,

where L is the indicator function for positive values (i.e., it maps positive numbers onto one, and non-positive numbers onto zero). (Note that (6) implies $R = 1 - \tau_b$ when the financing

choice is interior). To understand (7), consider a marginal increase in the firm's capital stock. On the marginal benefit side, an extra unit of capital raises the expected after-tax revenue by $E(R\partial_k F)$, and it increases the credit-constrained firm's upper debt limit by θ, which brings a potential interest tax shield of $\theta r[1 - \tau_b - E(R)]$. On the marginal cost side, an extra unit of capital raises the after-tax opportunity cost of capital by increasing the depreciation cost, $\delta E(R)$, the interest cost, $r(1-\tau_b)$, and the cost of constraining the future capital stock, $-\beta\mu E(\partial_k V')$. Since the firm's investment is subject to an irreversibility constraint, the capital stock that the firm ends up with is $\max(k^*, k_0^S)$, where k^* is the firm's desired capital stock (if the irreversibility constraint is not binding) .

Even without any form of taxation, k^* falls short of the capital stock that equates the expected marginal revenue of capital to the depreciation rate plus the real interest rate because the term $\beta\mu E(\partial_k V')$ is non-positive. With capital irreversibility, investment carries the extra cost of increasing future capital commitments. Therefore, a larger capital stock today reduces the firm's value in the next period. (See the references for investment irreversibility in the introduction for further discussion on this point).

With taxation, the desired capital stock falls short of that under a neutral corporate tax system (symmetric with full loss offset and uniform tax rates, $\tau_c = \tau_b$) for two reasons. First, even if the firm is able to deduct its entire opportunity cost of capital by financing all of its investment with debt ($\theta = 1$), an asymmetric corporate tax penalizes the firm more heavily during good times when both the marginal revenue of capital and the marginal effective tax rates are high, than it subsidizes the firm during bad times when both of these terms are low. In other words, the two factors in the expectation $E(R\partial_k F)$ in (7) are negatively correlated,

and so their expected product is smaller than the product of their expected values. In the "neutral" case, the firm faces the same marginal tax rate during good and bad times, and so R is a constant. Second, if the firm is unable to finance all of its capital with debt because the maximum debt-to-capital ratio, θ, is less than one, then it has to declare as taxable income the portion of the cost of its capital that is financed with equity. If, in addition, the firm's financing choice is at the corner, then equity is effectively taxed more heavily than debt. Thus, forcing the firm to use more equity than it desires discourages investment.

III. The Value Function and Comparative Statics

This section has two purposes. The first purpose is to characterize the firm's value function in an infinite horizon. The second purpose is to describe how the parameters of the model affect this value function and the firm's desired capital stock. These two tasks are preliminary to the evaluation of the corporate tax effects in the next section.

Suppose, for the moment, that the firm cannot carry back or carry forward its losses. (This implies that x_0 is no longer a state variable in the value function.) Standard results from stochastic dynamic programming are:[8]

> **Proposition 1**: The value function of the firm with an infinite horizon, V^*, exists and is unique. For all $p_0 \in P$, $V^*(\cdot, p_0)$ is continuously differentiable, bounded, non-increasing, and concave in K. For all $k_0^S \in K$, $V^*(k_0^S, \cdot)$ is increasing in p_0.

8See Stokey, Lucas, and Prescott (1989) sections 9.1 and 9.2, pp. 241-270 for all properties except differentiability. See Sargent (1980) for the type of argument necessary to establish differentiability. The argument in Sargent is also useful for establishing that $\partial_k V^*$ is bounded above by 0 and below by $-(r+\delta)/(1-\beta)$.

The generalization of Proposition 1 to the case in which losses can be carried back or carried forward requires a transformation of the value function, but apart from that it is fairly straightforward:

Proposition 2: If losses can be carried back or carried forward, the value function of the firm with an infinite horizon, V^*, can be decomposed as:

$$V^*(k_0, x_0, p_0) = \tau_c S(x_0) - \tau_b x_0 + W^*(k_0, x_0, p_0) \tag{8}$$

where, in the range of admissible values for its arguments, the function W^* is continuously differentiable, bounded, non-increasing and concave with respect to k_0^S and x_0, and increasing with respect to p_0.[9]

We now proceed to examine how the parameters of the model affect the value function, V^*, and the desired capital stock, k^*. The complexity of our model precludes the derivation of general monotonicity results in comparative static analysis.[10] Therefore, we turn to numerical simulations and focus on the quantitative effects of various parameter changes on V^* and k^*. Our assumptions and base-case parameter values are described below.

We assume the following form for the revenue function: $F(k, p) = pAk^{\alpha}$; where

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9Moreover, the first derivatives of W^* are bounded: $-(r + \delta) / (1 - \beta) \leq \partial_k W^* \leq 0$, and $-(\tau_c - \tau_b) \leq \partial_x W^* \leq 0$.

10 Although for some special cases, strong monotonicity results are possible. For example, in the absence of an asymmetric corporate tax, the desired capital, k^*, is increasing with p_0 if Q is strictly monotone, non-increasing with respect to β and μ, and decreasing with respect to r and δ. Likewise, if $g \leq 0$, k^* is increasing with p_0 if Q is strictly monotone, non-decreasing with respect to τ_b, non-increasing with respect to β, μ, and τ_c, and decreasing with respect to r and δ. See Faig and Shum (1996). Also, see Abel and Eberly (1996) for extensive comparative static results for investment irreversibility without taxation.

A and α are parameters of the production function. This form implies that the firm's average cost function has the conventional U-shape. The stochastic process of the output price, p, obeys the following martingale: as long as p is in the interior of the interval $[\underline{p}, \bar{p}]$, a shock to the output price occurs in each period with probability 0.5. If a shock occurs, p is either multiplied or divided by a factor ε, $\varepsilon > 1$, with probabilities that satisfy the martingale property $E(p) = p_0$.[11] The bounds of the interval $[\underline{p}, \bar{p}]$ are absorbent.

The parameter values in the base case are as follows. The output price in the last period, p_0, is normalized to one. The uncertainty factor in the output price, ε, is 1.1.[12] The interval for the output price, $[\underline{p}, \bar{p}]$, is $[\varepsilon^{-6}, \varepsilon^{6}]$. The real interest rate, r, is 0.03. The depreciation rate, δ, is 0.08. For the production function, the parameter α is 0.5 and the parameter A is 2.2. The fixed cost, g, is 11. These values are chosen so that the firm in a steady state without taxation will choose $k = 100$ to breakeven. The personal income tax rate, τ_b, is 0.28. The combined tax rate on corporate income and dividend, τ_c, is 0.54.[13] The depreciation factor for carry-backs, ρ^+, is 0.63. The depreciation factor for carry-forwards,

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11 Actually, we assume that p is a stochastic value within a small interval around εp_0, p_0, or $\varepsilon^{-1} p_0$, respectively.

12 Different firms face very different price risk. For instance, the annual conditional standard errors for relative prices of wholesale industrial products vary from 0.025 (textiles) to 0.14 (crude petroleum). At the firm level, the disparity of price risks is even larger. With our assumptions, the conditional standard deviation of p before hitting the absorbing bands is 0.07.

13 We are assuming a corporate tax rate of 0.34 for the firm, and an effective personal tax rate on equity of 0.20.

ρ^-, is 0.89.[14] The maximum debt-to-capital ratio, θ, is 1. The firm's after-tax discount factor, β, is $[1+ (1-\tau_b)]^{-1}$. The initial capital stock, k_0^S, and cumulated profits, x_0, are zero, so we are analyzing a firm that have just entered into the market. In the future, the firm will face a survival rate, μ, for its capital stock of 0 if the investment technology is flexible and 0.98 if the technology is irreversible. (As explained in section II, we let μ differ from $1 - \delta$ to allow for factors such as pure maintenance costs, partial flexibility, and the aggregation of several types of capital).

In Table 1, we present some of the comparative statics results for a firm with an irreversible investment technology. Uncertainty, the real interest rate, the survival rate of capital and depreciation all have noticeable effects on the firm's desired capital stock. The combination of uncertainty and irreversibility has a strong negative impact on the desired capital stock. Interestingly, the impact on the value of the firm is (mostly) in the opposite direction, because the firm can adjust its production (subject to the irreversibility constraint) to changes in the output price.

The real interest rate, r, has two opposing effects on investment. On the one hand, a higher r increases the firm's discount rate and makes the future less important. Investment is encouraged as a result because the negative impact of having to commit to a larger capital stock in the future is reduced. On the other hand, a higher r increases the opportunity cost of capital, and discourages investment. The simulation results suggest that the second impact overwhelms the first, at least within the chosen range of realistic interest rates. An increase

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14 The depreciation factor, ρ^+, approximates the 3-year limit for carry-backs with an annual inflation rate of 4 percent. The depreciation factor, ρ^-, approximates the 15-year limit for carry-forwards with the same annual inflation rate.

in r from 1 to 5 percent lowers the firm's desired capital stock by half.[15]

Similarly, depreciation has two opposing effects on investment. A higher rate of depreciation increases the opportunity cost of capital and lowers the firm's desired capital stock, but at the same time, it relaxes the irreversibility constraint by reducing the survival rate of capital. In Table 1, we show the effects of changing the depreciation rate and the survival rate of capital[16] independently. Since depreciation has by far the stronger impact of the two parameters, if we change them simultaneously (not shown), the effect of depreciation through the opportunity cost will dominate for our range of parameter values.

Having either cumulated profits or cumulated losses carried over from previous periods increases the value of the firm.[17] However, the two have different impact on the desired capital stock. As the firm increases its cumulated losses (x_0 becomes more negative), it has an incentive to generate more income in order to write off these losses. In this sense, the provision of loss carry-forward acts as an "automatic stabilizer", because it stimulates investment when the firm has cumulated losses, presumably during recessionary times.

The comparative statics results for the parameters considered above are fairly robust to our base-case assumptions. We have not discussed the effects of the tax parameters, financial structure or credit constraint, because these effects are sensitive to the firm's

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15 This effect mirrors the impact of interest rates on desired employment when firms face costs of adjusting employment. See Bertola (1992).

16 The survival rate of capital exerts its strongest impact on the firm's desired capital stock when μ is above 0.9, because we assume that the output price fluctuates by a factor of 10 percent.

17 With the base-case parameter values, the realization of profits in the three states of nature are -1.91, -0.12, 1.84, respectively. Therefore, the increment of 2 that we have chosen for cumulated profits in the comparative statics analysis takes at least one period to achieve.

profitability. We will examine them in detail in the next section.

IV. Effects of the Corporate Tax System on Investment

An asymmetric corporate tax system hinders investment in two dimensions. First, it discourages investment of active firms in their marginal choice of capital as discussed in section II. Second, it discourages the entry of new firms and/or encourages the exit of existing firms. Given the complexity of the model, we abstract from the exit decision and focus on the marginal choice of capital by active firms and the permanent entry of new firms.

We begin with the base-case assumption that firms can use up to 100 percent debt to finance their capital if it is in their interest to do so. With this assumption, the effects of corporate taxes on the desired capital stock of active firms depend crucially on their profitability, and we can distinguish three situations in which firms may find themselves. First, firms may be highly profitable with positive taxable income for many periods to come. These profitable firms finance their capital entirely with debt, and they face, effectively, a proportional tax on their always positive economic profits. Hence, the corporate tax system has little impact on their marginal investment decision. Second, at the opposite end, firms may be highly unprofitable with negative taxable income for many periods to come. These unprofitable firms have an interior financing choice, and the corporate tax system has an impact on their marginal choice of capital. The source of distortion is the negative correlation between these firms' retention rates, R, and their marginal revenue of capital. As discussed in section II, this negative correlation depresses the expected after-tax marginal revenue of capital (first expectation in [7]), and in turn, the desired capital stock. And third, firms may be in the middle of the profitability range, with enough expected revenue now to fully finance

their capital with debt (and hence the credit constraint is binding), but with the possibility of a loss in the near future. For these firms, the asymmetric corporate tax system has an effect on their investment not only due to the negative correlation between their expected retention rates and their marginal revenue, but also due to their expected retention rates falling short of the neutral $1 - \tau_{b.}$ (This is because their financing choice is at the corner. Recall from (6) and (7) that $R = 1 - \tau_b$ only if the financing choice is interior.) Figure 1 illustrates these three situations with the base-case assumptions of partial carry-over of losses ($\rho^+,\rho^-<1$), endogenous financing, and a maximum debt-to-capital ratio (θ) of one.

The two panels in Figure 1 show the effects of the asymmetric corporate tax on the desired capital stock for a firm with irreversible investment technology ($\mu = 0.98$) and a firm with flexible technology ($\mu = 0$) respectively. In both panels, the vertical axis measures the firm's desired capital stock, k^*, as a fraction of that under a neutral tax system. The other two axes measure the combined tax rate on corporate income and dividend, τ_c, and the fixed cost, g, which is our inverse measure of profitability. In each graph, we can clearly distinguish three regions corresponding to the three scenarios discussed in the previous paragraph. First, in the highly profitable region (low g), the asymmetric nature of the corporate tax is irrelevant, and so the tax is neutral with respect to the firm's marginal investment decision. Second, in the highly unprofitable region (high g), the firm's financing choice is interior. Firms in this region adjust their debt position in order to equate the expected retention rate, R, with $1 - \tau_b$. (Recall from [6] and [7] that when the financing choice is interior, $R = 1 - \tau_b$.) As a result, the effects of a change in τ_c are of second order of magnitude. Third, in the middle region (moderate g), the firm still has enough expected revenue to use full debt

financing, but it faces the prospect of a loss in the near future. In this case, the corporate tax exerts its biggest impact on the firm's marginal investment choice, as evidenced by the prominent valley in the firm's desired capital stock in each panel. Nevertheless, the effects are not very strong on an absolute scale. For the base-case τ_c of 0.54 and fixed cost of 11, the desired capital stock of firms with an irreversible investment technology and those with a flexible investment technology are only 4.5 and 2.5 percent lower, respectively, than the "neutral" capital stock. Interestingly, irreversibility leads to stronger tax effects, and over a wider range of fixed cost. The stronger effects can be explained by the slower adjustment of capital in firms with irreversible investment. Because their capital choices are constrained, these firms look farther ahead into the future when they make their investment decisions. This forward-looking behaviour reinforces the dynamic effects of the corporate tax asymmetry induced by the loss carry-over provisions.

The ability to carry losses across periods smooths the effects of corporate taxation by allowing current losses to lower the firm's effective tax rates in nearby periods that are profitable. How important are the loss carry-back and carry-forward provisions for reducing the asymmetry in the corporate tax system? The two panels in Figure 2 illustrate the corporate tax effects on the firm's desired capital stock in the absence of any loss carry-over provisions. Compared to Figure 1, the valleys in the middle region are deeper and narrower, and the plateaus in the high fixed cost region sit at a lower altitude. For the base-case, the desired capital stock of firms with an irreversible investment technology and those with a flexible investment technology are 5.5 and 4.5 percent lower, respectively, than the "neutral" capital stock. When losses cannot be carried back or carried forward, the future becomes less

important. This is especially true for firms with flexible investment, whose decisions are now totally independent through time. Moreover, the increased asymmetry of the corporate tax system reduces the expected after-tax marginal revenue of capital (first expectation in [7]) by making the covariance between the firm's retention rate and its marginal revenue of capital more negative. Hence, the desired capital stock falls, except for firms that have low fixed costs. Because these firms are so profitable and never had to rely on the loss carry-over provisions, they continue to face, effectively, a proportional corporate tax.

All public finance textbooks assert that the firm's financial structure is crucial to the understanding of the effects of corporate taxation. In the present model, this decision is endogenous. To assess the importance of an endogenous financing choice, we re-run the simulations using an *exogenous* financial structure, and compare the results to Figure 1. Quantitatively, the difference in the desired capital stock between firms with an exogenous financial structure of 100 percent debt (Figure 3) and firms with an endogenous financial structure is not large. Overall, we can make the following two observations in the comparison of these two types of firms. First, firms in the mid-profitability range invest less if they have an exogenous financial structure of 100 percent debt. The reason is as follows. Should these firms become unprofitable in the future, they cannot lower their debt to reduce their total tax liability. In other words, if they expect a loss in the next period, their bondholders would still have to pay large sums in personal income taxes, even though their debt has little value as a corporate tax shield. This disadvantage, in turn, discourages investment. Second, firms in the low profitability range invest more because when they are forced to use more debt than they would otherwise choose, their effective tax rate on corporate income falls short of the

personal tax rate on investors' alternative investment (say, in bonds), and so investment in the firm goes up.

In contrast, the difference in the desired capital stock between firms with an exogenous financial structure of 100 percent equity (Figure 4) and firms with an endogenous financing structure is much more dramatic. (In fact, the scale of the vertical axis in Figure 4 had to be modified to accommodate the strong effects). With full equity financing, firms cannot deduct their cost of funds. For highly profitable firms, the corporate tax is no longer a proportional tax on their economic profits. These firms now face a much lower expected retention rate, R, and investment is discouraged as a result. At the same time, highly unprofitable firms face an expected retention rate close to one, because they never pay taxes. Since the retention rate for alternative investment (again, in bonds) is $1 - \tau_b$, these firms actually invest more if they are forced to use full equity financing. If the financing choice is endogenous however, highly unprofitable firms will not only choose to finance all of their capital with equity, but they may also choose to invest in bonds (negative debt) and use their operating losses from production as a tax shelter. This ability to use the firm as a tax shelter implies that the expected marginal retention rate never surpasses $1 - \tau_b$. The strong effects we observe in Figure 4 accord with the usual findings of traditional tax models that assume fully equity-financed firms. In these models, real distortions are often exaggerated because the firms' financing decisions are not taken into account.

From the preceding analysis, it is clear that the magnitude of the effects of an asymmetric corporate tax depends critically on each firm's profitability. Hence, in order to assess the economic significance of the effects described in Figures 1 to 4, we must determine

the relative importance of each profitability range. To this end, we will focus on the marginal firm, that is, the firm which is indifferent between entering into the market or not. Once the marginal firm enters, over time, it may become highly profitable, moderately profitable, or highly unprofitable, all with a probability dictated by the stochastic process of p. Therefore, studying the actions of the marginal firm over its expected future gives us a reasonable averaging of the different profitability ranges that a firm may find itself in. Before we proceed however, we must first find the marginal firm by addressing entry decisions.

Entry decisions are a non-trivial issue when they involve costs and commitments that are difficult to reverse. We will assume that firms have to make a permanent commitment to the fixed cost g upon entry. Up until now, g has been interpreted as an inverse measure of a firm's profitability. From now on, we will interpret g strictly as a fixed cost. We will begin the analysis by assuming that g is a deductible expense. Later in the section, we will relax this assumption.

For comparison purposes, we add a third type of firms, those with a "fully" flexible investment technology, to our analysis. Like firms with a flexible investment technology, fully flexible firms are not subject to the irreversibility constraint (4). However, unlike flexible and irreversible firms, fully flexible firms do not have to commit to the fixed cost g. A fully flexible firm decides in each period if it wants to produce or not, and it pays g if and only if it is active in that period.

Firms that are fully flexible decide to produce when the expected net profits for the coming period are positive. In contrast, firms with an irreversible or a flexible investment technology decide to enter and commit to the fixed cost g when their value as active firms

outweighs the option value of waiting for further news about their future profitability. This option value can be easily computed using the recursion that if a firm decides not to enter, the option value of waiting is the expected present value of the same option in the next period. The marginal firm is then identified as the firm whose option value of waiting is equal to its value as an active firm.

In Table 2, we evaluate the economic impact of the corporate tax under six different scenarios: i) a neutral corporate tax system with full loss offset and equalized corporate and personal tax rates; ii) a symmetric corporate tax system with full loss offset; iii) an asymmetric corporate tax system with our base-case assumptions; iv) the base case without any loss carry-over provisions; v) the base case with an exogenous financial structure of 100 percent debt, and vi) the base case with an exogenous financial structure of 100 percent equity. The second column in Table 2 is the after-tax value of the firm upon entry. The third column is the expected present value of the tax revenue to be collected by the government. The fourth column is the social value of the firm, obtained by adding the first two columns together to obtain the present value of the total economic profits generated by the firm. The fifth column is the subsidy that the government must hand out in order to induce the firm to accept immediate entry. In the analysis, we assume that the government can credibly commit to paying the subsidy if and only if the firm enters immediately. The sixth column is the portion of the government's expected tax revenue (in present value terms) that is spent on the entry subsidy. It gives us an idea of the size of the tax distortions on the firm's entry decision. The last two columns are the present value of the average and the marginal welfare costs, respectively. They provide two measures of the tax distortions on the behaviour of

active firms. The average welfare cost is the loss in the social value of the firm as a percentage of the extra tax revenue (net of subsidy) collected, relative to the neutral tax system. The marginal welfare cost is the change in the social value of the firm as a percentage of the change in the tax revenue (net of subsidy) when τ_c is increased from 0.54 to 0.6. The exact formulae are given in Table 2. We repeat the simulations for each type of investment technology: irreversible, flexible and fully flexible. For each type, the value of g is the amount that makes firms with a neutral tax system indifferent between entering or not.

Except for the full equity-finance case, the distortions caused by the corporate tax on active firms are small. This is particularly so for firms that have a flexible or fully flexible technology. For example, the welfare cost is only 0.01 to 0.05 cent for every additional dollar of tax revenue (net of subsidy) raised. The welfare costs for firms with an irreversible investment technology are larger, but the absolute magnitude is still small. For example, the average welfare cost with the base-case assumptions is a mere 0.11 cent for each additional dollar raised. This average welfare cost is low due, in part, to the loss carry-over provisions (without them, the average welfare cost doubles), and, in part, to an endogenous financing choice (with exogenous full debt-finance, the average welfare cost quadruples). The corresponding marginal welfare cost is six times higher, but still insignificant in size. Hence, we can conclude that for active firms, the corporate tax system, despite its asymmetries, is quantitatively close to a neutral tax system, unless firms are forced to use full equity financing.

Quite a different story emerges when we focus on the subsidy required to induce entry. Even if the government can credibly commit to paying the subsidy if and only if a firm

enters immediately, with all the informational and/or incentive problems that this raises, the portion of tax revenue that would have to be spent on the subsidy is potentially sizable. In the base case (i.e., without any informational and/or incentive problems), the government must spend close to 2 percent of its expected tax revenue in order to induce a firm with an irreversible investment technology to enter. The amount required to induce a firm with a flexible investment technology to enter is slightly less, but comparable. (By definition, a firm with fully flexible investment technology has no irrevocable entry decision). The subsidy almost doubles in the absence of the loss carry-over provisions, and it more than triples with exogenous debt financing or exogenous equity financing. If the government could not commit to paying the subsidy only upon immediate entry, then the tax distortions on the entry decision would be much more expensive to remedy. For example, if the government simply promises a subsidy when entry occurs, the firm's penalty for waiting is the interest forgone on this subsidy. Consequently, the subsidy required to neutralize the tax distortions on the entry decision would be the subsidy listed in Table 2 divided by the after-tax real interest rate (which is 0.0216 given our assumptions). Thus, in the base case, the government would have to spend around 85 percent of the tax revenue. And without the loss carry-over provisions or without an endogenous financing choice, it would have to spend several times the present value of the tax revenue that it would ever expect to collect.

Let us now relax the assumption that firms are entitled to expense all of their entry commitments. Suppose firms have to pay a one-time non-deductible sunk cost at entry, in addition to the permanent tax-deductible commitment g. This sunk cost applies to firms that are otherwise fully flexible as well. The reason for allowing a portion of the entry

commitment to be non-deductible is that if firms have to finance its entry partly with equity, as often is the case, then that part of opportunity cost of funds cannot be deducted.

With a non-deductible sunk cost of 100,[18] firms choose to enter only when they are highly profitable. That is, the marginal firm is in the region where the corporate tax is approximately a proportional tax on profits. At the same time, precisely because firms are profitable and tax paying, the tax distortions on the entry decision are more important. The portions of tax revenue spent on entry subsidies are in the range of 5 to 9 percent, with relatively little difference among the three alternative assumptions on investment technology.

Again, for active firms, the ability to finance their capital with debt is responsible for the low welfare costs we observe in Table 3. One may question the relevance of these results on the grounds that in practice, debt is not adjusted as frequently as our model would predict, and it is rarely used to the full extent. While we have no final answer to these questions, we should point out that the results in Tables 2 and 3 are more robust than they might initially appear for the following arguments. First, even though firm's debt-asset ratios are fairly stable, their annual debt issues and retirement are very responsive to economic conditions (Mackie-Mason [1990], Shum [1996]). Moreover, there are many ways in which firms can shelter their income (e.g. leasing), and we have only captured the effects of one of them, namely, debt, in this paper. There is no reason why firms would not pursue their aggregate tax reduction strategy aggressively. Second, even though the degree of leverage in the United States is only around 40 percent, this level is not inconsistent with firms choosing debt and/or

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18 This is the value of the desired capital stock for firms with a flexible investment technology under a neutral tax system.

equity endogenously, as we assume in our model. To further address the question of full debt financing, we also consider the case in which firms can only finance their capital with up to 50 percent debt. This constraint can be a result of bankruptcy concerns, informational problems, or legal restrictions in bond covenants. Again, firms have to incur a non-deductible sunk cost of 100 at entry, and commit to a deductible fixed cost, *g*, in each period thereafter. Figure 5 and Table 4 summarize the results under this alternative scenario.

Imposing a 50 percent debt-to-capital constraint ($\theta = 0.5$) has a strong impact on highly profitable firms. For these firms, the corporate tax system is no longer a proportional tax on their economic profits. As a result, the corporate tax significantly depresses their desired capital stock (low *g* region in Figure 5). This effect however, does not depend much on the degree of investment irreversibility. Results consistent with the above findings are obtained when the entry decision is taken into account (Table 4). The average welfare cost generated by the corporate tax system are more substantial. On average, they are 3 to 4 cents for every dollar of tax revenue (net of subsidy) raised. Curiously, a tax system with full loss offset causes more distortions on the behaviour of active firms than our base-case system with partial carry-overs of losses. The distortions decline further with no carry-overs and exogenous finance. Hence, the consequences of the corporate tax asymmetry seem to be reversed when a percentage of the firm's capital income is constrained to be included in its taxable profits. This is not so however, for the distortion on the entry decision. The portion of expected tax revenue that the government has to spend on the entry subsidy increases as we move down the list of cases in Table 5, as it did in the previous tables.

V. Conclusion

We have demonstrated in this paper that for active firms, as long as capital can be financed with debt at the margin, the corporate tax system, though asymmetric, is quantitatively closer to a neutral tax on economic profits than a distorting tax on capital. With irreversible investment, the tax distortions on firms' desired capital stock are somewhat larger. But even then, the distortions are small on an absolute scale. This is due, in part, to firms' ability to carry back or carry forward their losses and, in part, to firms' ability to switch to equity financing when their profitability falls.

For marginal firms that are contemplating entry, irreversible investment and the corporate tax asymmetry have important consequences for government revenues and welfare costs of taxation. With free entry and a flexible investment technology, one could expect firms' economic profits to be close to zero. If so, the corporate tax system would raise trivial amounts of revenue from firms that are financing their capital mostly with debt. However, this argument is fallacious when sunk entry costs (or commitments) are involved. Firms in this environment would only enter into the market if they expect positive, and plausibly large, net profits. Without the latter, it is in the firms' best interest to wait for further news about their future profitability. Moreover, the asymmetric nature of the corporate tax system implies that during good times, firms have to pay taxes while during bad times, their taxes are not refunded at the full corporate tax rate. This fact reinforces firms' desire to ensure that they will be very profitable once they are in operation. As a result, a costly and irreversible entry combined with the corporate tax asymmetry mean that large sums of corporate tax revenue can be raised at a very low welfare cost, given that once firms enter, the tax distortions on their desired capital stock are small.

Unfortunately, this is not the end of the story. When firms consider entry in a particular location or sector, they take into account their future tax liabilities. As we have shown, the disincentive created by the corporate tax system for the entry of new firms is quantitatively large. Governments, particularly in small demarcations, have counteracted this disincentive by providing entry subsidies (or equivalently, tax holidays) to firms. Our results suggest that this strategy could produce fairly optimal results at a moderate cost if governments had perfect information and could credibly commit to their future policies. However, for this strategy to be feasible, the subsidies must be handed out if and only if the firms enter immediately. Otherwise, if firms expect that a similar offer may be available in the next period, the value of the subsidy required to induce an optimal amount of firms to enter approaches the entire tax revenue the government expects to collect.

This paper has managed to put together many features relevant to the analysis of the corporate tax system which, up until now, have been analyzed separately. They include: asymmetry, partial carry-over of losses, endogenous financing, credit constraints, incremental investment with various degrees of irreversibility, and entry decisions. Despite this achievement, the complexity of the corporate tax system and its interaction with firms' behaviour mean that many other features are left out of the analysis, most notably, the modelling of true economic depreciation versus tax-deductible depreciation (for a discussion on this topic, see Auerbach [1983], Mackie-Mason [1990], and Mintz [1995]), the modelling of other reasons why firms may choose an interior financial structure, such as bankruptcy costs, moral hazard and signalling (for an excellent survey, see Harris and Raviv [1991]), and the modelling of exit decisions (for an example, see Mauer and Triantis [1994]). Finally, this

type of analysis of the corporate tax system remains to be incorporated in a general equilibrium framework.

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Table 1
COMPARATIVE STATICS ANALYSIS
INVESTMENT TECHNOLOGY: IRREVERSIBLE

Uncertainty factor (ε)	***1***	***1.05***	***1.1***	***1.15***	***1.2***
Capital	***100***	***92.83***	***79.95***	***67.55***	***57.1***
Value	***0***	***-2.49***	***12.1***	***42.69***	***90.69***
Interest Rate (r)	***0.01***	***0.02***	***0.03***	***0.04***	***0.05***
Capital	***114.04***	***94.58***	***79.95***	***68.03***	***58.74***
Value	***297.12***	***73***	***12.1***	***-13.15***	***-25.38***
Depreciation Rate (δ)	***0.02***	***0.05***	***0.08***	***0.11***	***0.14***
Capital	***379.42***	***146.87***	***79.95***	***49.8***	***33.71***
Value	***350.73***	***120.46***	***12.1***	***-52.61***	***-94.33***
Survival Rate (μ)	***0.92***	***0.94***	***0.96***	***0.98***	***1***
Capital	***93.97***	***91.67***	***87.76***	***79.95***	***57.1***
Value	***15.03***	***14.72***	***14.05***	***12.1***	***2.13***
Cumulated Profits (x_0)	***-4***	***-2***	***0***	***2***	***4***
Capital	***80.58***	***80.47***	***79.95***	***78.84***	***78.53***
Value	***12.92***	***12.34***	***12.1***	***12.34***	***12.34***

Table 2
EVALUATION CORPORATE INCOME TAX

1 *Tax system*	*2* *Value of firm upon entry*	*3* *Present value of tax revenue*	*4* *Social value of firm upon entry*	*5* *Subsidy required to induce entry*	*6* *Portion of tax spent in entry subsidy*	*7* *Average welfare cost*	*8* *Marginal welfare cost*
TECHNOLOGY: IRREVERSIBLE (g = 6.73)							
Neutral	*195.72*	*76.11*	*271.83*	*0.00*	*0.00%*		
Full loss offset	*125.04*	*146.79*	*271.83*	*0.00*	*0.00%*	*0.00%*	*-0.00%*
Base case	*118.70*	*153.04*	*271.74*	*2.84*	*1.86%*	*0.11%*	*0.65%*
No carry-overs	*112.89*	*158.78*	*271.67*	*5.47*	*3.44%*	*0.21%*	*0.83%*
Debt finance	*102.01*	*169.49*	*271.50*	*10.42*	*6.15%*	*0.40%*	*0.87%*
Equity finance	*76.57*	*186.11*	*262.68*	*13.52*	*7.27%*	*9.48%*	*55.34%*
TECHNOLOGY: FLEXIBLE (g = 6.81)							
Neutral	*197.13*	*76.66*	*273.79*	*0.00*	*0.00%*		
Full loss offset	*125.94*	*147.85*	*273.79*	*0.00*	*0.00%*	*0.00%*	*-0.00%*
Base case	*119.95*	*153.84*	*273.79*	*2.80*	*1.82%*	*0.01%*	*0.02%*
No carry-overs	*114.32*	*159.44*	*273.77*	*5.43*	*3.41%*	*0.03%*	*0.04%*
Debt finance	*103.64*	*170.14*	*273.78*	*10.43*	*6.13%*	*0.01%*	*0.02%*
Equity finance	*75.74*	*188.36*	*264.10*	*14.38*	*7.63%*	*9.96%*	*58.08%*
TECHNOLOGY: FULLY FLEXIBLE (g = 11)							
Neutral	*146.09*	*56.81*	*202.91*	*0.00*	*0.00%*		
Full loss offset	*93.34*	*109.57*	*202.91*	*0.00*	*0.00%*	*0.00%*	*-0.00%*
Base case	*93.32*	*109.58*	*202.90*	*0.00*	*0.00%*	*0.02%*	*0.03%*
No carry-overs	*93.29*	*109.60*	*202.88*	*0.00*	*0.00%*	*0.05%*	*0.10%*
Debt finance	*93.31*	*109.59*	*202.90*	*0.00*	*0.00%*	*0.02%*	*0.04%*
Equity finance	*69.45*	*126.63*	*196.08*	*0.00*	*0.00%*	*9.78%*	*638.85%*

Note: Column 4 = column 2 + column 3.
Column 6 = column 5 / column 3.
Column 7 = (column 4 - "neutral" column 4) / (column 3 - "neutral" column 3 - column 5).
Column 8 = change in column 4 when τ_c is raised from 0.54 to 0.6 / (change in column 3 when τ_c is raised from 0.54 to 0.6 - change in column 5 when τ_c is raised from 0.54 to 0.6).

Table 3
EVALUATION CORPORATE INCOME TAX
Sunk Cost = 100

1 *Tax system*	*2* *Value of firm upon entry*	*3* *Present value of tax revenue*	*4* *Social value of firm upon entry*	*5* *Subsidy required to induce entry*	*6* *Portion of tax spent in entry subsidy*	*7* *Average welfare cost*	*8* *Marginal welfare cost*
TECHNOLOGY: IRREVERSIBLE (g = 3.79)							
Neutral	*295.71*	*115.00*	*410.71*	*0.00*	*0.00%*		
Full loss offset	*188.93*	*221.79*	*410.71*	*12.17*	*5.49%*	*0.00%*	*-0.00%*
Base case	*188.28*	*222.40*	*410.69*	*12.56*	*5.65%*	*0.03%*	*0.11%*
No carry-overs	*187.60*	*223.08*	*410.68*	*12.99*	*5.83%*	*0.04%*	*0.19%*
Debt finance	*186.39*	*224.21*	*410.60*	*13.76*	*6.14%*	*0.12%*	*0.46%*
Equity finance	*153.82*	*246.53*	*400.35*	*22.17*	*8.99%*	*9.48%*	*65.38%*
TECHNOLOGY: FLEXIBLE (g = 3.87)							
Neutral	*297.13*	*115.55*	*412.68*	*0.00*	*0.00%*		
Full loss offset	*189.83*	*222.85*	*412.68*	*12.03*	*5.40%*	*0.00%*	*-0.00%*
Base case	*189.36*	*223.31*	*412.68*	*12.36*	*5.54%*	*0.00%*	*0.00%*
No carry-overs	*188.80*	*223.87*	*412.67*	*12.77*	*5.70%*	*0.00%*	*0.00%*
Debt finance	*187.75*	*224.92*	*412.67*	*13.52*	*6.01%*	*0.00%*	*0.00%*
Equity finance	*153.96*	*248.24*	*402.20*	*22.39*	*9.02%*	*9.50%*	*64.47%*
TECHNOLOGY: FULLY FLEXIBLE (g = 4.06)							
Neutral	*294.84*	*114.66*	*409.51*	*0.00*	*0.00%*		
Full loss offset	*188.37*	*221.13*	*409.51*	*12.21*	*5.52%*	*0.00%*	*-0.00%*
Base case	*188.34*	*221.17*	*409.51*	*12.23*	*5.53%*	*0.00%*	*0.79%*
No carry-overs	*188.30*	*221.20*	*409.50*	*12.26*	*5.54%*	*0.00%*	*0.79%*
Debt finance	*188.31*	*221.20*	*409.50*	*12.26*	*5.54%*	*0.00%*	*0.79%*
Equity finance	*154.16*	*245.33*	*399.50*	*21.37*	*8.71%*	*9.16%*	*59.33%*

See note in Table 2.

Table 4
EVALUATION CORPORATE INCOME TAX
Maximum Debt: 50 percent of capital

1 *Tax system*	*2* *Value of firm upon entry*	*3* *Present value of tax revenue*	*4* *Social value of firm upon entry*	*5* *Subsidy required to induce entry*	*6* *Portion of tax spent in entry subsidy*	*7* *Average welfare cost*	*8* *Marginal welfare cost*
TECHNOLOGY: IRREVERSIBLE (g = 6.73)							
Neutral	*195.72*	*76.11*	*271.83*	*0.00*	*0.00%*		
Full loss offset	*105.62*	*163.26*	*268.88*	*3.15*	*1.93%*	*3.51%*	*15.85%*
Base case	*102.59*	*166.36*	*268.95*	*4.60*	*2.77%*	*3.37%*	*13.62%*
No carry-overs	*96.75*	*172.13*	*268.88*	*7.27*	*4.22%*	*3.32%*	*14.32%*
50 % Debt finance	*88.65*	*180.20*	*268.85*	*11.78*	*6.54%*	*3.23%*	*15.18%*
TECHNOLOGY: FLEXIBLE (g = 6.81)							
Neutral	*197.13*	*76.66*	*273.79*	*0.00*	*0.00%*		
Full loss offset	*106.33*	*164.41*	*270.74*	*3.19*	*1.94%*	*3.61%*	*16.03%*
Base case	*102.84*	*168.23*	*271.08*	*4.82*	*2.86%*	*3.13%*	*13.06%*
No carry-overs	*97.11*	*173.92*	*271.03*	*7.50*	*4.31%*	*3.07%*	*13.78%*
50 % Debt finance	*88.60*	*182.43*	*271.04*	*12.30*	*6.74%*	*2.95%*	*14.46%*
TECHNOLOGY: FULLY FLEXIBLE (g = 11)							
Neutral	*146.09*	*56.81*	*202.91*	*0.00*	*0.00%*		
Full loss offset	*80.54*	*120.38*	*200.92*	*0.00*	*0.00%*	*3.13%*	*13.72%*
Base case	*80.54*	*120.41*	*200.94*	*0.00*	*0.00%*	*3.09%*	*13.41%*
No carry-overs	*80.54*	*120.38*	*200.92*	*0.00*	*0.00%*	*3.13%*	*13.72%*
50 % Debt finance	*80.54*	*120.42*	*200.96*	*0.00*	*0.00%*	*3.07%*	*13.32%*

See note in Table 2.

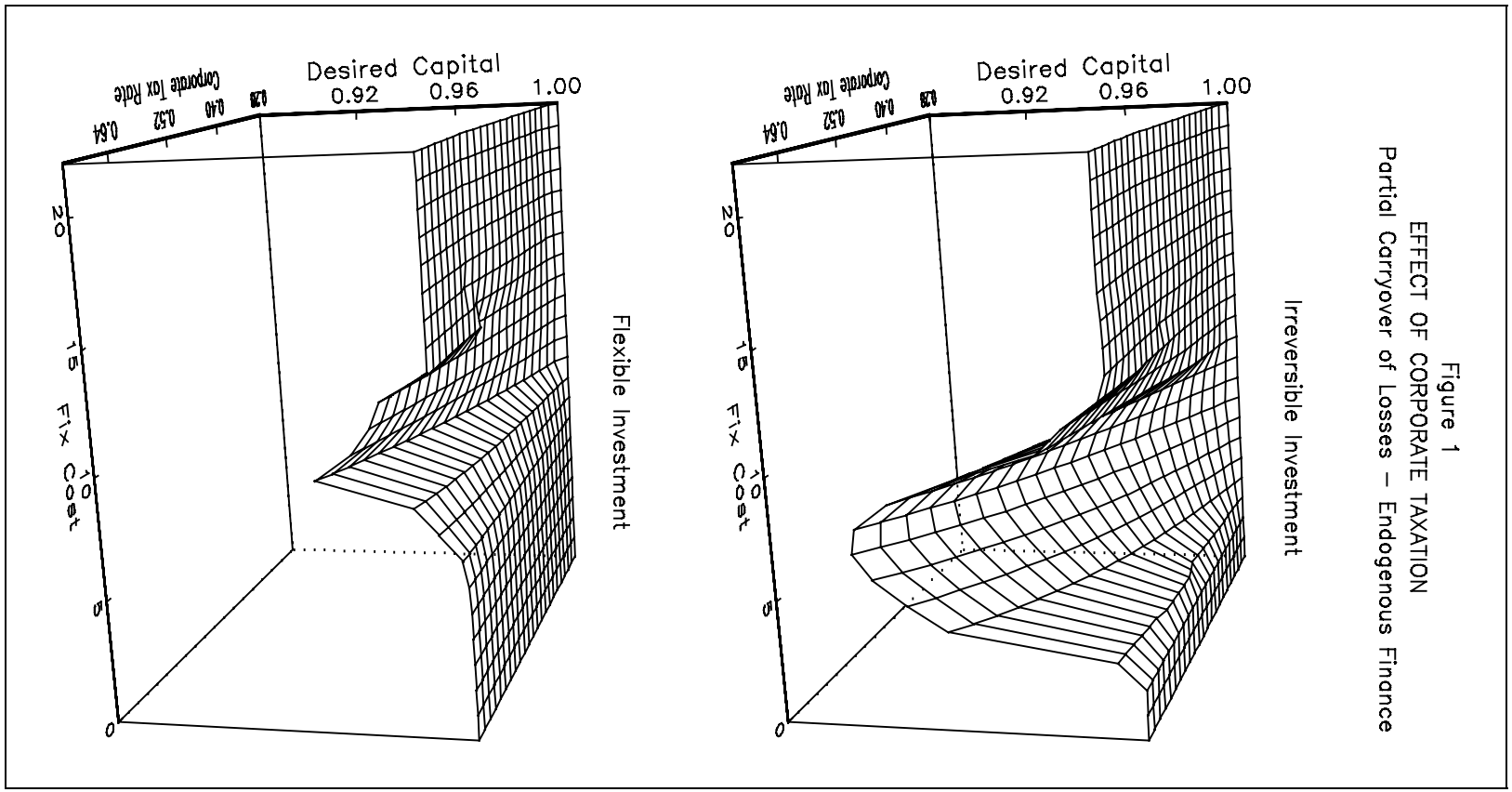

Figure 1
EFFECT OF CORPORATE TAXATION
Partial Carryover of Losses – Endogenous Finance

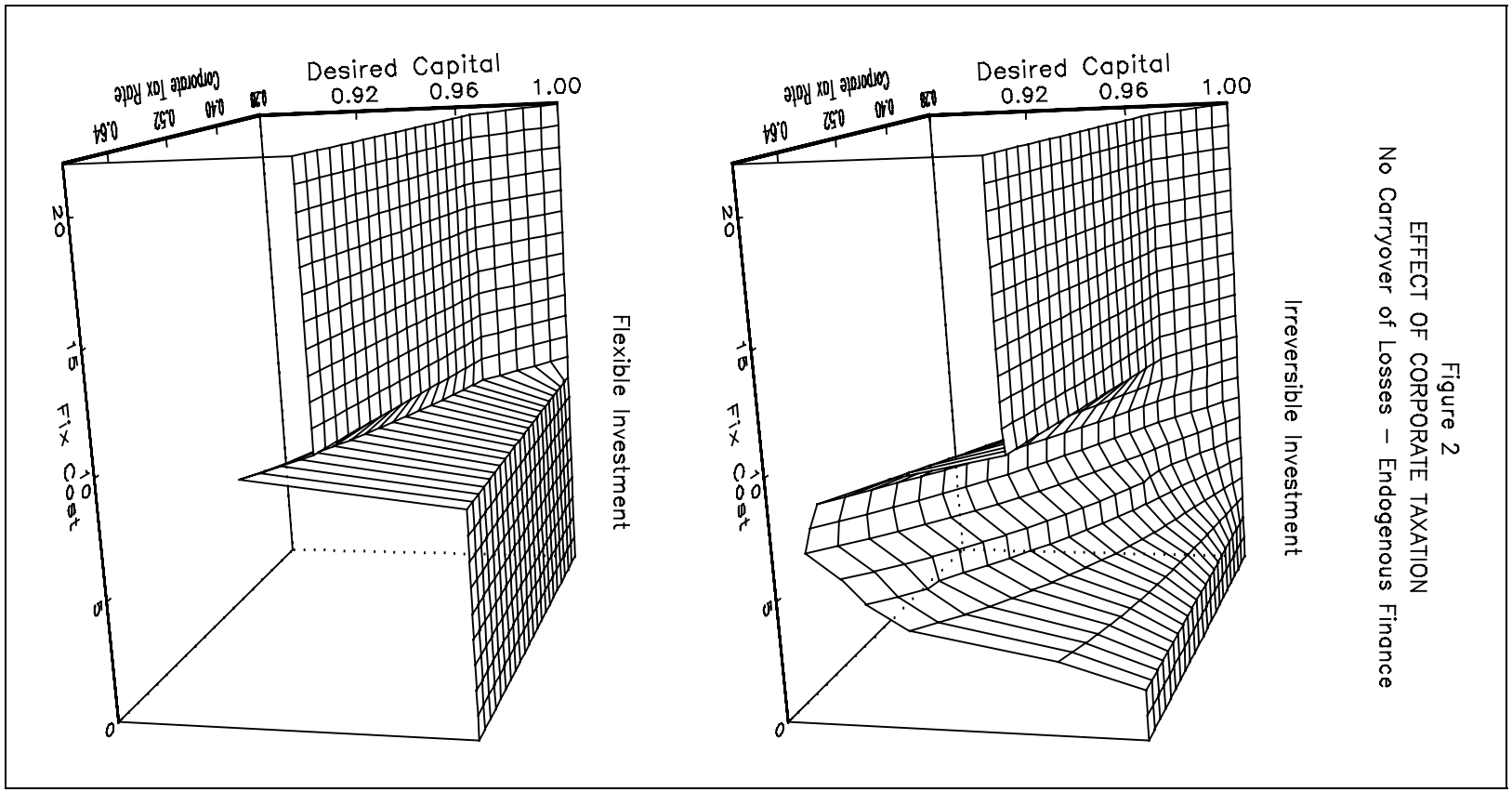

Figure 2
EFFECT OF CORPORATE TAXATION
No Carryover of Losses – Endogenous Finance

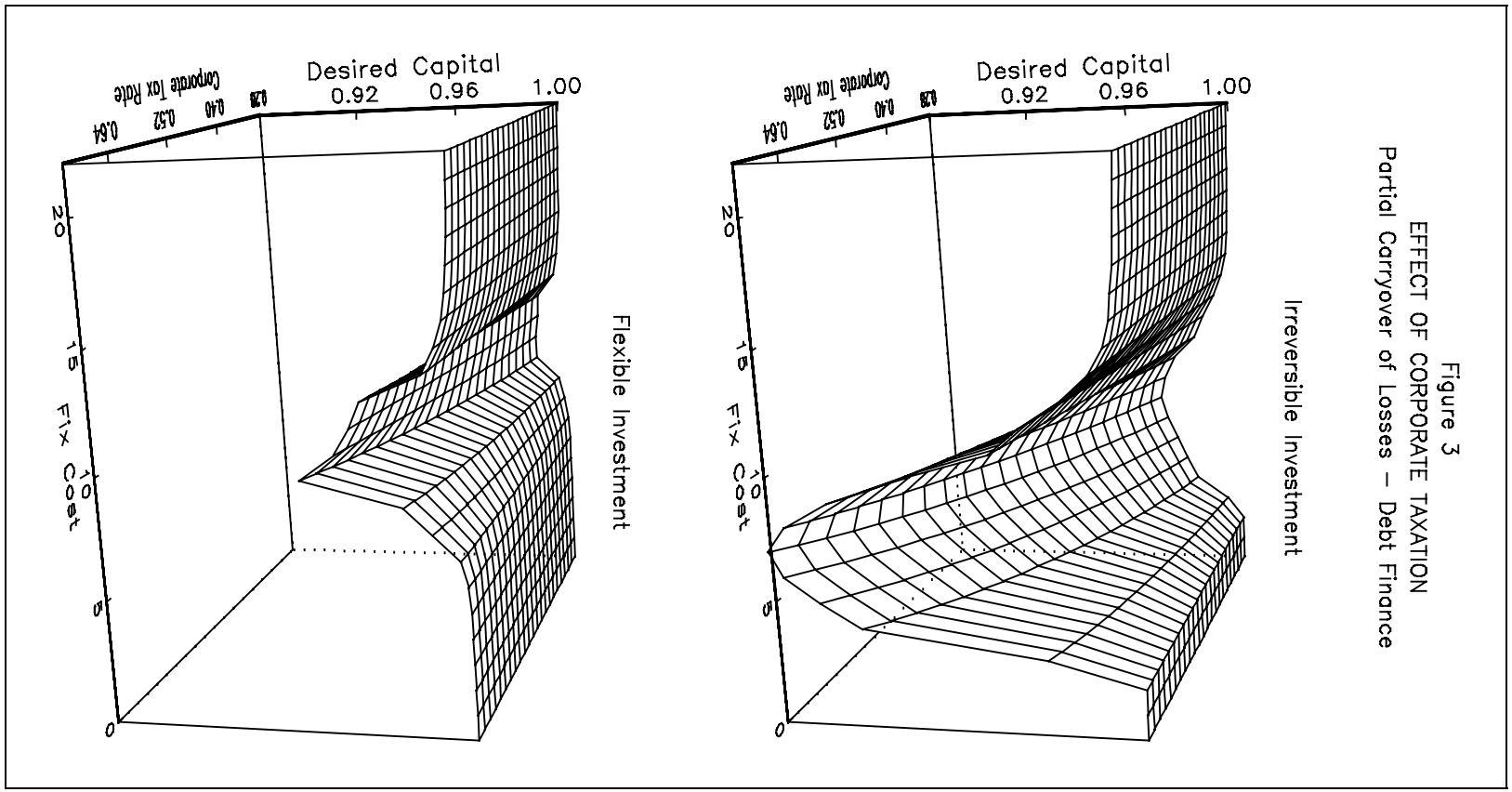

Figure 3
EFFECT OF CORPORATE TAXATION
Partial Carryover of Losses – Debt Finance

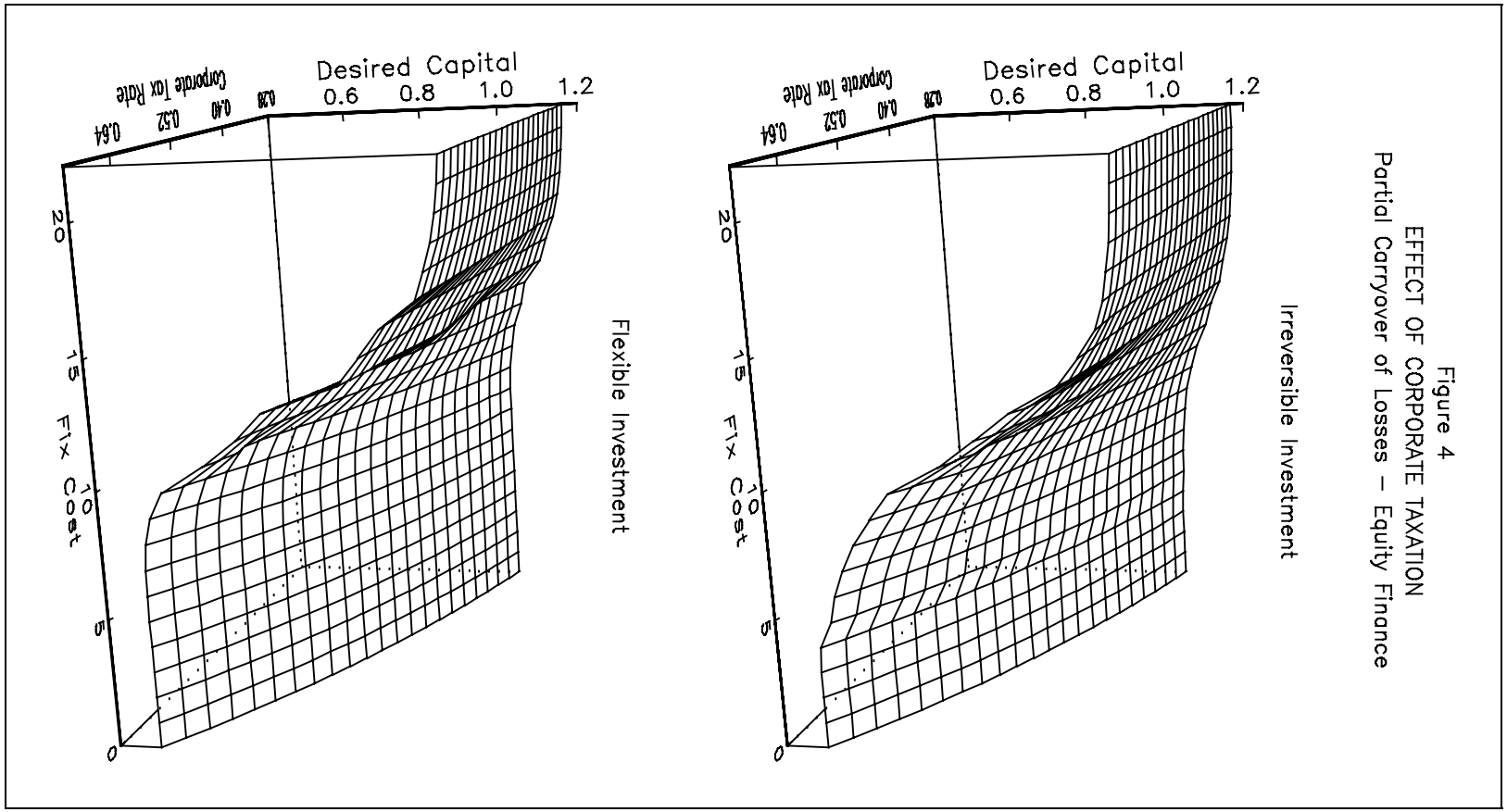

Figure 4
EFFECT OF CORPORATE TAXATION
Partial Carryover of Losses – Equity Finance

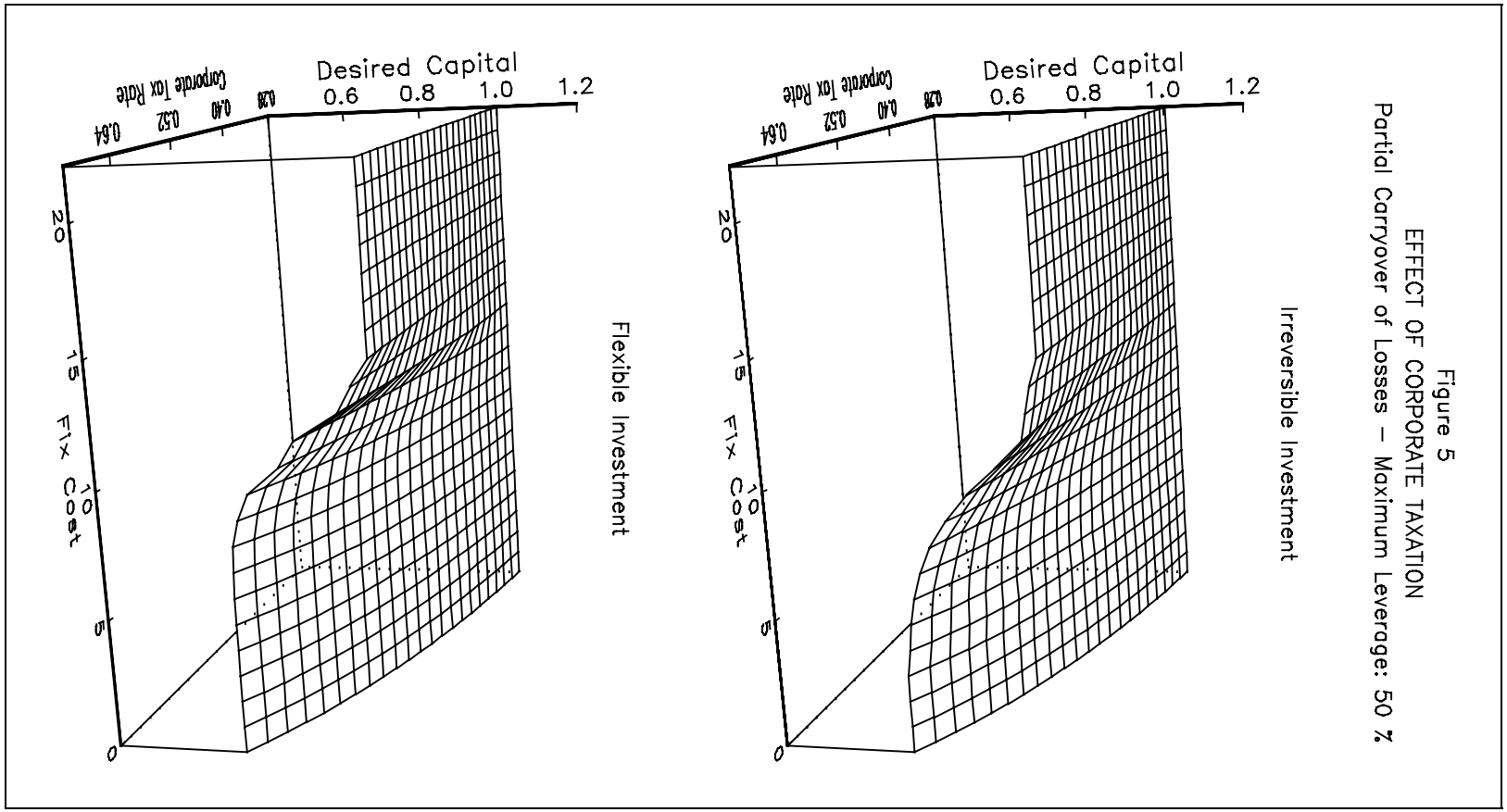

Figure 5
EFFECT OF CORPORATE TAXATION
Partial Carryover of Losses – Maximum Leverage: 50 %