ESSAYS ON CORPORATE TAXATION
AND THE FIRM

by

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for the degree of doctor of philosophy
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Abstract of Ph.D. Dissertation
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Essays on Corporate Taxation and the Firm


Essay I proposes a two-stage dominant firm model which allows for cost-reducing investment by the dominant firm prior to quantity competition. Market structure is endogenous, and accommodated and impeded entry equilibria with and without underinvestment are characterized. Tax effects are generally consistent with economic theory but special cases arise: for example, (i) small tax changes alter market structure through entry or exit; (ii) some tax changes have no impacts on market variables; and (iii) a subsidy to non-producing fringe is welfare-improving. The analysis emphasizes the importance of market discontinuities.

Essay II proposes a particular collusive equilibrium in a repeated oligopoly model with homogeneous quantity-setting firms. The industry sustains tacit collusion by using credible and severe punishments of deviations. The paper focuses on the impact of changing the refundability of tax losses. The analysis of the most collusive equilibrium with losses indicates that a tax policy which increases refundability reduces industry output, increases market price, and therefore strengthens tacit collusion. In addition, the policy increases government revenue and reduces social welfare.
Essay III develops theoretical expressions for the user cost of capital in the presence of tax asymmetries. An empirical model is developed to estimate the probability of a given tax status on the basis of firm characteristics. A structural switching regression model of the firm’s demand for capital goods is developed next. This model uses estimated probabilities as inputs and is utilized to investigate the potential endogeneity of the cost of capital using a balanced panel of Canadian companies. Results suggest that tax status affects the firms’ capital acquisition behaviour.
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INTRODUCTION

In this dissertation, three essays treat various issues in understanding and evaluating firm behaviour in response to taxation. The first essay characterizes market equilibrium configurations that can arise in a dominant firm model. Then, the effects of capital taxes and subsidies are analyzed using the model. The second essay analyzes the impact of giving refunds of corporate taxes in an oligopolistic supergame model. The third essay uses a panel of large public Canadian companies to analyzes whether tax asymmetries affect firms' investment decisions.

The first essay is concerned with the effect of tax policies when there is imperfect competition in product markets. The industry is described by a two-stage dominant firm-competitive fringe model. In the first stage, the dominant firm benefits from a differential movement advantage in that it may carry out cost-reducing investment. In the second stage, the dominant firm and the fringe engage in quantity competition. A large number of market equilibrium configurations exist due to the presence of discontinuities and because market structure is endogenous. The analysis concentrates on accommodated and impeded entry equilibria with and without underinvestment. Comparative static effects of capital taxes and subsidies are generally consistent with economic theory but special cases arise: for example, (i) small tax changes alter market structure through entry or exit; (ii) some tax changes have no impacts on market variables; and (iii) a subsidy to non-producing fringe is welfare-improving. The analysis emphasizes the importance of market discontinuities and the difficulties in identifying optimal tax policies in the presence of such discontinuities.

The second essay is also concerned with tax policies with imperfect competition in product markets. In addition, it is concerned with the asymmetric treatment of gains and losses under the corporation tax. The industry is collusive and the game-theoretic environment is that of a repeated oligopoly supergame with homogeneous quantity-setting firms. The industry sustains tacit collusion by using credible and severe punishments of deviations which can lead to losses in punishment phases. To exploit this phenomenon, the essay focuses on the impact of changing the refundability of tax losses on the ability of firms to collude. The analysis of the most collusive equilibrium with losses indicates that a tax
policy which increases refundability reduces industry output and increases market price. Thus, counter to intuition, the policy strengthens tacit collusion. The policy also increases government revenue and reduces social welfare.

The third essay pursues the issue of tax asymmetries and analyzes whether they affect investment behaviour at the firm level. To this end, theoretical expressions for the user cost of capital in the presence of tax asymmetries are developed. The key feature of the user cost with asymmetries is time-dependence, which has important empirical implications. A Poisson regression is developed and used to estimate the probability of a given tax status on the basis of firm characteristics. The results from that stage exhibit high consistency with the theory. Next, a structural switching regression model of the firm's demand for capital goods is developed. The structural model uses estimated Poisson probabilities as inputs and is utilized to investigate the potential endogeneity of the cost of capital using a balanced panel of Canadian companies. The hypothesis of exogenous switching is rejected and the results therefore suggest that tax status affects the firms' capital acquisition behaviour.
Essay I

Capital Taxation in a Dominant Firm Model with Sunk Investment
1.0 INTRODUCTION

The analysis of taxation under imperfect competition in product markets has been a valuable interface between industrial organization and public economics for some time. That literature focuses, for the most part, on the analysis of the commodity taxation under a wide range of market structures.\(^1\) Capital taxation under imperfect competition raises a number of interesting theoretical issues which do not arise when studying commodity taxation. Examples are strategic interactions between firms which arise from past investments, differential taxation of firms, capital intensity and differential efficiency of production, and so on.\(^2\)

The present paper examines some of these issues in a dominant firm model. The dominant firm is established and endowed with an exogenous \textit{ex ante} absolute cost advantage over the competitive fringe. The model has two stages: in the first (pre-entry) stage, the dominant firm may invest in order to reduce its marginal cost of production in the second (post-entry) stage: in the next stage, previous investments are sunk, and the dominant firm either competes in quantities against a competitive fringe, or takes over the entire market if entry is successfully impeded.

In the traditional dominant firm model, the fringe reacts passively to changes in output or price by the dominant firm. In order to decide whether to enter the industry or not, and how much output to produce if it does, the fringe needs to know what the dominant firm will produce or charge in the competition stage. Without a commitment of some sort by the dominant firm, there is no credible information upon which the fringe can make the above decisions. Investment in the pre-entry stage endows the dominant firm with the ability to precommit itself to some position which narrows the range of actions of the fringe, which cannot precommit. Hence, the initial asymmetries which ensure dominance are couched in terms of "differential movement advantage", in the language of Geroski and Jacquemin (1984). Assuming that capital (which can be interpreted as capacity) is costly and sunk once purchased, its presence constitutes a commitment on the part of the dominant firm to produce at least a well-defined level of output in the second stage.
The dominant firm model is often used in the literature to describe a wide number of market situations in which the distribution of market power cannot realistically be characterized as symmetric.\textsuperscript{3} The model is particularly well-suited to study the impacts of policies which focus on asymmetries, such as tax breaks for small firms in Canada. Effective corporate tax rates in Canada vary by sectors, level of concentration and firm size.\textsuperscript{4} Taxes that fall on capital will affect the firms' investment and production decisions, and hence perturb the market equilibrium. In a related vein, Holmes (1996) presents a discussion of this industry structure and analyzes the effects of policies that affect the industry price.

The present model exhibits several original features when compared with the literature. First, the use of sunk capital for the purpose of reducing costs and possibly impeding entry, has never been examined formally in the context of a dominant firm model. For example, Mintz and Seade (1990), and Holmes (1996) do not allow for commitment. Second, the model allows for equilibria in which the dominant firm purchases less capacity in the pre-entry stage than the level required to produce output in the post-entry stage. This result has been previously obtained under conditions which are incompatible with the model.\textsuperscript{5} Finally, the analysis pays particular attention to the discontinuities inherent to this market structure, in addition to those which arise from the technology.

The paper is organized as follows. Section 2.0 presents the model. Section 3.0 characterizes the market equilibria and restrictions on the set of equilibria. Section 4.0 analyzes the effects of changes in capital taxes or subsidies on various equilibrium regimes. In addition, it contains a brief discussion of the implications of the results for optimal taxation. Finally, Section 5.0 concludes the paper by a summary and a discussion of some policy implications.
2.0 A DOMINANT FIRM MODEL WITH SUNK INVESTMENT

2.1 The Model

The dominant firm (henceforth, DF) model usually characterizes an industry in which one firm is a price maker that faces smaller price taking firms. Taken together, the latter group constitutes the competitive fringe. The "no-entry" version of the model is characterized by five key assumptions: the DF is much larger than any other individual firm because of its lower costs; apart from the DF, all firms are price-takers; the number of fringe firms is fixed so no new entry in the industry can occur; the DF knows the demand curve facing the industry; and the DF can determine how much output the fringe will produce at any price.

In what follows, the standard model just described is augmented by incorporating the differential movement advantage discussed in Section 1.0. All firms have complete information. In the pre-entry (first) stage, the DF has the option of purchasing organizational capital. This asset may be thought of as a set of contracts or contingencies, which can include (but are not limited to) capacity, labour contracts, R & D expenditures, product or industry-specific capital, and so on. Organizational capital is assumed to have the following properties: first, it does not physically depreciate; second, it is sunk once purchased due to the absence of rental or resale market; and third, it reduces the DF’s marginal cost of production in the post-entry (second-stage). The first two assumptions ensure that the commitment to producing some level of output in the second stage is credible. The third property represents the pecuniary benefit from previous investment. Organizational capital is therefore interpreted as a generalized concept of productive capacity; henceforth, "capital" and "capacity" will be used interchangeably from now on.

The first stage ends once all investments have been made by the DF. The fringe does not have that opportunity to invest prior to quantity competition and is therefore inactive in this stage. In the second stage, production and quantity competition (if any) take place and the entire production is sold to consumers at the market-clearing price. Fringe firms must purchase all the capital they need and produce output during the second stage. The DF can add (but not subtract) to the capacity purchased in the first stage. Also assume that it is
always profitable for the DF to engage in production. Finally, ignore discounting and depreciation since they would not affect the qualitative results.  

The formal exposition of the game proceeds backwards, beginning with the second stage. The DF and the fringe, which consists of \( n \) identical small firms, are indexed by \( d \) and \( f \) respectively. It is assumed that \( n \) is fixed, which is not unreasonable in a two-period model. Firms produce a homogeneous output and face an inverse market demand function \( p(Y) \), where \( Y = y_d + ny_f \), and \( y_d \) and \( y_f \) are the quantities produced by the DF and each fringe firm respectively. The usual restrictions are imposed on demand: \( p(Y) \) is twice continuously differentiable, satisfies \( p' = \partial p/\partial Y < 0 \) for all \( Y \geq 0 \) such that \( p(Y) \geq 0 \), and finally \( \lim_{Y \to \infty} p(Y) = 0 \). Let \( R^d(y_d,y_f) = p(y_d + ny_f)y_d \) and \( R^f(y_f) = py_f \) denote the total revenue functions of the DF and each fringe firm respectively. The cost side is formalized later.

Each fringe firm perceives the market to be competitive so its revenue function satisfies \( \partial R^f/\partial y_f = p \) and \( \partial^2 R^f/\partial y_f^2 = 0 \). The DF acts as a monopolist on its residual demand; this curve exhibits a kink at the point where the market price equals the fringe’s shutdown price, \( p_s \). It follows that the DF’s marginal revenue function, which is denoted by \( MR^d \), exhibits a discontinuity at \( p_s \). For any \( p \leq p_s \), the DF is the sole producer in the market. In light of this important market discontinuity, the only restriction imposed is that \( MR^d \) be nonincreasing in both \( y_d \) and \( ny_f \). With respect to \( y_d \), the restriction rules out local optima which would result from intersections between the DF’s marginal cost and upward sloping segments of \( MR^d \). With respect to \( ny_f \), the restriction ensures that the DF perceives its output as a strategic substitute for the fringe’s output. The corresponding assumption on behalf of the fringe is not required since \( \partial^2 R^f/\partial y_d \partial y_f = p' < 0 \) anyway. The strategic substitutability of outputs ensures that the effects of investment and the nature of quantity competition in the post-entry stage are consistent with each other.

In the first stage, the DF makes a costly investment in capacity. Investment reduces the marginal cost of producing output up to capacity in the second stage and commits the DF to use that capacity for production. If the DF wishes to purchase more capacity in the second stage, it can do so at a higher cost. In any case, the price received by fringe firms falls when the DF increases output. Since fringe firms take \( p \) as given, they end up
producing less. There is no need to make the assumption that capacities are strategic substitutes in the first stage, as in Besley and Suzumura (1992), because there is no active strategic interaction between the DF and the fringe in the first stage here.

The firms’ technologies are summarized by their cost functions, and taxes on capital enter the model through costs. This follows from the interpretation of the corporate income tax as a levy whose incidence falls on capital. Let \( k_d \) denote capacity purchased in a competitive market in the first stage and assume that it is measured in the same units as \( y_d \). Assume that the DF can produce output at a constant marginal cost \( c \) up to capacity \( k_d \).

Every unit produced above \( k_d \) incurs an additional cost of \( c_0 \). The short-run marginal cost of producing output is given by:

\[
MC^d = \begin{cases} 
  c & \text{for } y_d \leq k_d, \\
  c + c_0 - \tau_d & \text{for } y_d > k_d.
\end{cases}
\]

where \( \tau_d \) is a tax per unit of capital used by the DF. The short-run total cost of producing output is:

\[
C^d = \begin{cases} 
  cy_d & \text{for } y_d \leq k_d, \\
  ck_d + (c_0 - \tau_d)(y_d - k_d) & \text{for } y_d > k_d.
\end{cases}
\]

where \((y_d-k_d)\) is the additional capacity that must be purchased in the second stage to produce output \( y_d \) in the case in which \( y_d > k_d \). It is important to note that (2) exhibits a kink at the point where \( y_d = k_d \). The constant unit cost of capacity is \((c_0 + \tau_d)\) and hence the total cost of capacity is denoted by \( G^d = (c_0 + \tau_d)k_d \). It follows that the long-run marginal cost is \((c + c_0 + \tau_d)\). Note that fixed costs are ignored since they play no role in the analysis that follows.

The total cost function of each fringe firm is \( C^f(c, c_0, y_f, \tau_f) \), where \( \tau_f \) is a tax per unit on capital used by the fringe firm. Given that each fringe firm has no prior commitment in capacity, it must install all the capacity it needs in the second stage so \( y_f = k_f \). This general
cost function satisfies \( C^f_y = \partial C^f/\partial y_f > 0 \) and \( C^f_{yy} = \partial^2 C^f/\partial y_f^2 > 0 \). The marginal cost function of each fringe firm is \( C^f_y \), so \( S(p) = nC^f_y \) is the entire fringe's marginal cost curve or supply function. In addition, \( \partial C^f_y/\partial \tau_f > 0 \) so the tax rate is a shift parameter in the marginal cost function. For simplicity, assume that \( C^f(c,c_0,0,\tau_f) = 0 \). To ensure the existence of a cost advantage in favour of the DF, assume that \( S(p) \) lies above \( MC^d \) for all levels of output. Finally, assume that \( p(0) > C^f_y(c,c_0,0,\tau_f) \) to ensure that the fringe is viable for some range of prices.

There are issues concerning the marginal cost and purchases of capacity in the second stage. First, note that (1) closely resembles the rigid marginal cost function used by Dixit (1980, 97). His rigid function has a vertical segment where \( y_d = k_d \). This is incorrect in light of the kink in total costs. The appropriate marginal cost function must have a discontinuity where \( y_d = k_d \). As soon as \( y_d \) exceeds \( k_d \), the marginal cost of production jumps from \( c \) to \( (c+c_0+\tau_d) \). This correction complicates the analysis by introducing a second source of discontinuity in the market.

Second, the possibility that the DF purchase capacity in the second stage in equilibrium must be shown. It is customary in models with strategic investment to assume that output equals previously installed capacity in equilibrium. This conclusion is inconsistent with cost structures such as (2) which allow for additional capacity. Moreover, the conclusion is simply incorrect. The DF's profit is \( \pi^d = R^d - C^d - G^d \). Substitute the expressions for \( C^d \) and \( G^d \) to write a general expression for profit:

\[
\pi^d = R^d - c k_d - (c_0 + \tau_d)(y_d - k_d) - (c_0 + \tau_d)k_d.
\]  

In the \( y_d \leq k_d \) case, assume \( y_d = y_1 = k_d \) and let \( \pi_1 = R_1 - c y_1 - (c_0 + \tau_d)k_d \). Hold \( k_d \) constant to examine the \( y_d > k_d \) case. Next, let \( y_d = y_2 > y_1 \). In this case, profit is denoted by the expression \( \pi_2 = R_2 - (c_0 + \tau_d)(y_2 - k_d) - (c_0 + \tau_d)k_d \). Note that \( R_2 > R_1 \) since a downward movement along the elastic portion of the demand curve increases revenue. Holding \( k_d \) constant, compare \( \pi_1 \) to \( \pi_2 \) using the fact that \( k_d = y_1 \). For instance, for purchasing additional capacity to be preferred to producing up to capacity, or \( \pi_1 < \pi_2 \), the condition that must hold is \( (c_0 + \tau_d)(y_2 - k_d) < R_2 - R_1 \). The condition requires that the
incremental cost of purchasing additional capacity be less than the incremental revenue obtained from selling the additional units of output produced using that new capacity. The firm produces up to capacity if the inequality is reversed. Another way of justifying the possibility of purchasing additional capacity in equilibrium is to note that there is no a priori restriction that \((c_0 + \tau_d)\) be larger than \(c\). One can use the derivation just presented and the second line in (2) to see that it may be advantageous in total cost terms to purchase additional capacity if \((c_0 + \tau_d) < c\). As expected, an increase in the gross unit price \((c_0 + \tau_d)\) of additional capacity would, ceteris paribus, discourage its use.\(^{14}\) In terms of (1), \((c_0 + \tau_d)\) is the length of the discontinuity in \(MC^d\). This may be interpreted as the penalty in terms of marginal cost of purchasing additional capacity in the second stage.

The above emphasis on total, as opposed to marginal conditions, is justified by the presence of discontinuities on both the revenue and cost sides. With such discontinuities, it is not possible in a global sense to proceed backward from the quantity competition stage to the investment stage as in Besley and Suzumura (1992). As shown by Tirole (1988), calculating the subgame perfect Nash equilibrium of a two-stage game in a Cournot oligopoly is a trivial exercise in which continuity is never questioned.

2.2 Firm Optimization

Again, proceed backward and begin with the second stage. In that period, the DF and fringe firms choose their outputs given the DF’s capital investment profile \(k_d > 0\). The profit per fringe firm is expressed as:

\[
\pi_f = p y_f - C^f(c, c_0 y_f, \tau_f).
\]

The first-order necessary condition for a profit maximum is:

\[
\frac{\partial \pi_f}{\partial y_f} = p - C_y^f = 0.
\]
Price equals marginal cost since each fringe firm is a price taker. For the market as a whole, however, $p' < 0$. Any individual fringe firm perceives that $p' = 0$ since it believes that its output decision cannot affect the market price. The second-order condition associated to (5) is satisfied by the assumption that $C_{yy}^f > 0$. In order to determine how $y_f$ varies as $y_d$ changes, note that $p = p(y_d + ny_f)$ for the market as a whole. Thus, rewrite (5) as $p(y_d + ny_f) = C_{yy}^f$. Totally differentiate this last expression and rearrange to obtain:

$$\frac{dy_f}{dy_d} = \frac{-p'}{np' - C_{yy}^f} < 0. \tag{6}$$

The sign of this expression follows from previous assumptions. The expression says that each fringe firm’s output supply falls as the DF’s output rises. That (6) holds for the entire fringe is easily seen by multiplying through by $n$. The DF model is therefore consistent with the fact that the fringe perceives outputs as being strategic substitutes. By virtue of (6), $y_f = y_f(y_d)$ and this is something the DF takes into account in making its optimal output choice.

Consider the total cost of capacity and the total cost of output (2) with the two possible cases ($y_d \leq k_d$ and $y_d > k_d$) to obtain the DF’s profit:

$$\pi^d = \begin{cases} R^d - cy_d - (c_0 + \tau_d)k_d & \text{for } y_d \leq k_d, \\ R^d - ck_d - (c_0 + \tau_d)(y_d - k_d) - (c_0 + \tau_d)k_d & \text{for } y_d > k_d. \end{cases} \tag{7}$$

where $R^d = p(y_d + ny_f(y_d))y_d$ from (6). As pointed out earlier, (7) is not differentiable globally due to discontinuities in revenues and costs. It follows that the usual continuous first and second-order conditions cannot be used to characterize a global market equilibrium pair $(y_d, y_f(y_d))$. As well, continuous restrictions on second-order derivatives to characterize conditions for existence, uniqueness, and local stability are not available.
In light of these complications, the approach followed here is to characterize the relevant subset of market equilibria that can arise in the model. Such equilibria are grouped under two market structures consisting of accommodated and impeded fringe entry. Blockaded entry equilibria could also arise. Entry is blockaded when the DF's cost advantage is so great that it behaves as a monopolist on the entire market demand. This type of equilibrium is ignored since it is devoid of strategic interactions. Moreover, the comparative static effects of exogenous changes on the equilibrium are well-known in that case.

3.0 CHARACTERIZATION OF MARKET EQUILIBRIA

3.1 Restrictions on the Set of Equilibria: Excess Capacity

In order to simplify the subsequent analysis, restrictions on the possible set of equilibria are discussed first. In the present model, "underinvestment" refers to situations in which the DF purchases additional capacity in the second stage. In other words, underinvestment occurs when the DF purchases capacity in the first stage which is insufficient to produce its optimal level of second-stage output. The alternative in which the DF second-stage optimal output is just equal to capacity installed in the previous stage is the "no underinvestment" case. For completeness, "overinvestment" would refer to the idea of excess (or idle) capacity in equilibrium.\(^\text{15}\)

As discussed in Section 2.0, the possibility of underinvestment hinges upon the trade-off between the benefits and costs of purchasing capacity in advance as opposed to purchasing it in the second stage. Examples of first-stage investments include capital-intensive production technology, long-term labour contracts with rigid wages, minimal temporary lay offs and variability in hours worked, and so on. The benefits of making such investments in the first stage, as opposed to the second stage, come from the following. The production of the first \(k_d\) units of output is attractive since their marginal cost is lower as opposed to that of units beyond \(k_d\).
The following two mutually exclusive Propositions summarize the characterization of relevant equilibria:

**Proposition 1.** If it exists, an equilibrium with no underinvestment is unique.

**Proposition 2.** If it exists, an equilibrium with underinvestment is unique.

**Proof.** From the assumption that $MR^d$ is nonincreasing in $y_d$ and $ny_f$, and from the structure of (1), the intersection between $MR^d$ and $MC^d$ must be unique.

To my knowledge, the underinvestment equilibria described under Proposition 2 have not been studied in the literature. For example, the underinvestment in fixed costs described by Bulow et al. (1985b) arises only with strategic complements and represents accommodating behaviour on the part of the incumbent firm. This is, of course, inconsistent with the present model. Propositions 1 and 2 describe credible equilibria since the DF always uses its entire capacity in the post-entry stage, regardless of the timing of its acquisition. Those equilibria do not depend on the empty threat of installing capacity that will not be used in the second stage. In that respect, they are similar to perfect equilibria in games in which all firms behave strategically.

Credibility is therefore crucial to answer the question of whether excess (or idle) capacity can be observed in equilibrium. Excess capacity is defined here as capacity that is not used by the DF in the post-entry stage, whether entry occurs or not. The issue is taken up by Dixit (1980) and Bulow et al. (1985a, b) in their characterizations of perfect Nash equilibria in two-stage quantity-setting games. The equilibrium in the present model is subject to the same discipline as a perfect equilibrium through the credibility requirement.
As noted by Bulow et al. (1985b):

Building extra capacity converts marginal costs into fixed costs and so raises a firm's output. Therefore, such actions may deter entry. However, beyond a certain point, additional capacity will not deter entry further. Capacity deters competitors only if they believe the capacity will be used after entry. Thus the most extra capacity a firm will build is the amount it will actually use if entry occurs. Dixit (1980) and Spulber (1981) (effectively assuming strategic substitutes) concluded that if it would be profitable to use all capacity after competition enters, then it surely would be profitable to use all capacity if no entry occurs. Hence no capacity would be built and subsequently left idle.

With strategic complements and quantity competition, however, a firm will want to supply less if it remains a monopolist than if competitors produce. Consequently, capacity can be built that the firm could credibly threaten to use in the event of entry but that would be left idle if entry was deterred (504).

Hence, the proof of Propositions 1 and 2 implies that there cannot be excess capacity in the present model. From an economic standpoint, a model of quantity competition with perfect certainty simply has no role for excess capacity. Following Propositions 1 and 2 and the above discussion, one can state:

**Corollary 1.** Initial equilibria with idle organizational capital do not exist.

*Proof. (Adapted from Tirole [1988, 318].)* The firm could obtain the same product-market outcome by accumulating only $y_d$, thus saving $(c_0 + \tau_d)(k_d - y_d)$.

### 3.2 Accommodated Entry Equilibria

An accommodated entry equilibrium is a market outcome in which both the DF and the fringe produce positive amounts of output to serve market demand. Following the above discussion, there are two possible equilibrium configurations: one with underinvestment and one without it. Given the discontinuity in the DF's marginal revenue at $p = p_s$, $MR^d$ in an accommodated entry equilibrium is characterized by:
where $R_y^d = \frac{\partial R^d}{\partial y_d}$ and $y_f = y_f(y_d)$. Substitute (6) into (8), simplify, and omit arguments in order to obtain $MR^d = p + \gamma y_d p'$, where $\gamma = -C_y^f/(np' - C_y^f)$ and $0 < \gamma < 1$. Optimality conditions on the cost side are discussed below as they depend on whether there is underinvestment or not.

**Regime A. Accommodated Entry without Underinvestment**

This is very similar to the Cournot oligopoly case studied by Dixit (1980) and described in greater detail by Tirole (1988). Take the investment profile $k_d^A > 0$ as given. Let the profit-maximizing output and capacity in this regime be denoted by $y_d^A$ and $k_d^A$ respectively. The solution satisfies $y_d^A = k_d^A$ by virtue of Proposition 1 and Corollary 1. Recall from (2) that $C_d^A$ has a kink at $y_d = k_d^A$. Hence, $MC_d^A$ is established by taking the left-side limit of the derivative of $C_d^A$ with respect to $y_d$. The calculation is appropriate given that $k_d^A$ is sunk in the second stage. Using (8) and (1), the first-order necessary condition that characterizes a profit maximum in Regime A is:

$$p + \gamma y_d^A p' = c = \lim_{y_d^A \to k_d^A} C_y^d.$$  

Marginal cost equals marginal revenue since the DF acts as a monopolist on its residual demand. Since global differential results cannot be stated here, it is assumed that the second-order necessary condition is satisfied. Solve (9) for $y_d^A$ to get $y_d^A(k_d^A) = k_d^A$, and then substitute $y_d^A$ into $y_f(y_d)$ to obtain the output per fringe firm, $y_f^A(k_d^A)$. The equilibrium market output and price are $Y^A = y_d^A + ny_f^A$ and $p^A = p(Y^A)$. Figure 1 illustrates the equilibrium Regime A, with $v = (c + c_0 + \tau_d)$ used in the diagram. The equilibrium $y_d^A$ is found by locating the point at which the lower segment of $MC_d^A$ just touches the upper continuous segment of $MR_d^A$. Equilibrium quantities and price are derived as shown in the diagram. With $y_d^A = k_d^A$ in equilibrium, the discontinuity in
MC\textsuperscript{d} occurs at precisely that point: the DF produces the entirety of its output at the lower marginal cost c.

**Regime B. Accommodated Entry with Underinvestment**

Take the investment profile $k_d^B > 0$ as given. Let the profit-maximizing output in this regime be denoted by $y_d^B$. Using Proposition 2 and Corollary 1, this solution must satisfy $y_d^B > k_d^B$. Unlike in Regime A, MC\textsuperscript{d} is now calculated by taking the right-side limit of the derivative of C\textsuperscript{d} with respect to $y_d$. The first-order condition that characterizes equilibrium Regime B is:

$$p - \gamma y_d p' = c + c_0 - \tau_d = \lim_{y_d \to k} C_v^d.$$  \hspace{1cm} (10)

Holding marginal revenue constant in (9) and (10), it must be the case that $y_d^B < y_d^A$ since marginal cost here is higher than in (9). It follows that $k_d^B < k_d^A$.\textsuperscript{19} Figure 2 illustrates the equilibrium Regime B. In this configuration, the DF wishes to produce an amount of output which exceeds capacity installed in the first stage, $k_d^B$. Given previous assumptions, this production plan requires second-stage investment of exactly $(y_d^B - k_d^B)$. Unlike in Figure 1, it is now the higher segment of MC\textsuperscript{d} which intersects the upper segment of MR\textsuperscript{d}. Output up to $k_d^B$ is produced at marginal cost c while the remaining $(y_d^B - k_d^B)$ units are produced at higher marginal cost $(c + c_0 + \tau_d)$.

The discussion focuses on the characterization of equilibrium regimes, not on the optimal amount of first stage investment *per se*. It is worth reiterating from the discussion in Section 2.0 that the possibility and extent (if any) of underinvestment is, *ceteris paribus*, decreasing in the length of the discontinuity in MC\textsuperscript{d}, $(c_0 + \tau_d)$. An illuminating interpretation of the choice of $k_d$ in the first stage is that it constitutes the choice of the cost function the DF will face in the second stage. For the purpose of tax analysis, the importance of the actual value of $k_d$ is limited because it is sunk in equilibrium. Taxes on capital can therefore have equilibrium impacts on output and second-stage investment, but not on $k_d$. 
3.3 **Impeded Entry Equilibria**

An impeded entry equilibrium is a market outcome in which the DF produces the entire industry output and hence \( n_y = 0 \). In such an equilibrium, market output is sufficiently high so that the market price is equal to \( p_s \), the fringe's shutdown price. The fringe makes zero profit at \( p_s \) and it is assumed that it does not enter (or shuts down) as it could earn zero profits elsewhere in the economy. On the one hand, this equilibrium can arise when the initial cost advantage in favour of the DF is just sufficient to keep the fringe out. On the other hand, it can also be brought about by tax policies, as will be shown below.

An impeded entry equilibrium must be distinguished from an equilibrium in which entry is blockaded. In the latter, the DF's cost advantage is so large that it behaves as a monopolist on the entire market demand and thus ignores the fringe entirely in its decisions. It is straightforward to show that market structure is relatively insensitive to exogenous perturbations of the equilibrium in a blockaded entry equilibrium.\(^20\) As will be shown below, that is not generally true of the impeded entry equilibrium.

**Regime C. Impeded Entry without Underinvestment**

Take the investment profile \( k_d^C > 0 \) as given. The profit-maximizing output in this regime is denoted by \( y_d^C \). By Proposition 1 and Corollary 1, this solution entails \( y_d^C = k_d^C \). While \( MC^d \) may be calculated as in (9), \( MR^d \) is discontinuous at \( y_d^C \). The equilibrium is illustrated in Figure 3. At \( y_d^C \), \( MR^d > c \) if one interprets point g as the point on the upper segment of marginal revenue which corresponds to the output at the kink in residual demand. The special feature of the equilibrium is that the lower segment of \( MC^d \) is located somewhere at the discontinuity in \( MR^d \). The upper segment of marginal cost is, of course, irrelevant.

**Regime D. Impeded Entry with Underinvestment**

Following the reasoning in the discussion of Regime B, the DF may underinvest in an impeded entry equilibrium as well. In this case, \( y_d^D > k_d^D \) given an investment profile \( k_d^D > 0 \). The firm purchases additional capacity of \( (y_d^D - k_d^D) \) in the second-stage. At the
equilibrium output $y_d^D$, $MR^d > (c_c_0 + \tau_d)$, with $MC^d$ calculated from (10). The optimal choice of $k_d$ is made according to the principles outlined under the discussion of Regime B. Figure 4 shows the equilibrium under Regime D. Unlike in Regime C, it is now the upper segment of $MC^d$ which is located at the discontinuity in $MR^d$.

Beyond that fact that they have been neglected in the literature, one way to motivate impeded entry equilibria is with regards to comparative static analysis of taxes on capital. In Figure 4, an initial equilibrium located near point g may be disturbed dramatically by an exogenous tax increase. If, for example, a tax change is large enough and/or the initial equilibrium is close enough to point g, then tax policy could change market structure from impeded to accommodated entry. Switches in regimes of this kind are discussed in the next Section.

4.0 EFFECTS OF CHANGING TAX RATES

4.1 Taxation, Market Structure, and Discontinuities

The impact of government policies under conditions of imperfect competition in product markets has recently been investigated in recent by Horstmann and Markusen (1992), and Alm and Thorpe (1995). This work emphasizes the importance of discontinuities in market adjustment. The authors reach the conclusion that allowing market structure to be endogenous can produce policy impacts which differ considerably, both in direction and magnitude, from those obtained under the assumption of fixed market structure. For example, small changes in policy variables can cause discontinuous market adjustments by inducing firms to exit or enter an industry. It follows that the marginal comparative static methods usually employed to analyze small policy changes cannot capture the effects of discontinuities in market adjustment.

At the same time, their analyses still use continuous global first-order conditions from profit maximization to establish the boundaries between regimes which are functions of cost and demand parameters. This is acceptable in their models because taxes are the only sources of discontinuity. In contrast, the present model incorporates discontinuities on both
cost and revenue sides as well. The drawback from the present approach is that market equilibria are more sensitive to perturbations and global continuous first-order conditions are not available for the purpose of analysis. The advantage is that a richer range of market impacts can be characterized by relaxing restrictions.

The following Sections examine the impact of capital tax policies on relevant market equilibria. Due to the lack of global differentiability, the comparative static analysis is mainly diagrammatic but is guided by previous assumptions. It is assumed that taxes are assessed and collected in the second stage. In his dominant firm model, Holmes (1996) analyzes policies which affect the market price. He considers output or market share restrictions on the dominant firm, a price floor, and mentions taxes that can be interpreted as falling on output. While the first two policies he considers add complications (e.g. the need for a rationing rule), the comparative static results he obtains are well known.

The emphasis on capital taxes simplifies the analysis by focusing on tax rates which are simply shift parameters in marginal cost functions. In order to put the tax analysis in the relevant industry context, consider examples of tax policies in Canada which favour small firms over large firms. First, preferential corporate income tax rates to small businesses are important measures. The combined federal-provincial tax rate on small businesses is 0.20. In comparison, the average rate for large non-manufacturing firms is 0.43 while the rate for large manufacturing businesses is approximately 0.36. Second, the Small Business R & D Tax Credit is another major measure. It allows small businesses to claim an R & D tax credit at a rate of 0.35, while the corresponding rate for large businesses rate is 0.20. Finally, small businesses are generally exempt from federal and provincial capital taxes. Large firms, on the other hand, are generally subject to capital taxes if they exceed a threshold defined according to assets. For example, the federal large corporation tax applies on assets in excess of $10 million. In closing, it is worth noting that provincial capital taxes are more important than federal ones.
4.2 A Tax on the Dominant Firm

The impact of a capital tax imposed on the DF is examined by changing \( \tau_d \), holding \( \tau_f \) constant. The focus is on impacts on (1) since marginal conditions affect the equilibrium. The change in \( \tau_d \) alters the after-tax cost of capital purchased in the second stage only. This change shifts the (upper) segment of MC\(^d\) which is located to the right of the discontinuity in the marginal cost function. Total conditions (profits) also change. By (2), a change in \( \tau_d \) affects the after-tax unit cost of capital purchased in the second stage. In addition, the change in \( \tau_d \) affects the total cost of capacity \( G^d = (c_0 + \tau_d)k_d \). It is worth noting that the policy does not affect the location of the discontinuity in MC\(^d\) with respect to the \( y_d \)-axis. The reason is that capital purchased in the first stage is sunk in the quantity competition stage. To summarize, tax policies are analyzed in the second stage only given that they cannot affect the quantity of capital sunk in the first stage.

4.2.1 A Tax on the DF when Industry Is Initially in Regimes A or B

Consider the impact of the tax policy described above when the market is initially in an accommodated entry equilibrium. A tax in initial Regime B (see Figure 2) shifts the upper segment of MC\(^d\) upwards, as illustrated in Figure 5.\(^{23}\) The new equilibrium is determined by the intersection of MC\(^d\) after the shift and MR\(^d\). The tax reduces the DF's output, second-stage capital purchases \( y_d-k_d \), and industry output \( Y \). The DF loses market share to the fringe, whose output \( z = ny \) increases, and the market price \( p \) increases. The impacts on the profits of the DF and fringe follow directly.

A subsidy to the DF when initially in Regime B shifts the upper segment of MC\(^d\) downwards and may produce two different results. If small, the subsidy reverses the impacts shown in Figure 5 but Regime B is maintained. A sufficiently large subsidy may locate the (formerly) upper segment of MC\(^d\) at the discontinuity in MR\(^d\). The qualitative impacts are the same as those from the small subsidy, except that the equilibrium switches to Regime D (market structure changes). Note that the subsidy does not have to be large to switch regimes if the initial equilibrium is located near the discontinuity in MR\(^d\).
A tax in initial Regime A (Figure 1) has no impact on the equilibrium. It is easy to show using Figure 1 that the tax would only increase the length of the discontinuity in $MC^d$ by shifting the upper segment of the function. While $\pi^d$ would fall, the tax would not affect market behaviour. In contrast, a subsidy in initial Regime A can yield three different outcomes. Again, using Figure 1, it is easy to show the following possibilities. First, a small subsidy could shift the upper segment of $MC^d$ downwards but not all the way to c. The equilibrium would be unaffected and only $\pi^d$ would increase. Second, a somewhat larger subsidy, could shift the upper segment of $MC^d$ down past c but not all the way to point g on $MR^d$. This would switch the equilibrium from Regime A to Regime B: $y_d$, $(y_d-k_d)$, and $Y$ would rise, while $ny_f$ and $p$ would fall. The third possibility is that an even larger subsidy could push $MC^d$ at the discontinuity in $MR^d$. This would switch the equilibrium from Regime B to Regime D.

In summary, a subsidy on the DF (or a tax on the fringe, as will be shown in Section 4.3.1 below) may force the fringe to cease production. The effects on market variables are continuous down to the fringe's shutdown price but nothing occurs beyond that point. By itself, the switch from an accommodated to an impeded entry equilibrium does not cause discrete changes in market variables. This result should be contrasted with Alm and Thorpe (1995). In one of their examples, taxes cause the industry to be unprofitable for two (identical) duopolists but profitable for a single monopolist. Their model lacks of theory of exit since its symmetry means that the identity of the firm that must exit is indeterminate.

In the present model, market asymmetries make it possible for the fringe to exit. More importantly, the discrete effects on market variables reported by those authors are due to the switch from an intermediate form of market structure (duopoly) to a polar one (monopoly). Similar effects could occur here if tax policies changed equilibrium market structure from accommodated to blockaded entry. This is unlikely to occur with reasonable tax parameters.

4.2.2 A Tax on the DF when Industry Is Initially in Regimes C or D

Consider the impact of capital taxes on the DF when the market is initially in an impeded entry equilibrium. Using Figures 3 and 4, it is straightforward to show that a tax in initial Regimes C or D would shift the upper segment of $MC^d$ upwards. There are two
possibilities here. If MC^d remains located at the discontinuity of MR^d, then the equilibrium is not affected and the tax only reduces industry profits. When initially in Regime D, the odd result is that although the gap between price and marginal cost falls, there are no efficiency benefits from the tax since neither output nor market price change.

The second possibility is that the tax could switch regimes if the industry is initially in Regime D and the equilibrium is located close enough to the discontinuity in MR^d and/or the tax is large enough. The equilibrium would switch from Regime D to Regime B if the upper segment of MC^d ends up intersecting the upper continuous segment of MR^d. In that case, the output contraction by the DF raises the price enough so as to allow entry by the fringe. In other words, y_d, (y_d-k_d), and Y fall, while ny_f and p increase. Note that nothing can happen to the equilibrium if initially in Regime C since the tax affects the segment of MC^d which is irrelevant to the firm.

4.3 A Tax on the Competitive Fringe

4.3.1 A Tax on the Fringe when Industry Is Initially in Regimes A or B

The impact of a capital tax imposed on the fringe is examined by changing \( \tau_f \), holding \( \tau_d \) constant. As indicated earlier, \( \tau_f \) is a shift parameter in the fringe's marginal cost function or supply function \( S(p) \). Two different results may arise when the industry is initially in Regime B. First, the tax could leave the equilibrium in Regime B. This possibility is illustrated in Figure 6. The relevant portions of residual demand and \( MR^d \) functions move up following the upward shift in \( S(p) \). The tax increases \( y_d \), \( (y_d-k_d) \), and \( p \), while it reduces \( ny_f \) and \( Y \). While the DF gains market share at the expense of the fringe, market output ends up below its level prior to the tax change. A subsidy on the fringe simply reverses these effects by shifting \( S(p) \) down instead. In the Canadian case, a subsidy would illustrate the impact of tax policies designed to favour small firms.

Second, the tax could switch regimes from B to D if the tax is large enough or if the fringe's market share is initially very small. It is not too difficult to show this using Figure 6 as a starting point. If the upward shift in \( S(p) \) were sufficiently large, \( MR^d \) would shift up enough so as to cause the upper segment of MC^d to be located at the discontinuity in
MR<sup>d</sup>. The fringe would then be taxed out of production. The direction of changes in
market variables remains the same as in the previous case.

A tax in initial Regime A also gives rise to two distinct possibilities. First, the tax
could maintain Regime A. Using Figure 1, one can show that it is possible for the upper
continuous segment of MR<sup>d</sup> to be located at the discontinuity of (unchanged) MC<sup>d</sup>. This
reversion of the discontinuities' role means that y<sub>d</sub> does not change. Yet, n<sub>f</sub> and Y fall, and
p increases. This is a particularly odd case. The DF's profits still increase since it produces
the same output as before but now sells at a higher price, thanks to the tax.

The second possibility is that the tax could change market structures from initial
Regime A to Regime C. It is possible to show using Figure 1 that the policy could cause
the lower segment of MC<sup>d</sup> to be located at the discontinuity of MR<sup>d</sup>. In that case, the fringe
ceases production and y<sub>d</sub> (or Y after the switch) falls, while p increases. In addition, the
market size reduction from the tax is such that the DF's carries a small amount of
involuntary excess capacity. Its level equals the difference between equilibrium outputs
before and after the tax change. It is clear that market equilibria are quite sensitive to taxes
on the fringe because of the initial market asymmetry.

4.3.2 A Subsidy to the Fringe when Industry Is Initially in Regimes C or D

Consider a tax policy which consists of a subsidy to a latent or non-producing fringe.
Prior to any tax change, n > 0 but y<sub>f</sub> = 0. Imposing a tax on a latent fringe would not
produce revenue so it is not a sensible policy for the government to adopt. Instead, the
relevant question is whether a subsidy to the latent fringe can favourably affect market
variables. Figures 3 and 4 can be used to conduct the thought experiment. In either regime,
suppose that a small subsidy is offered to the latent fringe. The subsidy offer shifts S(p)
down since it would reduce the fringe's marginal cost of producing output. This shift would
be insufficient to induce the fringe to enter if the resulting market price remained below the
fringe's shutdown price. This is illustrated with the aid of Figure 7 for initial Regime D.
The policy has interesting implications: while the fringe's output and profits remain at zero,
y<sub>d</sub> (or Y) and (y<sub>d</sub>-k<sub>d</sub>) increase and p falls. The subsidy offer acts as an exogenous increase
in market size which lowers the kink in residual demand. The policy thus closes the gap
between \( p \) and \( MC^d \). The welfare implications of some of the tax policies described thus far are briefly discussed next.

### 4.4 Efficiency and Optimal Taxation

In the absence of market discontinuities, the standard optimal tax results from the literature on taxation under imperfect competition are applicable.²⁴ Roughly speaking, the inputs of imperfectly competitive sectors should be subsidized while those from the competitive sector should be taxed. Mintz and Seade (1990) derive equivalent results in a dominant firm model without commitment and leadership by the DF. They find that the optimal tax policy should aim at increasing the DF’s market share using subsidies on the DF as well as taxes on the fringe. This policy enhances welfare in a second-best sense by reallocating production towards the relatively more efficient dominant firm. Allocative efficiency is enhanced by narrowing the gap between price and the DF’s marginal cost. At the optimum, however, production efficiency is not maintained since the policy makes the DF too capital-intensive.

The validity of those standard results rests on the assumption that the nature of the equilibrium does not change. Given the sensitivity of the equilibria described above to exogenous tax perturbations, the assumption is not globally tenable. As shown by Alm and Thorpe (1995), changes in equilibrium regimes following tax changes may reverse the usual welfare results. An example of this phenomenon in the present analysis is the following. In contrast with the accommodated entry case, the optimal tax policy in an impeded entry regime would call for subsidization of the latent fringe, along with a tax on the DF. As pointed out earlier, the subsidy on the latent fringe would increase market size for the DF. The tax on the DF would further contribute in closing the gap between price and marginal cost. This optimal tax result holds provided that the policy does not itself induce a switch in regimes back to an accommodated entry equilibrium (allow the formerly latent fringe to enter). If that were the case, then the policy would no longer be optimal. The reversion in optimal tax results illustrated by the example are clearly incompatible with policy-making. The results of the analysis of capital taxes suggest that the identification of optimal tax policies can be very sensitive to initial equilibrium conditions. The design and
implementation of taxes under imperfect competition should proceed cautiously and should be conditioned on the particular nature of imperfect competition in the industry of interest. This is in accord with Myles (1995a), who suggests that input taxes under such conditions should be industry-specific.

5.0 SUMMARY AND CONCLUSIONS

The dominant firm model presented here adds to the literature by providing for the possibility of commitment and the existence of equilibria with underinvestment. The model gives a key role to market discontinuities to assess the impacts of capital taxes on firms. The impacts of tax policies in accommodated entry regimes are generally consistent with economic theory. As opposed to standard theory though, allowing the nature of equilibrium regimes to change following tax changes produces a number of unusual market outcomes.

The interaction between discontinuities (including tax-induced ones) and endogenous market structures imply that even small changes in taxes can alter market structure. In some equilibrium configurations, taxes may even have no market impacts at all. The nature of optimal tax policies depends on initial equilibrium regimes and whether they change or not as a result of policies. Such results may suggest the possibility of using taxes to manipulate industry structure.

The sort of iterative tax policy that would be necessary in the presence of the range of tax impacts discussed above is clearly not feasible in practice. That the analysis of tax policies under imperfect competition is a difficult task is not a conclusion specific to the present model. Alm and Thorpe (1995) have come to a similar realization in the context of a symmetric (and much less discontinuous) duopoly model. This suggests the need for a more comprehensive theory of taxation under imperfect competition, as emphasized by Myles (1995b).
NOTES

1. See Myles (1995b), ch. 11.


3. Carlton and Perloff (1994), and Holmes (1996) provide numerous examples. Those include open economy applications.

4. See Halpern and Mintz (1992) for data and further discussion.

5. Bulow et al. (1985b) contains such a result. This will be discussed in more detail in Section 3.1 below.

6. The present model differs in important respects from the more complicated one presented by Holmes (1996). First, his benchmark case assumes that the fringe firms are as efficient as the dominant firm, and that no firm can commit to future actions. This makes it difficult to justify the existence of the dominant firm in the first place. Second, he incorporates discounting and depreciation. It is straightforward to show that such refinements do not affect comparative static results qualitatively. Third, he constrains output and capacity decisions to take place simultaneously in each of the two periods. In addition, output is constrained to equals capacity in each. In this framework, the second period is a static repetition of the first period with fundamentally unchanged initial conditions. Finally, he does not consider the possibility of equilibrium entry deterrence.

7. In a model with free and instantaneous entry, the dominant firm would not be able to set the price as high as in the case in which entry is limited or impeded. Assume that an unlimited number of competitive fringe firms may enter, but leave other assumptions unchanged. Then, fringe firms will enter as long as they can earn positive profits. In the long-run, fringe firms cannot make profits: they either break even or exit. If the fringe produces in the long-run, the market price cannot exceed the minimum of the fringe's (now U-shaped) average cost. With its cost advantage, the dominant firm still makes positive profits. Its profits are, however, lower than if entry did not occur.

8. This assumption was first made by Dixit (1980) although he did not use the expression "strategic substitutes." The terminology is from Bulow et al. (1985a, b). See Tirole (1988) for a summary discussion of the relevant concepts and an alternative taxonomy.

9. Tirole (1988) views as "normal" the case in which outputs or capacities are strategic substitutes with quantity competition.

11. In Maggi (1996), $r_d = 0$ and $c_0$ in (1) and (2) is replaced by $\theta \geq c_0$. Parameter $\theta$ has several interpretations. It may represent the higher cost of inputs purchased outside the firm, as opposed to in-house production. Alternatively, it may represent the cost of overtime work. Generally speaking, $\theta$ captures the importance of capacity constraints in his model. As will be shown below, this complication affects the results in a predictable way so it is omitted.

12. Following Carlton and Perloff (1994), it is assumed that the fringe's supply curve is its marginal cost curve above $p_s$, the minimum of its average cost curve. At that price, each fringe firm makes zero profit and is indifferent between producing and shutting down. Were the fringe to have a U-shaped average cost curve, it would then produce a positive amount of output at $p_s$. This would imply the existence of a minimum efficient scale for the fringe and hence a discontinuity in its supply function. In turn, this would rule out the possibility of a small fringe or small scale entry, while complicating the diagrammatic analysis. Consistent with the simplification, fringe firms are assumed to have no fixed costs. Using the notation in the text, let $nC_y/y_f$ be the average cost function. To justify the coincidence between the intercepts of average and marginal cost functions, invoke L'Hôpital's rule so that

$$\lim_{y \to 0}(nC_y/y_f) = \lim_{y \to 0}(C_y) = nC_f(0) = p_s.$$ 

Average costs will be omitted from diagrams in order to simplify the presentation.

13. Excess capacity ($y_d < k_d$) is not a matter of concern as will be shown below.

14. Setting $\theta \geq c_0$ (in $C^d$ or, equivalently, in the condition just stated) as in Maggi (1996) would strictly speaking reduce the range of outcomes in which additional capacity is purchased in the second stage, holding $T_d$ constant. It would not necessarily eliminate such outcomes in equilibrium, as he erroneously claims.

15. Note that the usage of those terms here differs from that of Bulow et al. (1985b) and Tirole (1988). In particular, the taxonomy of business strategies and the calculus presented in Tirole is redundant here given (6).

16. It is easy to show that a sufficient condition for the second-order condition to be satisfied is that demand be concave, or $p'' \leq 0$. Using the Routh-Hurwicz condition, one can also show that linear demand ($p' = 0$) and linear marginal costs for the fringe firm ($C_y = 0$) are sufficient conditions to obtain a market equilibrium that is unique and locally stable. Neither set of conditions is necessary, though.

17. Functions $y_d^A(k_d^A)$ and $y_f^A(k_d^A)$ should include cost and tax parameters as arguments. Those are omitted from the exposition for the sake of notational simplicity.

18. Preliminaries for the interpretation of Figure 1 and further diagrams are outlined here. (All diagrams appear at the end of the paper.) The market demand curve is $DD$; linear demand is a simplifying assumption only. The DF's residual demand curve is $p_dD'D$, where $p_d$ is the residual demand's choke-off price. Residual demand consists of the horizontal difference between the market demand curve and fringe's supply curve $S(p)$. The residual and market demands coincide at point $D'$, where the market price equals the fringe's shutdown price $p_s$. 
Segment 0p_s is also part of the fringe's supply function since the fringe does not supply anything if p \leq p_s. In the linear case, the slope of the DF's marginal revenue function is twice that of p_d D' when p_f < p < p_d, and twice that of D'D when 0 < p < p_f. The discontinuity in MR_d occurs at point D', the kink on the residual demand. The length of the discontinuity is increasing in the difference between the slopes of segments p_d D' and D'D, as evaluated in the neighbourhood of the kink. To sum up, marginal revenue has two separate continuous segments, p_d g and hm. The equilibria studied here focus on the range p_d g h, whereas range hm would apply to blockaded entry equilibria. On the cost side, function cdef is the (discontinuous) marginal cost function (1) with point e open.

19. Spence (1977) derives the result that the profit maximizing quantity of output, given the level of capacity, increases with capacity. While it is acknowledged that his result is derived for the case where investment in capacity reduces marginal cost in a continuous fashion, the result nonetheless provides additional support to Propositions 1 and 2, and Corollary 1.


21. The analysis of taxes presented in the following Sections was developed independently from Alm and Thorpe (1995). See Gendron (1996) for references.

22. See, for example, Mintz and Seade (1990) and the references cited therein.

23. Superscripts on market variables that denote regimes are omitted to avoid cluttering the diagrams.

24. See, for example, Willig (1983), and Myles (1987, 1989, 1995a, b).
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Essay II

Corporation Tax Asymmetries:

An Oligopolistic Supergame Analysis
1.0 INTRODUCTION

The accumulation of corporate tax losses in many countries in recent history has raised a number of important issues concerning the economic impact of corporate tax policies. The study of tax losses entails important dynamic aspects that are emphasized in both the theoretical and the empirical literature. In addition, the empirical work on the topic underscores the economic significance of tax losses. The appropriate modelling strategy to study the impact of tax losses and their non-refundability (asymmetry) must be a dynamic one.

A common feature of corporate tax systems around the world is the non-refundability of tax losses. As pointed out by Appelbaum and Katz (1996), eight OECD countries allow firms to carry losses back for a limited number of years, thereby claiming a refund of past taxes paid. In addition, all OECD countries allow firms to carry losses forward at no interest but for longer periods. For example, the corporate tax system in Canada has carryback and carryforward limits of three and seven years respectively, in addition to limited instances of refundability such as the partly refundable scientific research and development tax credit for small businesses.

Those measures constitute limited instances of refundability but they are far from making those tax systems symmetric or neutral. Mintz (1991) points out that tax losses and the lack of refundability thereof raise important issues with respect to market structure. In spite of that, he notes that the topic has received virtually no attention. The entire body of literature he surveys does indeed embody the assumption of perfect competition in product markets. On the one hand, it is easy to understand governments' reluctance to move to a neutral system such as the cash flow tax. This would involve the payment of tax refunds in bad economic times and would make corporate tax revenues even more unstable. On the other hand, the emerging literature on taxation under imperfect competition suggests that the impacts of taxation under such conditions can differ markedly from those under perfect competition.

One notable exception to the literature discussed by Mintz is the recent paper by Appelbaum and Katz (1996). Those authors study the impact of tax asymmetries on market structure in the context of a static model with market uncertainty.
The present paper is similarly positioned but takes a rather different route. The model explores a structural justification for the non-refundability of tax losses. The framework is a dynamic one in which oligopolistic firms interact repeatedly and collusive behaviour may be supported by non-cooperative equilibria. In the traditional supergame literature, such equilibria are supported by the Cournot-Nash reversion. This is a punishment mechanism which specifies that all industry members revert to Cournot competition once any individual firm deviates from its collusive output share.¹ Davidson and Martin (1985, 1991) use this model to study tax incidence under imperfect competition. Their models, however, cannot allow for the existence of tax losses since profits are positive even in the Cournot-Nash reversion phases.

In contrast to the above, the present model allows for punishments that are more severe than the Cournot-Nash reversion in order to support tacit collusion. The most collusive equilibrium studied here can generate short-run losses during the punishment phase. Such losses can be partially recouped in the future; hence, the availability of tax loss refunds can affect the most collusive outcome.² Tax loss refund provisions diminish the impact of any loss incurred during the punishment phase. It is shown that a policy that increases tax loss refundability reduces the most collusive output and raises prices. More generally, in the symmetric information environment studied here, refunding losses in any way can have this collusion-enhancing effect.

The work of Abreu (1986) is now the standard view on tacit collusion. This emerged from his wish "to study the maximal degree of collusion sustainable by credible threats for arbitrary values of the discount factor" (192, italics in original). His 1986 and 1988 papers focus on strategy profiles that yield the most severe punishments or outcome paths. Those punishments constitute subgame-perfect equilibrium strategies which can be severe enough under certain conditions so as to make negative profits possible during the punishment phase.

Although Abreu is interested in characterizing the most collusive equilibrium, the idea I wish to convey here can be made simple by restricting attention to symmetric punishments. Such punishments require all firms to produce identical output streams, whether the oligopoly is in a collusive or punishment phase. It is important to note that symmetric punishments
constinite a generalization of punishments based on Cournot reversions. In particular, symmetric punishments can support lower outputs and higher prices than a simple Cournot reversion by invoking the punishment phase in which firms can make short-run losses. It is precisely those short-run losses that constitute the focal point of the paper.

The paper is organized as follows. Section 2.0 presents the game-theoretic model of oligopoly interaction. Section 3.0 presents a description of the tax treatment of losses and characterizes the outcome paths and equilibria with a hybrid cash flow tax. Section 4.0 analyses the effects of changes in refundability on profits, output, revenues and welfare. Finally, Section 5.0 concludes the paper by a summary and a discussion of possible extensions.

2.0 THE MODEL

Suppose an oligopolistic industry consists of n firms which play an infinitely repeated Cournot game with discounting. In each period, all firms simultaneously choose output quantities and maximize profits. Firms wish to maximize the present value of their profits. For the moment, let any taxes be subsumed in the profit functions. Uncertainty is ignored throughout.

Each firm makes its quantity decision in period t knowing what every other firm has produced in all previous periods. Firms are identical, quantity-setting and produce a homogeneous output. Let $C(x)$ denote the total cost of producing $x$ units of output. Let $P(X)$ denote the industry's inverse demand function, where $X = nx$ is total industry output.

The profit per firm, when each produces output $x$, is then given by $\pi(x) = P(nx)x - C(x)$. Let $\pi_i(x) = \max_y P[y + (n-1)x]y - C(y)$ be the maximal profit that firm $i$, $i = 1,...,n$, can earn in a single period while deviating, given that all other firms are each producing $x$. The value of $y$ that maximizes the above expression is the firm's best-response or deviation output, which depends on the output produced by the remaining $n-1$ firms. The restrictions required are summarized as follows.
Assumption 1. The functions \( \pi(x) \) and \( \pi'(x) \) satisfy:

(a) \( \pi(x) \) is strictly concave;
(b) \( \pi'(x) \) is nonnegative, continuous, convex, nonincreasing, and satisfies \( \pi'(0) > 0 \);
(c) there exists a unique \( x^a \) such that \( \pi(x^a) = \pi'(x^a) \).

Denote the action set of firm \( i \) by \( S_i = [0,x'(\delta)] \), where \( \delta \in (0,1) \) is the discount factor common to all firms. Let \( \delta = 1/(1+r) \) where \( r \) is the firms' fixed one-period discount rate. Output \( x'(\delta) \) satisfies \(-\pi(x'(\delta),0,\ldots,0) > \delta/(1-\delta)\sup_x \pi(x,0,\ldots,0) \). This inequality says that it is never in a firm's interest to produce output beyond \( x'(\delta) \). If a given firm did, even with all other firms producing nothing, then it would not be able to recoup the ensuing one-period loss even by producing monopoly output forever after. Attention is thus restricted to bounded strategy sets \( S_i \). Since \( \pi(x) \) is strictly concave, \( \arg\max \{\pi(x) | x \in S\} \) is a singleton whose unique element is \( x^m \).

Let \( G = (S_i, \pi; i = 1, \ldots, n) \) denote the one-shot Cournot game. Assumption 1 implies that \( G \) has a unique symmetric pure-strategy Nash equilibrium. Let \( x^i \in S_i \) be the output per firm such that \( \pi(x^i) = 0 \). The supergame with discounting is obtained by repeating \( G \) infinitely often and evaluating profits using the discount factor \( \delta \). The definitions that follow provide the notation necessary to study the outcome paths from this game. It is important to note that the collusive industry does not simply behave like a monopolist here: the industry enforces tacit collusion using a scheme that punishes deviations from collusive behaviour. In the general case where firms are not extremely patient and/or do not necessarily expect collusive interaction to last forever, the required incentive constraints rule out the monopoly outcome as a constrained joint profit maximum. The following Proposition summarizes the model's structure thus far.

Proposition 1. Under Assumption 1:

(a) \( x^i > x^L > x^n > x^m \);
(b) \( \pi(x^m) > \pi(x^n) > 0 > \pi(x^i) \);
(c) \( \pi(x^n) = \pi^d(x^n) > 0; \)

(d) if \( x_2 > x_1 \geq 0 \), then \( \pi^d(x_1) \geq \pi^d(x_2) \).

Proof. See Abreu (1986).

The contents of Proposition 1 are illustrated in Figure 1. For instance, Part (c) implies that the best-response profit function \( \pi^d(\bullet) \) is just tangent to the profit function \( \pi(\bullet) \) at output \( x^n \) since static Cournot-Nash profit-maximization by each firm is itself a best-response. Part (d) underscores the key feature of the model with respect to best-response profit functions: the more all other firms attempt to restrict joint output, the higher is the one-period gain from deviating for a single firm.

The supergame environment is further characterized as follows. A tacitly collusive agreement is one in which individual firms jointly maximize profits by restricting industry output. Each individual firm within the cartel can, however, increase its one-period profits by producing a level of output which is higher than the share specified by the joint profit-maximization program. A deviator who plays his best-response obtains strictly higher one-period profits than any other firm, given that all other firms abide by their collusive output shares. This can be shown using Figure 1 and noting that \( \pi^d(\bullet) > \pi(\bullet) \) away from \( x^n \). For example, a best-response in a collusive phase (\( x \) is to the left of \( x^n \)) is to produce more than \( x \), given that all other firms play an output \( x \) such that \( x \in (x^m,x^p) \).

Given the incentive to cheat at the individual firm level, the industry must choose a punishment output that makes it optimal for firms to tacitly collude rather than defect if higher profits than the Cournot-Nash level are to be reaped. Similarly, subgame-perfection requires that firms prefer to cooperate in their own punishment in anticipation of future profits that such behaviour would provide.

To simplify matters, it is assumed that the punishment is symmetric in the sense of Abreu (1986). A symmetric carrot-stick strategy profile \( (x,x^p) \) is defined as follows: if all firms produce \( x \) or \( x^p \) in the previous period, each firm produces \( x \) this period; for any other profile of output, each firm produces \( x^p \) this period. The key result from Abreu (1986) for
the present purposes is summarized in the Proposition that follows.

**Proposition 2.** Under Assumption 1, a symmetric carrot-stick strategy profile \((x,x^p)\) is a subgame-perfect equilibrium if and only if:

\[
\pi^d(x) + \delta \pi(x^p) \leq (1 + \delta) \pi(x) \tag{1}
\]

\[
\pi^s(x^p) + \delta \pi(x^p) \leq \pi(x^p) + \delta \pi(x) \tag{2}
\]

**Proof.** See Abreu (1986).^3

The profit-maximization program available to the industry is characterized by the two firm-specific incentive constraints (1) and (2). The first constraint is a no-defection condition. It requires that an individual firm weakly prefer collusion forever to a sequence of deviation, punishment, and collusion forever after. In other words, the firm must weakly prefer collusion to deviation in a collusive phase. The second constraint is a punishment-acceptance condition. It requires that a deviator weakly prefer to participate in the punishment, and collude forever after to a sequence of best-response to the punishment (which is itself a deviation), punishment, and collusion forever after. This constraint says that the firm prefers to cooperate in its own punishment rather than deviate. In summary, the two constraints ensure that the discounted profits from deviation do not exceed the discounted profits from collusion.^9

The key issue at this point is whether the punishment can be severe enough so as to generate a loss for each firm in the punishment phase. (Taxes are ignored until the next Section since their presence would not affect the qualitative conclusions to be drawn below.) Abreu (1986) shows that there exist games in which the most severe punishment involves losses during the punishment phase.

**Proposition 3.** By virtue of Assumption 1, there exists a \(\delta\) and a subgame-perfect equilibrium path \((x,x^p)\) such that \(\pi(x^p) < 0\).
Proof. See Abreu (1986).

Proposition 4. Under Assumption 1, joint profits are maximized for the smallest value of \( x \) such that \((x,x^p)\) is a symmetric carrot-stick strategy profile and both (1) and (2) hold with equality.

Proof. Let the no-defection locus (NDL) be the set of output pairs such that (1) holds with equality, and let the punishment-acceptance locus (PAL) be the set of output pairs such that (2) holds with equality. Let \( x' \) be the most profitable collusive output that can be supported by a Cournot reversion. Without loss of generality, one can restrict attention to discount factors such that outputs obey the inequality \( x^m < x' < x^n \). Think of NDL as being drawn as in Figure 2, with punishment output on the vertical axis. Then:

Result 1. NDL is downward-sloping when the collusive output is between \( x^m \) and \( x' \), and is upward-sloping when collusive output is near \( x^n \).

Proof. Let \( x \in [x^m,x'] \). It will be shown that there exists an \( x^p \) such that \( x^p > x^n \) and \((x,x^p)\) is on NDL. Point \((x',x^p)\) is on NDL by definition, and so is point \((x',x^n)\). Thus, the following two equations hold:

\[
\pi^d(x') - \pi(x') = \delta \left[ \pi(x') - \pi(x^n) \right].
\]  
\[ (3) \]

\[
\pi^d(x^n) - \pi(x^n) = \delta \left[ \pi(x^n) - \pi(x^m) \right].
\]  
\[ (4) \]

Following the definitions of \( x' \) and \( x^n \), subtracting (4) from (3) yields:

\[
- \int_{x'}^{x^n} \left[ \pi^d(x) - \pi'(x) \right] dx = - \delta \int_{x'}^{x^n} \pi'(x) dx.
\]  
\[ (5) \]
Now, take any $x < x'$. The change in the left-hand side of NDL that takes place when output is reduced from $x^n$ to $x$ is given by:

$$-\int_{x'}^{x} [\pi'(x) - \pi'(x)] dx - \int_{x'}^{x} [\pi'(x) - \pi'(x)] dx.$$  \hspace{1cm} (6)

The corresponding change in the right-hand side of NDL is given by:

$$-\delta \int_{x'}^{x} \pi'(x) dx - \delta \int_{x'}^{x} \pi'(x) dx.$$  \hspace{1cm} (7)

By virtue of Assumption 1, the function $[\pi'(x) - \pi(x)]$ is convex since $\pi(x)$ is concave. It follows that the second integral in (6) is positive and strictly larger than the second integral in (7). In turn, this means that the left-hand side of NDL rises by more than its right-hand side when output falls from $x^n$ to $x$, if the punishment output is held constant at $x^n$. To restore the equality in NDL, $x_p$ must be increased. I conclude that NDL must be downward-sloping when $x$ is between $x^m$ and $x^r$.

**Result 2.** PAL is has a downward-sloping segment between $x^m$ and $x^n$. Furthermore, PAL reaches its peak at $x^m$.

**Proof.** Point $(x^n,x^n)$ is on PAL by definition. Take any output $x$ obeying the inequality $x^m < x < x^n$ and write PAL as $\pi'(x) - (1-\delta)\pi(x) = \delta \pi(x)$. When $x = x^n$, the left-hand side of the expression is strictly smaller than the right-hand side. On the other hand, if $x^p$ is very large, the left-hand side becomes very large because of the concavity of $\pi(x)$ and the non-negativity of $\pi'(x^p)$. Thus, by the mean-value theorem, there exists a value of $x^p$ such that the expression holds with equality. This shows that there is a downward-sloping segment in PAL between $x^m$ and $x^n$. To show that the segment peaks at $x^n$, take a point $(x,x^p)$ on PAL such that $x$ is close to $x^m$. Reducing $x$ will cause the right-hand side of PAL to rise initially, and then fall back to its original level as $x$ falls below the joint profit-maximizing output $x^m$.

Now, to finish the proof of Proposition 4, note that Results 1 and 2 guarantee that NDL is steeper than PAL (as in Figure 2) at its leftmost intersection. Take any point $(x,x^p)$ that lies on the downward-sloping segment of NDL between $x^m$ and $x'$. If $x^p$ increases slightly
while \( x \) is held constant, then (1) must hold with strict inequality because the punishment is more severe. Thus, perfect equilibrium points must lie to the right of NDL. On the other hand, if \((x, x^p)\) is a point on the downward-sloping segment of PAL between \( x^m \) and \( x^a \), then cutting \( x \) slightly while holding \( x^p \) constant will ensure that (2) holds with strict inequality since the reward for adhering to the punishment is increased. Thus, perfect equilibrium points must lie to the left of PAL.

If \((x, x^p)\) is a symmetric carrot-stick strategy profile that does not lie on NDL, then it must lie to the right of NDL by the argument of the previous paragraph. Since that point cannot lie to the right of PAL, there will be a smaller output \( y \) such that \((y, x^p)\) is a symmetric carrot-stick strategy profile. Since collusive output is smaller, profits will be higher.

If \((x, x^p)\) is a symmetric carrot-stick strategy profile that lies on NDL but not on PAL, then it must lie to the left of PAL by the argument of the previous paragraph. Then, there is a symmetric carrot-stick strategy profile \((y, y^p)\) such that \( y < x \) and \( y^p > x^p \); this is due to the fact that NDL is downward-sloping. Again, collusive profits will be higher in this new equilibrium.

The contents of Proposition 4 are shown in Figure 2. The most collusive equilibrium is given by the pair \((x^*, x^{p*})\).

### 3.0 PATHS AND EQUILIBRIA WITH CASH FLOW TAXATION

The first part of this Section presents a characterization of the tax treatment of losses. Issues of investment and financial policy are ignored in order to keep the corporation tax system simple and because those issues have been examined in detail elsewhere.\(^{10}\) Losses arise in the model due to severe punishments of deviations. Taxation is initially asymmetric since gains are not treated in the same way as losses. Positive profits are taxed at a constant rate \( \tau \) but strictly negative profits (losses) do not entitle the firm to an immediate refund of \(-\tau \pi(\bullet)\). Instead, losses are carried forward at a zero rate of interest. This initial system is denoted a
"hybrid" cash flow tax, as opposed to a pure cash flow tax system in which losses are fully refundable.

In practice, tax losses can be claimed against future profits in ways that depend on the particular tax code. To simplify matters, I assume that the firm making a loss of \( \pi_t \) in period \( t \) simply receives a lump-sum refund of \( \rho \tau \pi_t \) in period \( t + 1 \). Let factor \( \rho \) be included to account for the possibility that the firm face restrictions or enhancements to its ability to utilize the refund in \( t + 1 \). For instance, the government may wish to pay interest on loss carryforwards, which can be captured by setting \( \rho > 1 \).

Recall that the firms' discount rate is \( r \) and assume that the government pays interest on carryforwards. Then, \( \rho \) is equal to one plus the interest rate paid on such carryforwards. It is straightforward to show the following using (1) and (2). First, allowing carryforwards to earn interest at rate \( r \) so that \( \rho = 1 + r \) is equivalent to a full immediate refund in present value. The tax system is symmetric (or neutral) in that case. On the other hand, if carryforwards earn no interest (so that \( \rho = 1 \)) then the tax system is characterized by the asymmetry described earlier.\(^{11} \) It is assumed in what follows that \( \rho \) is included in the interval \([1, 1 + r]\).

Apart from the treatment of investment, the exposition of the next paragraph closely follows Auerbach (1986). He finds that asymmetries, even in the cash flow tax case, have complicated impacts on firm behaviour. While there are several economic arguments in favour of cash flow taxes, their main advantage for the present purposes is that they can be fit into Abreu's (1986) framework.\(^{12} \)

I now introduce some definitions and present a heuristic discussion on how losses are generated. Let \( L_t \) represent the accumulated loss carried forward from period \( t - 1 \), with \( L_t \geq 0 \) for all \( t \). For a firm which is not taxable at the margin, current after-tax profits are \( \pi_t \) and the loss carried forward to the next period is given by \( L_{t+1} = L_t - \pi_t \). For a firm that is taxable at the margin, \( \pi_t > L_t \) and the corresponding after-tax profits are equal to \((1 - \tau)\pi_t + \tau L_t \).
In particular, if $\pi(\cdot)$ is the pre-tax profit function satisfying Assumption 1, then the after-tax profit function (notation: tilde) is given by:

$$
\pi(\cdot) = \begin{cases} 
(1 - r) \pi(\cdot) & \text{if } \pi(\cdot) \geq 0, \\
(1 - \delta p r) \pi(\cdot) & \text{if } \pi(\cdot) < 0.
\end{cases}
$$

(8)

Let after-tax best-response profit function simply be $\pi^d(\cdot) = (1-r)\pi^d(\cdot)$ since $\pi^d(\cdot) \geq 0$ for outputs in $S_i$.

Two comments are in order. Firstly, it is straightforward to show that the after-tax profit functions $\pi(\cdot)$ and $\pi^d(\cdot)$ satisfy Assumption 1 by using the fact that retention rates in (8) are constant. Secondly, (8) is constructed under the assumption that losses must be written off in the period that immediately follows the loss. Underlying this assumption is the requirement that collusive profits following the punishment be sufficient to absorb the tax loss. Thus, the present value of the refund taking place in the next period must be equal to a lump-sum equivalent given in the period in which the loss occurs. This equivalence ensures that the one-period (static) game remains the same over time and hence that the supergame approach is an appropriate one.

The after-tax incentive constraints that embody two-phase punishments are characterized in the following Proposition, which immediately follows from Proposition 2 and the fact that both $\pi(\cdot)$ and $\pi^d(\cdot)$ satisfy Assumption 1.

**Proposition 5.** A symmetric carrot-stick strategy profile $(x,x^p)$ is a subgame-perfect equilibrium for the game with taxes if and only if:

$$
\pi^d(x) + \delta \pi(x^p) \leq (1 + \delta) \pi(x).
$$

(9)

$$
\pi^d(x^p) + \delta \pi(x^p) \leq \pi(x^p) + \delta \pi(x).
$$

(10)

Following this proposition and the fact that the analogue to Proposition 4 holds for the game with taxes as well, the most collusive equilibrium is the pair $(x,x^p)$ such that (9) and (10) both hold with equality.
4.0 EFFECTS OF CHANGING REFUNDABILITY

The impact of changes to the extent of refundability on the most collusive equilibrium is examined in this Section. Recall that parameter $\rho$ is an increasing index of refundability. The direct approach, which consists in solving for comparative static impacts of changing $\rho$ on $x$ and $x^p$, is not informative. The difficulty is that the change in $\rho$ shifts both NDL and PAL in the same direction in output space. This makes it impossible to determine what happens to collusive output. Appelbaum and Katz (1996) run into a very similar problem when they analyse the effects of past losses on output. While they provide some conditions that might help attach a sign to their comparative static effects, they do not resolve the fundamental ambiguities.

The approach proposed here in order to resolve this problem is to move the analysis from output space to after-tax profit space. Naturally, this requires a slight notational change. Let $\hat{\pi}^c$ and $\hat{\pi}^p$ denote realized after-tax profits per firm in collusive and punishment phases, respectively. Define the function $b(\hat{\pi}) = \{\hat{\pi}(\star): \hat{\pi}(\star) = \hat{\pi}\}$. The value $b(\hat{\pi})$ describes after-tax profits obtained by deviating from a situation where all firms' after-tax profits are $\hat{\pi}$.

Applying the analogue of Proposition 4 to the after-tax case implies that the most collusive equilibrium will involve a pair of after-tax profit levels $(\hat{\pi}^c, \hat{\pi}^p)$ satisfying:

$$b(\pi^c) + \delta \pi^p \leq (1 + \delta) \pi^c.$$  \hspace{1cm} (11)

$$b(\pi^p, \rho) + \delta \pi^c \leq \pi^p + \delta \pi^c.$$  \hspace{1cm} (12)

In order to find deviation profits $b(\hat{\pi})$, simply determine the level of output for each firm that generates a level of after-tax profit of $\hat{\pi}$, and then calculate the profit that a firm could earn by unilaterally deviating. There are two ways in which $\rho$ might affect this calculation. Firstly, the deviation profit might be negative so that changing $\rho$ will change after-tax profits directly. In order to keep the analysis simple, assume in what follows that fixed costs are zero. In that case, deviation profits cannot be negative since the firm can always produce nothing during that period. Hence, $\rho$ cannot have any direct effect on deviation profits.
Secondly, there is a more complicated possibility that \( p \) might affect deviation profits indirectly by changing the level of output that supports profits per firm of \( \bar{\pi} \). In that case, changing \( p \) will affect the profit that the firm can obtain from deviating away from that output. A collusive phase is profitable by definition so refunds are never made in such a phase. Thus, changing \( p \) has no effect on \( b(\bar{\pi}^c) \). This initial situation is illustrated with the aid of Figure 3, which shows combinations of outputs and after-tax profits. As shown in the diagram, \( \bar{\pi}^c \) has an associated collusive output of \( x_1^c \). The corresponding deviation profits are given by \( b(\bar{\pi}^c) \).

In a punishment phase with losses, however, changing \( p \) will change the losses associated with any level of output. The equilibrium output pair prior to the change in \( p \) is \((x_1, x_1^p)\) in Figure 3. Increasing refundability, for example, would rotate the thick segment in the negative quadrant up to the dashed segment in the diagram. This means that the punishment output that supports a level of punishment profits of \( \bar{\pi}^p \) must increase from \( x_1^p \) to \( x_2^p \). Therefore, to support any given after-tax profit level in the punishment phase, firms will have to produce a higher output, which will reduce profits that can be obtained by deviating. This can be seen in Figure 3 by noting that deviation profits associated to \( x_2^p \) are lower than those associated to \( x_1^p \). In short, \( b(\bar{\pi}^p, \rho) \) is a nonincreasing function of \( \rho \).

To recapitulate: when \( p \) is increased from \( \rho_1 \) to \( \rho_2 \), after-tax profits in the punishment phase rise for any level of output. To see this, read punishment profits off the dashed line as opposed to the thick one. The loss associated to \( x_1^p \) is less severe on the dashed line than it is on the thick line. It follows that the punishment output necessary to support the initial level of \( \bar{\pi}^p \) must increase from \( x_1^p \) to \( x_2^p \). Deviation profits corresponding to \( x_2^p \) and \( x_1^p \) respectively are such that \( b(\bar{\pi}^p, \rho_2) \) is less than \( b(\bar{\pi}^p, \rho_1) \). The incentive to deviate in a punishment phase falls. The main result of this Section is summarized in the next proposition.

**Proposition 6.** If the most collusive equilibrium involves losses in the punishment phase, then an increase in refundability will enhance collusion and reduce the most collusive output.
Remark. Increasing $p$ makes it less profitable for firms to deviate in the punishment phase. This makes it possible to enforce a more severe punishment. It is that fact that enhances the firms' ability to collude.

Proof. By Proposition 4, the most collusive equilibrium must satisfy the following equations:

$$b(\pi^c) + \delta \pi^p = (1 + \delta) \pi^c. \quad (13)$$

$$b(\pi^p, p) + \delta \pi^p = \pi^p + \delta \pi^c. \quad (14)$$

The first term on the left-hand side of (14) is the only one that is affected by a change in $p$. For any given punishment output, increasing $p$ reduces the loss in a punishment phase. The severity of the initial punishment, which is measured by $\hat{\pi}^p$, can only be maintained by increasing the punishment output. This means that the associated best-response profits $b(\hat{\pi}^p, p)$ must fall. Then, holding $\hat{\pi}^p$ constant, collusive profits must fall in order to maintain the equality in (14). The overall effect just described can be seen differently by redrawing NDL and PAL in after-tax profit space. With after-tax profit in a punishment phase on the vertical axis, these loci resemble the ones drawn in Figure 4.

It will be shown that NDL cuts PAL from above in after-tax profit space. Pick a point $(\hat{\pi}^c, \hat{\pi}^p)$ on NDL near the most collusive equilibrium $(\hat{\pi}^c, \hat{\pi}^p)$: the point must satisfy $\hat{\pi}^c < \hat{\pi}^c$ as well as $\hat{\pi}^p > \hat{\pi}^p$. The existence of such a point can be established by picking a symmetric carrot-stick strategy profile $(x, x^p)$ that lies on the downward-sloping segment of NDL in output space. By Results 1 and 2 in the Proof of Proposition 4, PAL must lie to the right of this point in output space. Holding punishment output constant at $x^p$, PAL can be satisfied by raising collusive output. In after-tax profit space, holding $x^p$ constant is equivalent to holding $\hat{\pi}^p$ constant. Increasing collusive output amounts to reducing $\hat{\pi}^c$. Thus, PAL lies to the left of the above point $(\hat{\pi}^c, \hat{\pi}^p)$ in after-tax profit space. The result in Proposition 6 is then shown in Figure 4.
The initial most collusive equilibrium in Figure 4 consists of the pair of profits \((\hat{r}_i^c, \hat{r}_i^p)\). At that point, NDL and PAL intersect. Increasing refundability rotates the thick segment of PAL in the loss region to the dashed one; the new segment is labelled \(\text{PAL}'\). Since NDL does not move, the new most collusive equilibrium depends on the position of \(\text{PAL}'\). The new equilibrium is given by the pair \((\hat{r}_2^c, \hat{r}_2^p)\). This point is characterized by lower (more negative) punishment profits and higher collusive profits. For ease of comparison with Figure 2, \(\hat{r}^n\) in Figure 4 denotes after-tax Cournot profits.

Proposition 6 goes against the natural intuition according to which increasing refundability makes the punishment easier to bear. In conclusion, the policy serves to strengthen collusion in the industry. As pointed out earlier, there exists a literature based upon static models which usually favours increasing the symmetry of tax systems.\(^{10}\) The model presented above shows that such a conclusion is reversed once imperfect competition in a dynamic context is taken into account.

An important feature of the foregoing analysis is that losses do not occur in equilibrium. This results from the fact that (13) and (14) intersect at the most collusive equilibrium. Thus, both incentive constraints (11) and (12) hold with equality at that point. For that reason, firms do not deviate and hence punishments never have to be used in equilibrium. The impacts of changing refundability are thus deduced from behaviour off the equilibrium path. An interesting corollary from Proposition 6 is that the policy increases government revenues, holding the tax rate constant. Note that the comparative static results from changing the tax rate while holding \(\rho\) constant follow directly because an increase in \(\tau\) increases the tax value of losses.

For the purposes of welfare analysis, it follows from the above that collusive output is the only measure of production that matters. By reducing collusive output, the policy which consists of enhancing loss refunds increases industry price. If the firms’ marginal costs are nondecreasing, the policy has the unambiguous effect of widening the gap between price and marginal cost.\(^{17}\) The partial equilibrium welfare impact of the policy is obvious in this case: its output repression effect reduces welfare.
5.0 SUMMARY AND CONCLUSIONS

This paper applies a supergame oligopoly model of an industry to study hybrid corporate cash flow taxes with different tax loss regimes. The after-tax incentive constraints facing the firms embody all the important timing features of punishments, reversions to collusion, taxes and refunds. Unlike most of the literature in which loss offsets are analysed in the context of risk-taking, tax losses result from collusive enforcement in the present model.

The analysis of changes in refundability on the most collusive equilibrium with losses reveals that enhancing tax loss refundability reduces collusive output along the equilibrium path. The policy produces such an effect by weakening the incentive to deviate in a punishment phase. Refundability thus helps to sustain tacit collusion and hence hinders competition in the industry. From a partial equilibrium standpoint, the policy reduces welfare.

It is possible to make this framework more realistic by allowing for uncertainty. Subject to some conditions, uncertainty will do away with the counterfactual result that losses are not observed in equilibrium. Behaviour on and off the equilibrium path under perfect certainty reveals the qualitative features of the comparative static results under uncertainty. Welfare effects under uncertainty would not be as clear-cut, however, since the behaviour of output in the actual punishment phase would have to be taken into account. The appropriate framework for this analysis would be inspired by the work of Abreu et al. (1986, 1990).
NOTES


2. See Myles (1995) for a recent survey and additional references cited here.

3. See the surveys by Fudenberg and Tirole (1989), and Shapiro (1989).

4. See Abreu (1986); more on this below.

5. In that respect, the present paper must be contrasted with the literature on loss offsets which typically focuses on the impact of refundability on risk and risk-taking. Key papers in that vein include Domar and Musgrave (1944), Mossin (1968), Stiglitz (1969), and Mintz (1981). See also the surveys by Mintz (1995) and Myles (1995). As will be shown below, refundability matters, even without uncertainty.

6. Recent examples of industries that have been studied using the supergame approach include retail-gasoline in Canada (Slade [1992]) and salt in the United Kingdom (Rees [1993]). Furthermore, antitrust action in the form of conspiracy charges has been undertaken against sellers of compressed gas to hospitals (Canada), Southern road contractors (United States), and ready-mix cement (world-wide). In her survey, Slade (1995) reports empirical results which suggest that outcomes are generally more collusive than the Nash equilibria of their associated one-shot games.

7. As shown by Abreu (1986), asymmetric punishments generally yield more collusive outcomes. Such punishments, however, are not as neatly characterized as symmetric ones and may give rise to analytical difficulties. Their consideration here would not, qualitatively speaking, affect the results.

8. Loosely speaking, the punishment paths specified here enlarge the set of discount factors which can support collusion, as opposed to punishments based on Cournot-Nash reversions. Abreu shows by way of an example that the lower bound on the discount factor need not be large.

9. Constraints (1) and (2) could also be written with an extra term on each side, $\delta^2 \pi(x)/(1-\delta)$, which represents an infinite series of collusive profits. The constraints in the text have been simplified by subtracting that term from each side.

10. See Auerbach (1986) and Mayer (1986) on investment and financial policies respectively.
11. Intermediate situations characterized by $\rho < 1 + r$ also reflect a tax asymmetry. In any of these cases, the cash flow tax is a hybrid one. This can help illustrate the fundamental difference between a corporate income tax and a pure cash flow tax. Under the former, it is the return to shareholder equity that is taxed because interest on debt is deductible from the corporate income tax base. If one redefines profit in the present model as return to equity, then the corporate income tax affects the discount rate because of interest deductibility. In contrast, the (pure) cash flow tax base consists of revenues net of investment expenses. Such expenses are equivalent to depreciation and imputed costs for the use of capital (i.e. debt and equity financing costs). In the hybrid cash flow tax model studied here however, not all costs are deductible if one uses a weighted average cost of debt and equity financing.

12. For a thorough discussion of cash flow taxation, see Boadway et al. (1987, 1989); for a real-world application, see Stangeland (1995).

13. Those derivations are available from the author upon request.

14. In their supergame analysis of tax incidence with collusion and entry, Davidson and Martin (1991) posit the existence of sunk entry costs. Follow the literature on entry deterrence (see Tirole [1988]) and assume that entry costs are also fixed. Davidson and Martin show that the general equilibrium effects of pure profit taxes, output taxes, and general and partial factor taxes are ambiguous. Taxes trigger two opposing forces which act through the discount rate. One favours collusion while the other favours entry. If, for instance, sunk costs are capital-intensive (the usual interpretation in the entry deterrence literature), then the increase in sunk costs following general factor taxes more than offsets the incentive to enter. I conclude that little stands to be gained from positing fixed costs and/or allowing the number of firms to be endogenous in the present model.

15. Figure 3 is no more than Figure 1 expressed in terms of after-tax profits. Beyond that, the interpretation of the two diagrams is the same.

16. In addition to the previously cited literature on taxation and risk-taking, see Myles (1995) for a brief summary, and Boadway et al. (1989) for specific proposals.

17. This result may still be obtained in the decreasing cost case if marginal cost does not decline too rapidly as output expands.
REFERENCES


Figure 1
Pre-Tax and Best-Response Profit Functions
Figure 2

Most Collusive Equilibrium in Output Space
Figure 3

Effects of Increasing Refundability I: Outputs and After-Tax Profits
Figure 4

Effects of Increasing Refundability II: After-Tax Profits
Essay III

Corporation Tax Asymmetries
and
Firm-Level Investment in Canada
1.0 INTRODUCTION

The analysis of investment decisions has spawned a voluminous literature, much of which has been devoted to evaluating the economic impact of tax incentives on investment. The role of corporate tax policy hinges upon whether such tax incentives work or not. For instance, proponents of industrial policies would argue in favour of such incentives if one could show that they are effective. Up until recently, the overall empirical evidence on the effectiveness of tax incentives on investment was weak. This conclusion is well documented in recent surveys by Chirinko (1993) and Mintz (1995b). Recent work by Cummins, Hassett and Hubbard (1994, 1995, 1996) has, however, produced results that run counter to the conclusions reached up to that point. Those authors use firm-level panel data and tax reforms as experiments to conclude that tax policy had an economically significant impact on investment during reform episodes.

Notwithstanding this welcome development, recent empirical work on investment still ignores important features of corporate tax systems which may help explain why observed impacts are small in some circumstances. One such feature is that tax systems do not treat gains and losses in a symmetric fashion. In the terminology of the related literature on taxation and risk-taking, full loss offsets are not allowed under an asymmetric tax system (see Mintz, 1995b). In Canada, the United Kingdom, and the United States, firms can carry losses back up to 3 years, thereby claiming a refund of past taxes paid in those years. Firms can also carry losses forward at no interest but for longer periods, during which losses are offset against future tax liabilities. In Canada and the U.S., the carryforward limit is 7 and 15 years respectively, while there is none in the U.K.

There is strong evidence at the outset that tax asymmetries constitute an economically significant phenomenon. In the case of Canada, this is documented by Mintz (1988) and Glenday and Mintz (1991), while Auerbach and Poterba (1987), and Altshuler and Auerbach (1990) provide U.S. evidence. It is tempting to attribute the large stocks of unused tax-loss carryforwards to the 1981-82 recession. The evidence cited above is not sufficiently up to date to monitor the utilization of losses accumulated during that period. Although corporate profitability has subsequently improved, there is evidence that large stocks of unused tax
attributes have persisted well into the 1990s. In Canada, for example, cumulative reported book operating losses amounted to $86 billion in 1993. That year, unclaimed capital cost allowances (tax depreciation), capital losses, and unclaimed resource deductions amounted to $17, $11, and $7 billion respectively. Given the restrictions on transferability of losses presently embodied in the tax law, it is unlikely that those stocks of losses will be used up rapidly.

The present study seeks to assess the impact of tax asymmetries on the firm’s capital employment decision. First, it explores the theoretical impact of asymmetries on tax incentives. Second, the study investigates empirically whether the capital accumulation decisions of tax-exhausted firms differ from those of taxpaying firms. A panel data set of Canadian firms is used to this end. Empirical studies by Devereux (1989), Devereux, Keen and Schiantarelli (1994), and Anderson (1995) constitute exceptions in that they incorporate tax asymmetries. Up to now, Anderson (1995) is the only study of this kind performed using Canadian data. While Devereux, Keen and Schiantarelli (1994) give a very meticulous treatment to asymmetries, their results suggest that asymmetries do not noticeably improve the performance of Euler (cost of capital) and Tobin’s Q investment equations.

The present study takes a different route. On the theoretical side, expressions for the user cost of capital incorporating asymmetries are developed which are inspired from the tax holiday framework of Mintz (1990, 1995). The innovations generated by this approach lie in a more careful treatment of important features of the tax system and more specifically tax depreciation, and in the treatment of expectations with respect to tax status. On the empirical side, the approach is in the spirit of Anderson’s (1995) switching regression model. An important difference with his study is that firm-level panel data are used here, rather than a cross-section. This allows one to take into consideration the fact that tax losses constitute a dynamic phenomenon.

The study is organized as follows. Section 2.0 presents an optimizing model of the firm which incorporates tax asymmetries. Section 3.0 presents a description of the data and discusses the empirical implementation of the model. Section 4.0 presents the first stage of the empirical analysis (Poisson regressions). Section 5.0 presents the second stage of the empirical analysis (switching regressions). Section 6.0 provides concluding remarks and
discusses extensions. Appendix A contains derivations of the user cost of capital, while Appendix B describes the data.

2.0  A MODEL OF FIRM OPTIMIZATION WITH TAX ASYMMETRIES

2.1 The Problem of the Firm

The firm’s objective is to maximize the value of shareholders’ equity by choosing capital each period. In the absence of debt, payments made to shareholders are equal to the cash flow of the firm, or revenues net of expenditure on gross investment and corporate taxes. Several assumptions need to be made at this point. First, the firm is fully financed using equity. This is a simplifying assumption only: since interest paid on debt is fully deductible from the corporate tax base in Canada, the stock of debt vanishes when the firm’s optimality conditions are computed. Some implications of debt financing will nevertheless be discussed below. Second, the price of output grows at the same rate as the price of capital goods. This simplifying assumption is made in order to obtain a tractable expression for the user cost of capital that allows for tax-exhaustion. More specifically, the assumption allows one to use the Fisher effect to convert nominal cash flows into real ones. The effect stipulates that \((1 + r)(1 + \pi) = (1 + R)\), where \(r\) is the firm’s real discount rate, \(\pi\) is the expected inflation rate, and \(R\) is the nominal discount rate. The second assumption will be relaxed in the empirical version of the model. Third, risk is not modelled explicitly. Let \(V_t\) denote the present value of the firm’s cash flow at the beginning of period \(t\):

\[
V_t = \sum_{i=0}^{T} \frac{1}{(1 + r)^i} [F(K_i) - (1 - A_i)q_i I_i - C(K_i)] + \frac{u S_i}{(1 + R)^{r - t}}
\]

where \(K_i\) is the gross capital stock, \(I_i\) is gross investment, \(F(K_i)\) is the production function, \(C(K_i)\) is the adjustment cost function, \(q_i\) is the price of capital goods relative to that of...
output, $A_t$ and $A$ are the present value of combined tax depreciation allowances and investment tax credit per dollar of capital in tax-exhausted and taxpaying periods respectively (see Appendix A), $u$ is the corporate tax rate, and $T^*$ is the future time period at which a tax-exhausted firm becomes taxpaying. Except for a positive marginal product $F_t' = \partial F(K_t)/\partial K_t$, no other restrictions are imposed on the production and capital installation technologies at this point. Labour inputs are ignored since wages are fully deductible from the corporate tax base. Adjustment costs are assumed to be capital-based and to be deductible from the tax base. Finally, $S_{T^*}$ is the stock of carryforwards as of time $T^*$ so the second term represents their discounted tax value at that time. The stock of carryforwards accumulated up to time $T^*$ is constructed according to:

$$S_{T^*} = S_0 - \sum_{t=0}^{T^*-1} [(1-\pi)^t F(K_t) - (1-\pi)^t q_t I_t - (1-\pi)^t C(K_t)], \quad S_0 \geq 0.$$  

(2)

where $Z_t$ is the present value of deferred tax depreciation allowances per dollar of old capital (see Appendix A), and $S_0$ is the initial stock. Capital accumulation is governed by the equation $K_{t+1} = (1-\delta)K_t + I_t$, where $\delta$ is the economic depreciation rate. In order to eliminate $I_t$, substitute the accumulation equation into (1) and (2) and combine them. After substitution, the firm’s objective is to choose $K_t$ to maximize $V_t$. In the tax-exhausted case ($t < T^*$), the first-order condition is:

$$\frac{\partial V_t}{\partial K_t} = \frac{1}{(1+r)^t} \left[ F_t' + q_t (1-\delta)(1-A_t) - C_t' \right] - \frac{q_{t-1}}{(1+r)^{t-1}} (1-A_{t-1})$$

$$- \frac{u}{(1+R)^t} \left[(1+\pi)^t F_t' - (1+\pi)^t (1-\delta) q_t Z_t - (1+\pi)^t C_t' \right]$$

$$- \frac{u(1+\pi)^{t-1}}{(1+R)^{t-1}} q_{t-1} Z_{t-1} = 0.$$  

(3)

where $C_t' = \partial C(K_t)/\partial K_t$ denotes marginal capital adjustment costs. The first-order condition in the taxpaying case ($t = T^*$) yields the standard user cost expressions (see Appendix A)
and is therefore omitted. In the continuous time analogue to this problem there would be a transversality condition with respect to the stock of losses. Let $u_t = u(1+R)^{-(T^*-t)}$ denote the discounted corporate tax rate. In the event that the firm uses debt while being tax-exhausted, the discounted corporate tax rate $u_t$ is used to value the deferred tax savings due to interest deductibility. Substitute $u_t$ into (3) to eliminate $u$. Then, replace $u$ in (A.2) or (A.3) to account for the reduced benefit of debt finance in the event of tax exhaustion. Finally, use the Fisher effect and (A.6) and (A.7) to construct a new variable defined as:

$$F_t' = \frac{q_t(\delta - r)(1 - \bar{A}_t) - (1 + r)\Delta [q_t(1 - \bar{A}_t)]}{(1 - u_t)} + C_t',$$

where $\Delta[\cdot]$ is the first-difference operator. Expression (5) is a general user cost formula which applies to both tax-exhausted and taxpaying firms. Tax status depends on the relative values of $t$ and $T^*$.

So far, little has been said of the firm's debt decision. Mintz (1995a) derives the user cost of the firm in a tax holiday context which considers debt policy and personal taxation. It is straightforward to show that the expression he obtains in this context is similar to (5). Unlike (5) though, his excludes adjustment costs but includes personal tax rates on dividends. If one assumes that dividend tax rates do not change between tax-exhausted and taxpaying states, or if one ignores personal taxation altogether, then user cost (5) can be used along with (A.2) or (A.3) when the firm uses debt.

An example of a model which uses (A.2) to calculate the cost of finance is the tax loss model. In that framework, the firm trades off the tax benefit from issuing debt due to interest deductibility in taxpaying states against the possible loss in the value of tax deductions in the event that the firm becomes tax-exhausted. User cost (5) captures the cost
and interest deductibility aspects of debt but cannot capture the direct impact of high leverage on the likelihood of tax exhaustion. In terms of the present model, increasing leverage may delay the return to taxpaying for a tax-exhausted firm, or increase $T^*$. The empirical analysis that follows does not explicitly consider this channel per se.

2.2 Production Technology and Capital Demand

In order to derive an expression for the firm's demand for capital, it is necessary to posit a functional form for the technology. One such form, the general two-factor CES production function, can be written as:

$$Q_t = F(K_t, L_t) = \gamma [\delta K_t^{-\rho} + (1 - \delta)L_t^{-\rho}]^{-\sigma/\rho}.$$  \hspace{1cm} (6)

where $Q_t$ and $L_t$ represent the firm's output and labour input in period $t$ respectively, and $\gamma$, $\delta$, and $\rho$ are the efficiency, distribution, and substitution parameters respectively. Parameters $\delta$ and $\rho$ here are standard notation and should not be confused with the economic depreciation rate and the nominal rate of return on equity which appear elsewhere in the paper. Also, $\nu$ is the degree of the function and one can write $\sigma = 1/(1 + \rho)$, where $\sigma$ is the elasticity of factor substitution. It is straightforward to show that the marginal product of capital can be written as:

$$\frac{\partial Q_t}{\partial K_t} = \delta \nu \gamma^{1-\rho/\nu} Q_t^{1-\rho/\nu} K_t^{-(1-\rho)}. \hspace{1cm} (7)$$

There are two possible ways of eliminating marginal adjustment costs from (5) in order to obtain a simple optimality condition out of (7). First, one could invoke a steady state argument to obtain the result that there be no change in the capital stock. In that case, the correct user cost of capital would be (5) with $C_t' = 0$. While this is correct for a firm that is growing along the adjustment path, it is not necessarily true for a firm in a loss position along the path. That would require the possibility of a long-run equilibrium with losses.
Second, one could impose the following restrictions, as discussed by Boadway (1987): if adjustment costs were deductible and if the nominal cost of finance were independent of taxes, terms involving the adjustment cost function would vanish from the optimality conditions. The problem, of course, is that terms involving the adjustment cost function are not observable. Boadway acknowledges that the problem is ignored in practice.

This analysis follows the usual practice and ignores $C_t'$ in (5). Denote the resulting user cost of capital (henceforth cost of capital) by $c_t$. Profit maximization by the competitive firm requires that $\frac{\partial Q_t}{\partial K_t} = c_t / p_t$, where $p_t$ is the price of output. Then, the firm's desired capital stock is given by:

$$K_t^* = \beta \left( \frac{P_t}{c_t} \right)^\gamma Q_t^{a-(1-a)\gamma}.$$

where $\beta^{1+\rho} = \delta \pi \gamma^{1-\rho} / \nu$. This is an expression for the long-run demand for capital with implicit dynamics which are richer than those from the usual standard neoclassical model; this is because $c_t$ depends on past and future events. Expression (8) forms the basis for the switching equation.

### 3.0 DATA AND EMPIRICAL IMPLEMENTATION

#### 3.1 The Data

The value of panel data for the purpose of studying investment behaviour has been recognized for some time now. There is evidence that mitigating the aggregation problem alone has been of some help in obtaining more economically plausible results. Chirinko (1993) discusses investment studies with panel data. Recent and important panel studies not surveyed therein should include Devereux (1989), Blundell et al. (1992), Devereux, Keen and Schiantarelli (1994), and Cummins, Hassett and Hubbard (1994, 1995, 1996). See also Bartholdy, Fisher and Mintz (1989) for related work.
The present study continues this trend. A balanced panel of 50 nonfinancial Canadian public companies with 19 years (1976-94) of time-series observations has been constructed. This amounts to a raw total of 950 observations. Cummins, Hassett and Hubbard (1996) use a panel of Canadian firms in their cross-country comparison of tax reforms. The disadvantages of their data set are that the panel is unbalanced, and variables entering the user cost are not as close to firm-specific values as the ones calculated here. Data sources and their contributions to the present study are briefly described below. Appendix B provides a detailed overview of data sources and the steps involved in data collection, transformation, and construction of variables.

Briefly, the principal data requirements for the estimation of the empirical version of the model developed above concern the user cost of capital, various stocks and flows, and prices. The construction of the cost of capital described in the previous Section requires considerable effort because several sources of data must be combined. Firms in the sample are sorted according to 4 broad sectors of activity: resource; manufacturing and processing (M&P); utilities, transportation and communications (UT&C); and "other", including construction, services and trades. Sample selection is dictated by data availability and the need to have enough complete time-series observations to take advantage of the time-dependent nature of the cost of capital.

The data set constructed as part of this study goes quite a long way in addressing the widespread problems of aggregation and poor measurement that plague many empirical studies on investment and taxes. To conclude this brief description of the data, Table 1 reports summary statistics on key firm characteristics from the sample.4

3.2 Issues in Empirical Implementation

Three issues are discussed in this Section: the discounting of tax depreciation allowances and risk; the cost of finance to the firm; and the endogeneity of the cost of capital. On the discounting of tax depreciation allowances, Summers (1987) and Gordon and Wilson (1989) argue that tax depreciation allowances are risk-free or nearly so and should therefore be discounted accordingly. The appropriate discount rate is certainly lower than the one the firm would use to discount the future returns from risky investments in physical
capital. This position is adopted in the empirical computation of the cost of capital and a treasury bill yield gross of personal taxes is therefore used to discount tax depreciation allowances.

Consideration of the cost of finance brings up the issue of risk. As pointed out earlier, the theoretical model ignores risk. The CAPM-based equity returns ($\rho$) used in this study do, however, incorporate risk premia calculated from market data. If one uses a weighted average cost of finance as in (A.2), the presence of risk-inclusive equity returns does not create any inconsistency. This is the case since debt is also risky and the corporate bond rate used to calculate it incorporates that risk.

With the pecking-order model specified in (A.3), a different story arises. Suppose that one accepts that informational asymmetries provide a convincing story behind the pecking-order model. Note that in (A.3) the nominal cost of retained earnings gross of corporate taxes $R_f$ is a risk-free rate. On the one hand, consistency of the model would require that the CAPM-based rate of return on new equity exclude risk since retained earnings (a form of equity) are treated as risk-free. On the other hand, the return on new equity should include the asymmetric information and transaction costs which are incurred when the firm issues new equity. In practice, transaction costs can be calculated but it is very hard to assess the costs due to asymmetric information. The fact that all the firms in the sample have survived for at least 19 years means that they are established and much less likely to suffer from the asymmetric information problems just alluded to. Yet, it is interesting to note that 60% of the observations in the sample are consistent with the pecking-order's full financing hierarchy. The risk-inclusive equity return $\rho$ is used to implement (A.3) and will be adequate as such as long as risk is an acceptable proxy for informational and transactional costs.

The endogeneity of the user cost of capital is the key empirical challenge of this study. Expansion of (5) shows that the cost of capital for a tax-exhausted firm is a complicated function of the time period ($T^*$) at which that firm resumes its taxpaying status. At the same time, the amount of time which must elapse before the firm becomes taxpaying again, ($T^*-t$), depends on current investment decisions for a firm that is tax-exhausted at time $t$. Current investment will affect future cash flows, but current investment does theoretically
depend on the cost of capital.

One piece of information which would help assess the tax position of a firm is the stock of tax-loss carryforwards. As shown by Auerbach and Poterba (1987), there are numerous problems associated with the construction of carryforward accounts. To summarize their findings, corporate accounting data simply do not allow one to construct an economically consistent and meaningful measure of carryforwards. The data interpretation problem is even worse in the Canadian case since tax depreciation (CCA) deductions are not mandatory. Finally, industry-specific time-series data on the time needed to use up losses are not available. For those reasons, a different approach is proposed below.

First, note that the sample separation of tax-exhausted and taxpaying firms is known from total income taxes. If a firm is tax-exhausted at any point in time, it is also known how many years ahead the firm begins paying taxes again. This information is used to construct a raw series for \((T^*-t)\) as follows. If, for example, a firm is tax-exhausted at time \(t\) but resumes taxpaying status at time \(t+3\), then the raw series takes on the values 3, 2, 1 and 0 at times \(t\), \(t+1\), \(t+2\), and \(t+3\) respectively. The series thus describes how many years hence a firm resumes taxpaying given that it is currently tax-exhausted. For a firm that is currently taxpaying, the series takes on a value of 0. Note that Altshuler and Auerbach (1990) found, using older U.S. data, that the facilitation of potential carrybacks serves to reduce the effective marginal tax rates faced by taxable firms. An end-of-sample problem is encountered in the case of one firm only. Direct use of this raw series to calculate (5) is inappropriate because of the endogeneity problem described above. Furthermore, direct substitution of the raw series would not make full use of the information on firm characteristics which is contained in the sample.

Second, note that the raw series \((T^*-t)\) just described is a count or sequence of nonnegative and noncategorical integers. Under certain conditions, a statistical model of counts such as the Poisson distribution may be used to describe the behaviour of the raw series. Let \(Y = T^*-t\) from the raw series. Assume that the explained variables \(Y_1, Y_2, \ldots, Y_{nT}\) have independent Poisson distributions with parameters \(\lambda_1, \lambda_2, \ldots, \lambda_{nT}\) respectively.
It follows that:

\[
Prob(Y_{it} - x) = \frac{e^{-\lambda_{it}} \lambda_{it}^x}{x!} \quad \text{for} \quad x = 0, 1, \ldots, \\
i = 1, 2, \ldots, n, \\
t = 1, 2, \ldots, T.
\]  

where \(x\) is the number of consecutive periods during which the firm is tax-exhausted. The formulation underlying (9) incorporates the assumption that the data are stacked by firm (a pooled sample). Given the novel nature of the present inquiry, the investigation of more sophisticated panel covariance structures is left for future work.

4.0 A POISSON REGRESSION

The assumption that the \(Y_{it}\) follow a Poisson distribution can be implemented using a Poisson regression. Maddala (1983) discusses the Poisson regression in detail, while Hausman, Hall and Griliches (1984) present an economic application which shares some of the features of the present one. The idea is to estimate (predict) the parameter \(\lambda\) using sample information and then substitute the estimate into (9) to calculate the probability of a particular tax status. The regression should incorporate explanatory variables which are suspected to influence the likelihood of tax exhaustion. Anderson’s (1995) empirical study on tax-exhaustion uses the probit model and cross-sectional data to estimate such a probability. In the present study, the Poisson regression is preferable to a probit because it exploits the count nature of the data on \(Y\). Assume for now that the \(\lambda_{it}\) are log-linearly dependent on the explanatory variables so that:

\[
\ln \lambda_{it} = \beta_0 + \sum_{j=1}^{k} \beta_j x_{jit}.
\]

a specification of the form \(\ln \lambda = X\beta\), where \(X\) is a vector of regressors which describe the characteristics of a firm, and \(j = 1, 2, \ldots, k\) is the number of regressors excluding the
intercept. Regressors are selected from available sample data on the basis just described, for (10) is not a structural model. The baseline set of explanatory variables consists of: the capital cost allowance (CCA) rate; deferred taxes and investment tax credit; lagged real investment; lagged real inventories; proportion of debt to total financing calculated at market values; real output; and real profits. Note that inventories, investment, output, profits, and deferred taxes and investment tax credit are scaled by assets. Given that there are four broad industry groups, it is reasonable to expect industry-specific effects so dummies are added for each of the four groups. In addition, given the length of the time-series, it is reasonable to expect that certain years will be closely related to the likelihood of tax exhaustion, such as recession years. Dummies for the years 1982, 1983 and 1990 are thus added. An alternative approach to the dummies could have been to use a measure of the cycle which depends on potential GDP. Finally, a dummy for foreign ownership is added for exploratory purposes.

Investment and capital stock measures are lagged to avoid contemporaneous simultaneity. Apart from the CCA rate, none of those variables are closely related to any concept of marginal tax parameters. One would instead expect the effect of such parameters to enter the analysis through the cost of capital. All four industry dummies are used and hence the intercept in (10) is omitted. Estimation is carried out in a nonlinear fashion using \( \lambda = \exp(X\beta) \) on the pooled sample over the 1977-94 period. Year 1976 is deleted in order to construct lags. The results from Poisson regressions on the full sample using the baseline set of regressors are presented in Table 2 below. The estimation procedure converges in 7 iterations. The mean of the dependent variable equals 0.2567, which also equals the mean of the predicted \( \lambda_{it} \) in this model. In addition, the mean probability of taxpaying in the sample is 0.8293. Given (A.5) and the inability to construct carryforward accounts, the Poisson methodology does not allow one to calculate the average time a firm takes to use up losses. The approach which consists of calculating that average amount of time has been used in the literature. Its shortcomings are that it sacrifices a significant amount of sample information through averaging and provides very limited information. In the end, the Poisson approach is far preferable.
The economic interpretation of the results contained in Table 2 is as follows. The dependent variable can be loosely interpreted as an index of tax exhaustion. Lagged investment measures have a positive effect but only lagged inventories are statistically significant at the 0.05 test size. This could suggest that future cash flows generated by past investment expenditures take more than one year to accrue. In the case of inventories, the estimate may incorporate the impact of the elimination of the inventory allowance in 1986. The inventory allowance is ignored in the construction of the user cost. Real output and profits have the expected sign and are significant. Higher output (ceteris paribus) and profits reduce the likelihood of tax-exhaustion. Deferred taxes and (deferred) investment tax credit have the expected sign and are significant. This variable is an imperfect proxy for the size of unobservable carryforwards. Debt financing as a proportion of total financing exhibits a strong positive relationship with the likelihood of tax-exhaustion. This lends support to the tax-loss model of financing. The negative and significant coefficient on the CCA rate is difficult to interpret. One would expect that variable to have no impact or, at most, be positively related to tax exhaustion. But then again, claimed CCA can differ significantly from permitted CCA. More will be said on this apparent puzzle below.

Coefficients on industry dummy variables are broadly consistent with a heterogeneous tax treatment of different industries in Canada. Those differences have been mitigated with the 1987-88 tax reform, though. For example, resource firms have sometimes been known to face negative effective tax rates due to a complex interaction of generous provisions. As expected, status as a resource firm is positively related to the index of tax exhaustion, but not in a statistically significant way. Status as a utilities, transportation and communications firm is negatively and significantly related to tax exhaustion. This is expected since the industry is characterized by relatively stable cash flows over time, partly due to regulation. The coefficient on the "other" dummy is borderline significant, while the one on manufacturing and processing firms is insignificant. This does not suggest overall industry effects that are strong enough to warrant adding cross-products as regressors. Preliminary regression results with cross-products (not reported here) suggest that the number of firms in some industry groups is not large enough to get reasonably precise estimates of those interaction coefficients. The negative and significant coefficient on the foreign dummy could
suggest that foreign-owned firms are required by their owners to be better performers than domestically-owned firms with similar characteristics. Alternatively, and perhaps more convincingly, the lower likelihood of tax-exhaustion of foreign firms may be observed because they magnify earnings prior to remittances. Finally, the year dummies have the expected signs since recession years are positively related to the likelihood of tax exhaustion. In addition, their coefficients are statistically significant. The above results, while valuable only from a qualitative point of view, display remarkable consistency with the theory.

Two issues concerning the above results must be addressed. First, the unexpected sign and significance of the coefficient estimate on the CCA rate, and second, statistical independence. An explanation for the CCA coefficient is that it may act as a dummy for economically significant changes due to the 1987-88 tax reform. CCA rates were reduced for a number of capital asset classes, and those reductions were sometimes important, as shown by Jung (1989). In order to test the hypothesis that the CCA rate embodies an effect of this sort, the Poisson equation is estimated separately on pre-reform (1977-87) and post-reform (1988-94) subsamples. Year dummies are deleted in order to focus on the impact of the reform (break) on estimates. Results are presented in Tables 3 and 4 respectively.

The key outcome of those separate regressions is that the coefficient on the CCA rate is statistically insignificant in each of the two subsamples, although the signs remain negative. Sign expectations below follow from the discussion of Table 2. In the 1977-87 subsample, the only coefficients which are statistically significant are the ones on profit, debt financing, and deferred taxes and investment tax credit. In addition, they all have the expected sign. The picture turns around once one considers the 1988-94 subsample. Apart from the coefficient on the CCA rate, the only insignificant one is that on debt financing. The coefficients on investment measures, output, profits, and deferred taxes and investment tax credit have the expected signs. All industry dummies remain negative but are all significant.

The interpretation of those results is that pre-reform and post-reform regimes differ economically, and that the CCA rate does not matter per se. In order to verify this interpretation further, separate regressions are estimated using the two subsamples with the restriction that the coefficient on the CCA rate be zero. In each case, likelihood ratio tests
cannot reject the restrictions. The results are not reported here, although one should note that they are qualitatively identical and quantitatively very close to those from unrestricted regressions (see Tables 3-4). This supports the hypothesis that the significant coefficient on the CCA rate over the full sample embodies part of this reform break and has no additional economic meaning. As an historical note, it should be mentioned that one of the objectives of reform was to slow down the accumulation of tax losses by reducing CCA, investment tax credits and tax rates. The recession that hit Canada in 1990-91 and the tight monetary policy at the time partly neutralized that impact by generating new losses.

The second issue is the statistical independence problem with using the predicted $\lambda_{it}$ from any of the above regressions to substitute for $(T^*-t)$ in the cost of capital. This is also encountered by Hausman, Hall and Griliches (1984) in their investigation of the patents-R&D relationship using panel data. In the tax exhaustion context, the problem manifests itself as follows. For example, a firm that is tax-exhausted this year, next year and the year after does not have independent probabilities of being tax-exhausted in each of those 3 separate years because loss carryforwards, which are unobservable to the econometrician, do accumulate during that bout of exhaustion. This accumulation of carryforwards does in turn delay the return to taxpaying status. For example, observations in $Y_{it} = [0,1,0,0,......0,0]$’ are independent since the model allows for immediate use of deductions upon return to taxpaying status, and there are no consecutive periods of tax exhaustion. If instead one has $Y_{it} = [3,2,1,0,1,0,.....0,2,1]$’, the second, third, and last element of this vector are not independent. Stated differently, being tax-exhausted in the previous period increases the firm’s likelihood of remaining so in the current period.

The results reported in Table 2-4 are obtained by using both dependent and independent observations. In order to test the sensitivity of the Poisson regression results to the lack of independence, the first equation is estimated after deletion of the dependent observations (62 in all). The 838 observations that remain are statistically independent. Table 5 below reports the results from this procedure. As expected, the mean of the predicted $\lambda_{it}$ falls (to 0.1575), and the mean probability of taxpaying in the sample increases to 0.8906. There are no substantial differences between these results and those found in Table 2, but some salient points deserve mention. Lagged investment has the same sign but
is now statistically significant, which would lend more support to the conjecture made earlier about investment and inventories. The coefficient on deferred taxes and investment tax credit suggests that such a variable is a better proxy for the stock of carryforwards when observations are independent. The proportion of debt in financing loses some significance, which lends additional support to the tax-loss model. Industry effects are now significant for the "other" group, and the sign on the resource dummy is now negative, although statistically insignificant. The size of the coefficients on foreign and year dummies fluctuates but the key qualitative change is that year 1982 appears to incorporate the effect of the subsequent year on the likelihood of tax-exhaustion.

A likelihood ratio test emphatically rejects the restriction that all observations are independent as in Table 2. The test statistic is 555.04, which far exceeds the critical value of 67.505 (Chi square with 62 restrictions). Note that the model described in Table 5 is not structural and that it is only useful insofar as it enables one obtain the predicted $\lambda_{it}$ which are needed to calculate the cost of capital. With this in mind, the way around the independence problem is to use the estimated coefficients from the independent model with the values of the regressors associated to dependent observations to calculate "independent" predicted values of $\lambda$ for the 62 previously "dependent" observations. This is an approximation which avoids the loss of observations (all inferences are asymptotic here) and the complications which arise from missing panel data points.

In closing, two points are emphasized. First, in light of the results shown in Tables 2-4, it would seem appropriate to use the equations described in Tables 3-4 to predict $\lambda_{it}$ separately for each subsample. One problem with this approach is a large loss of degrees of freedom. Another problem is the combination of the lack of independence and the break due to tax reforms. Splitting the sample would result in a loss of information to the extent that consecutive periods of tax-exhaustion are separated. For those reasons, the coefficient estimates from Table 5 are used to predict $\lambda_{it}$ according to the procedure just described.

Second, it must be pointed out that the Poisson approach to the tax exhaustion problem is the key novel element in this study and has a number of advantages. The predicted $\lambda_{it}$ are preferable to the raw series $(T^*-t)$ since the resulting continuous sequence exhibits much more variability. In addition, predicted $\lambda_{it}$ can account for the fact that a firm
that is taxpaying at time $t$, for example, has a non-zero probability of being tax-exhausted next period. The predicted $\lambda_{it}$ is substituted for $(T^*-t)$ in (5) to calculate the cost of capital.

5.0 THE CAPITAL DEMAND EQUATION

The objective of this Section is to examine empirically the potential endogeneity of the cost of capital (see Section 3.2) and its effect, among other things, on the firm’s long-run demand for capital. The econometric approach consists in estimating an endogenous switching model with known sample separation along the lines of Anderson (1995), from which the following exposition draws. Switching will be endogenous if the cost of capital is responsible for changes in investment behaviour. The obverse is exogenous switching, which will occur if changes in investment behaviour are only a function of exogenous firm characteristics. The framework is presented first, and modifications to accommodate the problem at hand are suggested next.

A firm is classified as taxpaying if total income taxes are positive, and tax-exhausted otherwise. There are only two regimes of interest and therefore the actual and unobservable amount of losses does not matter. A linear capital demand equation can be constructed by taking the logarithms on both sides of (8) and appending a stochastic error term. Alternatively, (8) could initially have a multiplicative error term. Firm indices are added in what follows. A general form of the equation is:

$$\ln y_{it} = \begin{cases} 
  x'_{it,N} \gamma_N + e_{it,N} & \text{if } \eta'z_{it} \geq u_{it}, \\
  x'_{it,T} \gamma_T + e_{it,T} & \text{otherwise.}
\end{cases}$$

(11)

where subscripts N and T denote tax status, tax-exhausted and taxpaying respectively. The left-hand side is the dependent variable, $x$ is a matrix of variables, and $\gamma_N$ and $\gamma_T$ are vectors of parameters. Finally, $e_{it,N}$, $e_{it,T}$ and $u_{it}$ are stochastic error terms, and $\eta'z_{it}$ is a stochastic criterion function of variables $z_{it}$ and parameters $\eta$ which determine whether or not firm i
pays taxes at time \( t \). Specify the indicator function:

\[
\text{ITOR}_{it} = \begin{cases} 
1 & \text{if } \eta'z_{it} \geq u_{it} \quad \text{(the firm is tax-exhausted)}, \\
0 & \text{otherwise}. 
\end{cases}
\] (12)

Anderson (1995) estimates \( \eta \) by probit methods, assuming that \( e_{it,N}, e_{it,T}, \) and \( u_{it} \) have a trivariate normal distribution with zero mean and a covariance matrix given by:

\[
\Sigma = \begin{pmatrix} 
\sigma_{N,N} & \sigma_{N,T} & \sigma_{N,u} \\
\sigma_{T,N} & \sigma_{T,T} & \sigma_{T,u} \\
\sigma_{u,N} & \sigma_{u,T} & 1 
\end{pmatrix}.
\] (13)

Consistent with (13), \( E(e_{it,N} | u_{it} \leq \eta'z_{it}) = -\sigma_{N,u} \phi(\eta'z_{it})/\Phi(\eta'z_{it}) \), and that \( E(e_{it,T} | u_{it} \geq \eta'z_{it}) = \sigma_{T,u} \phi(\eta'z_{it})/[1 - \Phi(\eta'z_{it})] \). The term \( \phi(\eta'z_{it})/[1 - \Phi(\eta'z_{it})] \) is a discrete analogue to the inverse of the Mill's ratio, which Heckman (1979) discusses in the closely related context of sample selection bias. In continuous applications, the functions \( \phi(\cdot) \) and \( \Phi(\cdot) \) are the standard normal density and cumulative functions evaluated at their argument. Note that the truncation of the distribution does not pose a problem here since all one needs to know is whether the firm is taxpaying or not (see [12]), not the actual amount of losses or gains.\(^{10}\)

Using (12) and (13), rewrite (11) as:

\[
\ln y_{it} = \begin{cases} 
\chi'_{it,N} \gamma_N - \sigma_{N,u} \frac{\phi(\eta'z_{it})}{\Phi(\eta'z_{it})} + v_{it,N} & \text{if } \text{ITOR}_{it} = 1, \\
\chi'_{it,T} \gamma_T + \sigma_{T,u} \frac{\phi(\eta'z_{it})}{1 - \Phi(\eta'z_{it})} + v_{it,T} & \text{otherwise}. 
\end{cases}
\] (14)

The Poisson regression estimated in the previous Section allows one to bypass the probit stage because the probability of tax exhaustion can be calculated directly as 1 minus the probability that the firms is taxpaying. The latter probability is computed by substituting the predicted \( \lambda_{it} \) and \( x = 0 \) into the Poisson limit (9), which yields \( e^{-\lambda_{it}} \). Let \( P_{it,T} \) denote the
probability of paying taxes, and substitute it for \(1 - \Phi(\cdot)\) in (14). Let the probability of tax exhaustion, \(1 - P_{i,t,T}\), be denoted by \(P_{i,t,N}\) and substitute it for \(\Phi(\cdot)\) in (14). The argument \(\eta'z_{it}\) [of \(\Phi(\cdot)\)] is identical in both equations in (14). Hence, one can simplify by assuming that \(\Phi(\eta'z_{it})\) is a constant.

Unlike Anderson (1995), who uses cross-sectional data, dynamics must be taken into account here given the time-series dimension of the data. A simple dynamic version of the model derived from (8) and (14) is the partial adjustment model:

\[
\ln K_{i,t} = \begin{cases} 
\beta_0 + \theta \ln K_{i,t-1} + \beta_1 \ln \left( \frac{p_t}{c_{it}} \right) + \beta_2 \ln Q_{it} - \beta_3 P_{i,tN}^{-1} + \nu_{i,t} & \text{if } ITOR_{it} = 1, \\
\beta_0 + \theta \ln K_{i,t-1} + \beta_1 \ln \left( \frac{p_t}{c_{it}} \right) - \beta_2 \ln Q_{i,t} + \beta_4 P_{i,tT}^{-1} + \nu_{i,t} & \text{otherwise.}
\end{cases}
\]  

where \(0 \leq \theta \leq 1\) is the adjustment parameter. Other parameters to be estimated are as follows: \(\beta_0 = \ln(1-\theta)\); \(\beta_1 = \sigma(1-\theta)\), the short-run elasticity of capital with respect to relative prices; \(\beta_2 = [\sigma + (1-\sigma)/\nu](1-\theta)\), the short-run elasticity of capital with respect to output; \(\beta_3 = \sigma_{N,u}(1-\theta)\); and \(\beta_4 = \sigma_{T,u}(1-\theta)\). Underlying structural parameters \(\beta\), \(\sigma\) and \(\nu\) describe the technology (see Section 2.3). Finally, \(\sigma_{N,u}\) and \(\sigma_{T,u}\) are covariances to be estimated.

The long-run elasticities associated with \(\beta_1\) and \(\beta_2\) can be calculated by dividing each respective estimated coefficient by the estimated value of \(1-\theta\). In accordance with the Poisson regressions, four industry dummies, a foreign and three year dummies replace the intercept \(\beta_0\) in the equation. Cross-equation covariance adjustments are required because the two expressions in (15) exhibit heteroskedastic errors of a known form. Details on such covariance adjustments appear in Maddala (1983, 120-21, 366-67). The results presented below are corrected for heteroskedasticity.

It has to be noted that the cost of capital is negative in 6.55% of all 900 observations. Given the complexity of the theoretical expression for the user cost, it is impossible to use comparative statics to point to a parameter in particular as causing the result. It is worth noting that resource firms, while they account for 16% of total observations, claim 24.4%
of the negative cost observations. Given the very generous treatment of the resource sector over the sample period in general, this result is not unexpected.

Negative user costs cause a problem because the double logarithmic specification in (15) cannot accommodate them. Two sensitivity analyses involving solutions to the problem were carried out. In the first one, the user cost is set equal to 0.002, a small but positive number. In the second one, observations with negative user costs are deleted from the sample. Estimation results under each scenario do not exhibit significant qualitative differences, although the effect of the loss of observations is felt in the second scenario. In estimations discussed below, negative user costs are set equal to 0.002 as this is judged to be preferable to the deletion of data points.

Before discussing results, it must be pointed out that the switching model uses probabilities and errors with different distributions. The resulting mixture of Poisson and normal distributions means that the ratios of estimated coefficients to their standard errors (t statistics) are a rough measure of statistical significance. The results from the estimation of the unrestricted switching regression (15) are presented in Table 6. There are industry effects associated with all groups except "Other". The foreign ownership and 1983 dummies are not statistically significant, while recession years 1982 and 1990 are. The effect of year 1983 seems to be incorporated in 1982. The adjustment parameter is close to (but statistically different from) one, which suggests slow adjustment of the capital stock to its optimal long-run value. The coefficient on relative prices has the right sign but is statistically insignificant. In isolation, this finding is in line with a large number of past studies which show small relative price effects. The output effect, however, is negative, very small, and statistically insignificant. Long-run elasticities corresponding to relative prices and output are 0.0489 and -0.0029 respectively. The covariance adjustment in the taxpaying regime is significant. This provides preliminary evidence in favour of the hypothesis that there is endogenous switching between regimes. A more convincing test of the hypothesis requires estimation of the restricted model, where the restriction is that the covariance adjustments are both zero.
Results from the estimation of the restricted model are presented in Table 7. Industry effects disappear, but 1982 and 1990 remain significant. Results concerning the adjustment parameter and relative prices are very similar to those from the unrestricted model. The coefficient on output is now positive but very far from statistical significance. Long-run elasticities corresponding to relative prices and output are 0.0490 and 0.0360 respectively. Although small, these implied long-run elasticities are much more sensible than those from the unrestricted model. A Chi square test is used to test the joint restriction that the coefficients on $-1/P_N$ and $1/P_T$ (covariance adjustments in tax-exhausted and taxpaying states) are zero. The test statistic is the difference between the sums of squared residuals (SSR) in the restricted and unrestricted models. Under the null, the statistic is distributed Chi square with two degrees of freedom (there are two restrictions). The test statistic is 96.447, which far exceeds the critical value of 5.991 with a test size of 0.05. As a check on this test, one may wish to use the asymptotic equivalence between the likelihood ratio test statistic and $rF$ (the number of restrictions times the F statistic, which is distributed Chi square with $r$ degrees of freedom under the null). The asymptotic statistic and the one reported in the text are quite close in all cases.\(^{11}\) So the restriction that both covariance adjustments are zero, or the hypothesis of exogenous switching, is rejected.

Needless to say, the long-run structural parameters recovered from the unrestricted equation are unsatisfactory. Given that tax exhaustion is taken into account here, the insignificant relative price effect may not be surprising at all. Using a different methodology, Cummins, Hassett and Hubbard (1995), "find no evidence that firms with tax loss carryforwards respond to changes in the tax components of the user cost"(141). They reach this conclusion by running OLS regressions of the logarithm of the investment rate on a constant, and the logarithm of the user cost of capital. For three major U.S. tax reform years, their coefficients on the user cost are negative and statistically significant for firms without carryforwards. For firms with carryforwards, coefficients are insignificant but negative in two case out of three. The authors' explanation is that, "This lack of responsiveness makes sense if firms expect to have to wait many years before they can claim any tax benefits"(141). This is compatible with the theory presented in this paper.
If one estimates the same regressions as Cummins et al. (1995) using the full 1977-94 sample, one would expect lower levels of significance since not all years are reform years. Using only taxpaying observations \( nT=766 \) yields a coefficient estimate of -0.0348, a standard error of 0.0194, and a t statistic of -1.7896. The corresponding numbers when only tax-exhausted observations \( nT=134 \) are used are -0.0399, 0.0577, and -0.6912 respectively. As expected, the user cost is relatively close to significance in the taxpaying case, but insignificant in the tax-exhausted case. Given that the price of output in the capital demand equation varies only over time, the averaging that arises by considering taxpaying and tax-exhausted observations together can help explain the insignificant relative prices in the switching regression.

The results concerning output are more baffling. The magnitude of output effects is expected to be more important than that of relative price effects. The results obtained here contradict this, especially in the unrestricted model. Two complementary explanations come to mind. First, the gross capital stock at book values is not an ideal measure of the capital stock since it incorporates accumulated book depreciation. Calculating the replacement value of the capital stock using the perpetual inventory method would not, however, solve the problem; see Appendix B. Therefore, using a yearly measure of change in the capital stock may be better than calculating the change from one year to the other in the stock itself as specified by the partial adjustment model. Second, the results clearly show the important explanatory power of the lagged capital stock. Contemporaneous output is closely correlated to the lagged capital stock or, in other words, the firm's potential output is closely associated to the machinery, equipment and buildings in place. In light of this, it may not be so surprising that output's explanatory power gets washed out.

Given the problem in the measurement of the capital stock, one may circumvent the poor results just described by interpreting (15) differently. At the steady state, \( K_{t+1} = K_t = K^* \), where \( K^* \) denotes the long-run value of the capital stock. Substitute \( K^* \) into the accumulation equation to see that steady state investment is only for replacement purposes since \( I_t = \delta K^* \). In order to replace \( K_t \) and \( K_{t-1} \) in (15) by \( I_t \) and \( I_{t-1} \) respectively, first note that \( K^* = I_t/\delta \). Then, treat the implicit coefficient on \( I_{t-1} \) in the steady state as \( 1/\delta \). Preliminary switching regressions using investment, whose results are not shown, are
encouraging. The most notable improvement is that the coefficient on output is positive and not very far from statistical significance in the unrestricted model. In addition, the coefficient on lagged investment, as opposed to lagged capital stock, falls substantially but remains strongly significant. While the lagged dependent variable retains considerable explanatory power in this specification, the adjustment speed is more plausible. The problem with this equation is that industry dummies seem to do a lot of work in the absence of prior adjustments. This is expected given the inter-industry variation in investment and its cyclical volatility, as opposed to the capital stock itself.

In order to solve the problem just identified, cross-products of industry dummies with other variables are constructed. This approach amounts to creating industry-specific regressors to take advantage of industry effects. There are several possible specifications but the most obvious one is to use cross-products involving the lagged dependent variable (investment). This exploits and distributes the considerable explanatory power of lagged investment across the industries. The results are shown in Tables 8 and 9.

In the unrestricted model, the only industry cross-product that remains significant is the "Other" one. The remaining two and the foreign dummy are insignificant. Year dummies are negative and significant, which is expected given that investment weakens during recessions. Also expected is the relatively high and significant coefficient on lagged investment. Again, note that the coefficient on the lagged dependent variable is lower in this case than with the capital stock. It is straightforward to show that the coefficient on lagged investment is equal to that on the cross-product of lagged investment and the omitted industry of one added it to and equation excluding lagged investment itself. In contrast to the equation using the capital stock, the most notable result is certainly the positive and significant coefficient on relative prices. This appears to lend credibility to the measurement issues concerning the capital stock. The coefficient on output is less impressive but is nevertheless encouraging. It is positive and of the same order of magnitude as the relative price coefficient. As opposed to the capital stock specification, long-run elasticities are way up, with values of 0.2920 and 0.1703 for prices and output respectively. Again, the correlation between contemporaneous output and lagged investment may explain why output does not have a larger coefficient. Relative elasticities become slightly more sensible in the
long-run.

The restricted results reported in Table 9 are qualitatively identical. Quantitatively, they are close although it must be noted that coefficients on lagged investment, relative prices and output all increase while their standard errors fall. Again, the test statistic for a Chi square test of the two zero restrictions is 15.069. This exceeds the critical value of 5.991 with a test size of 0.05. The null hypothesis of exogenous switching is rejected in favour of the alternative of endogenous switching between taxpaying and tax-exhausted regimes. An interesting result here is the following: although the last test rejects the restricted model, long-run elasticities are higher under that model, with values of 0.4379 and 0.2565 for prices and output respectively.

It is natural to wonder whether the rejection of the restricted model is robust to other specifications. Sensitivity analysis not reported here shows that it is indeed the case for equations with cross-products of industry dummies and (i) relative prices, (ii) output, and (iii) relative prices and output. Any specification with cross-products of industry dummies with lagged investment and output appearing together is not sensible given the correlation between the two interacted regressors. The remaining possibility is an equation with cross-products of industry dummies with lagged investment and relative price. In this case only one cannot reject the null that covariance adjustments are both zero. This result must be discounted given that individual t statistics and SSR under the unrestricted model are almost identical to those from the model described in Table 8. In other words, there seems to be a problem with the estimation of the restricted model in this particular case.

To conclude, the evidence presented on the joint significance of coefficients on $-1/P_N$ and $1/P_T$ suggests that there is endogenous switching between tax regimes. Investment behaviour changes depending on whether firms are taxpaying or tax-exhausted. Given the differences in modelling of the cost of capital and data nature and sources, the similitude between the broad result patterns presented here and Anderson's (1995) is striking. The results suggest that tax policy, via the asymmetries built in the tax system, influences investment decisions by firms. This is in sharp contrast to the results of Devereux, Keen and Schiantarelli (1994), and to the conclusions reached by Cummins, Hassett and Hubbard (1995) where they discuss firm tax status. Given that the present sample is not randomly
selected, caution must be exercised in interpreting the results. Nonetheless, the selection procedure clearly understates the extent of tax exhaustion in the population, and hence reasonable confidence may be given to the conclusions reached here.

6.0 SUMMARY AND CONCLUSIONS

This paper develops an expression for the user cost of capital which can accommodate firms that are taxpaying as well as tax-exhausted. The key modification to the usual user cost framework is made by taking into account the fact that the tax-exhausted firm is unable or unwilling to claim various deductions which it is entitled to by purchasing capital goods.

The first stage of the empirical work partly addresses the potential endogeneity of the cost of capital by estimating the firm's probability of a particular tax status on the basis of observable characteristics. Tax-exhaustion is modelled as a Poisson process. The results from a Poisson regression are remarkably consistent with the theoretical model, as well as with known industry and year-specific conditions. This model is an original contribution to the empirical literature on corporate taxation. The probabilities estimated from this analysis serve as inputs in the structural stage of the empirical analysis. In the second stage, a structural endogenous switching model with partial adjustment of the firm's long-run demand for capital is estimated. This framework allows the firm's capital acquisition decisions to vary according to tax status. The results from this estimation procedure, along with various sensitivity analyses, suggest that firms behave differently depending on whether they are taxpaying or not.

Two extensions to the present work immediately come to mind. First, the covariance structure should be refined to take full advantage of the panel structure of the data. This would lend more confidence to the results. Second, in light of the second stage results, the dynamic structure should be made more flexible and richer at the same time. Given the econometric techniques currently available, a retooling of the dynamics is in order. This program constitutes future work.
APPENDIX A: THE VALUATION OF TAX INCENTIVES WITH TAX EXHAUSTION

If the firm were always taxpaying in the sense of being able to use up all its deductions and credits, then the well-known formula for the user cost of capital (ignoring adjustment costs for the moment) which arises from firm optimization would apply. In equilibrium, the return gross of corporate tax on a marginal unit of capital must be equal to:

$$\frac{q(\delta - r)}{1 - u} (1 - A).$$  \hspace{1cm} (A.1)

where \( q \) is the price of capital goods relative to the price of output, \( \delta \) is the economic depreciation rate, \( u \) is the corporate tax rate, \( r \) is the real cost of finance net of corporate taxes, and \( A \) is the present value of combined depreciation allowances and investment tax credit on one dollar of capital.

The analysis considers two classes of models describing the financing decision of the firm: static trade-off models and pecking-order models. They are discussed briefly below. In static trade-off models, the firm is assumed to minimize its cost of finance by choosing its optimal debt/equity ratio prior to making its investment decision. In this class of models, the real cost of finance is given by:

$$r = \beta i (1 - u) + (1 - \beta) \rho - \pi.$$  \hspace{1cm} (A.2)

where \( i \) is the nominal interest rate on debt, \( \rho \) is the nominal opportunity cost (rate of return) of equity, \( \pi \) is the expected rate of inflation, and \( \beta \) is the proportion of investment financed by debt, with \( 0 < \beta < 1 \). This formulation incorporates the deductibility of interest paid on debt. Static trade-off models which are more general than the simple cost minimization model require the assumptions that the firm operates under constant returns to scale so that the debt-asset ratio is independent of the firm's capital stock.
In pecking-order models, firms obtain financing by exhausting the cheapest source of finance first before going to the next and costlier source. The theory thus predicts that a firm seeking finance prefers retained earnings to risky debt, and prefers risky debt to new equity. The marginal cost of funds is constructed by comparing the firm’s investment needs to the sources of funds down the pecking order: retained earnings first, then new debt, and finally new equity. The real cost of funds after corporate taxes under this model is specified as:

\[
 r = \begin{cases} 
 (1-u)R_f - \pi & \text{if } RE \geq I, \\
 (1-u)i - \pi & \text{if } RE < I \leq RE + D, \\
 \rho - \pi & \text{if } I > RE + D.
\end{cases}
\]  
(A.3)

where \( R_f \) is the nominal risk-free rate of return, \( RE \) represents retained earnings, and \( D \) represents new debt. The second and third lines have the familiar interpretation which follows from the fact that interest on debt is tax-deductible but equity costs are not. The marginal cost of the first source is justified by the fact that retained earnings are risk-free once held. The closest alternative to holding them in cash is to purchase treasury bills which yield the firm a nominal after-tax return of \( (1-u)R_f \). Strictly speaking, the cost ordering under the pecking order requires that \( \rho \) be inclusive of the asymmetric information and transaction costs that make new equity more expensive than retained earnings to the firm. This point is discussed in more detail in Section 3.2.

The advantages of the pecking-order approach over the static trade-off come from two sources. Firstly, the pecking-order exploits the knowledge of the marginal source of finance and assigns a single (marginal) cost of funds, rather than an average cost of funds. Secondly, the pecking-order remains an appropriate model of financing if there is reason to believe that the firm does not operate under constant returns to scale or that the debt-asset ratio is not independent of the firm’s capital stock. In any case, personal taxation is ignored by assuming that the marginal investor holds the assets and that stock prices capitalize personal taxes in equilibrium. Alternatively, one can make the small open economy assumption to separate investment from savings decisions. At any rate, Shoven and Topper
(1992) show that ignoring personal taxation affects the cost of capital in a consistent and predictable way.

To complete the discussion of (A.1), the present value of combined tax depreciation allowances and investment tax credit on one dollar of capital is given by:

$$A = \phi + \frac{(1 - \phi) u \alpha}{R + \alpha} (1 + R). \quad (A.4)$$

where $\phi$ is the investment tax credit (ITC) rate, $\alpha$ is the declining-balance tax depreciation (capital cost allowance [CCA]) rate, and finally $R = r + \pi$ is the nominal discount rate of the firm.

The implications of changes in tax status for tax incentives are summarized by Auerbach and Poterba (1987) in their study of loss-offsetting provisions in the United States:

Standard analyses of corporate investment incentives assume that firms claim depreciation allowances and investment tax credits as they accrue. For firms with loss carryforwards, however, accrual and realization occur at different dates. This timing difference can change both the relative tax incentives for investments in plant and equipment, and the overall investment incentive facing the firm (306).

Modifications must therefore be made to the framework outlined above in order to incorporate tax asymmetries. It is most useful to think of the situation in which a firm does not pay corporate taxes (in which case the firm is said to be tax-exhausted) as a tax holiday, albeit a forced one. The key difference between a tax holiday and tax exhaustion is that the duration of the former is exogenous while the latter's is endogenous. This is because tax exhaustion depends on the firm's decisions as well as economic conditions. Mintz (1990, 1995a) develops general expressions for the user cost of capital in the presence of tax holidays which are used as a starting point for what follows.

In Canada, it is not mandatory for firms to claim CCA deductions to which they are entitled. Such deductions can be deferred indefinitely. From the perspective of a dollar of investment made today, the present value of deductions on that dollar is smaller the further in the future it is going to be used. Modelling this necessitates amendments to the basic
formula in (A.4). Ignore risk considerations in what follows and assume that carryforwards never expire. Further suppose that the firm is tax-exhausted at time t with a stock of losses \( S_t \geq 0 \), and that it becomes taxpaying at some future time period \( T^* > t \). Also assume that a tax-exhausted firm does not claim deductions, as they would only serve to increase the stock of losses which will not usable until \( T^* \). Such a firm defers deductions and can only begin to use them when it becomes taxpaying. Such a deferral could cause the firm to be tax-exhausted for quite some time if unused CCA are large relative to revenues that accrue to the firm upon its return to taxpaying status. In order to simplify the analysis, assume that the firm is taxpaying at \( T^* \) so that deductions are used immediately. In this context, the present tax value of CCA and ITC per dollar is given by:

\[
A_t = \frac{\phi}{(1 + R)^{t^* - t}} + (1 - \phi)u \alpha \sum_{s = T^*}^{\infty} \left( \frac{1 - \alpha}{1 + R} \right)^{s - t}.
\]

(A.5)

where the first term on the right-hand side represents the present value of the ITC that would be given immediately were the firm taxpaying, and the second term represents the present tax value of CCA. That term takes into account that the CCA base is fully reduced by the ITC and that the undepreciated value of a dollar of capital falls by \( (1 - \alpha) \) each period. One can show that, upon expansion of the infinite sum and appropriate manipulations, (A.5) can be written as:

\[
A_t = \frac{\phi}{(1 + R)^{T^* - t}} + \frac{(1 - \phi)u \alpha}{(R + \alpha)} \left( \frac{1 - \alpha}{1 + R} \right)^{T^* - t}(1 + R).
\]

(A.6)

the discounted tax value of present and future CCA and ITC on one dollar of capital at time \( t \), given that the firm becomes taxpaying at time \( T^* \). The next step is to calculate the present value of deductions on old capital which are deferred until the firm becomes taxpaying again. Deferral takes place until time \( (T^* - 1) \) inclusive. It is assumed for convenience that deductions are used immediately from time \( T^* \) on. "Old capital" here refers to capital goods purchased while the firm was tax-exhausted so that no ITC nor CCA were claimed at that
time. The present value of deferred deductions per dollar of old capital is given by:

\[ Z_t = \alpha \sum_{s=t}^{T-1} \left( \frac{1 - \alpha}{1 + R} \right)^{s-t} - \frac{\alpha}{(R + \alpha)} \left[ 1 - \left( \frac{1 - \alpha}{1 + R} \right)^{T-t} \right] (1 - R). \] (A.7)
APPENDIX B: DATA SOURCES AND CONSTRUCTION

This Appendix provides details on all data sources, describes the processing and manipulations to which the data were subjected, and then describes the additional steps required to calculate some of the variables used in the analysis. The COMPUSTAT annual database of Canadian companies provides firm-specific accounting and flow of funds data and constitutes the single most important source of raw data for this study.

The selection of firms from COMPUSTAT was subject to the following constraints: (i) have a continuous series for a sufficient number of years; (ii) no missing or bad data points; and (iii) have enough coverage of required variables. Since 1976 is a year in which the quality and coverage of reporting improved dramatically, it was selected as the first year of the data set. The last year with reasonable coverage was 1994 and that was selected as well. Given the very poor postprocessing capabilities attached to COMPUSTAT on the database retrieval system at the University, firm selection from this point on required a visual examination of all the records. First, all the firms that did not have 1976-94 series were deleted from the database. Second, all firms that passed the first stage but did not have enough coverage of the variables were deleted. Finally, the selection process involved an examination of each data point for the remaining firms to detect missing or bad values; all firms with either were deleted.

In the end of this extremely time-consuming process, 50 firms were selected from the COMPUSTAT database. In hindsight, the number of firms could have been substantially higher as the number of variables required initially exceeded what was eventually used in the analysis. The list of 36 series below should confirm this. Numbers in square brackets below indicate COMPUSTAT's annual data item numbers. All series are in millions of current Canadian dollars, except [24] and [25] which are expressed in dollars and cents, and in millions of units, respectively.

The raw series retrieved from COMPUSTAT subject to the constraints discussed above are: accounts payable [70]; assets--total [6]; capital expenditures--flow of funds [128]; common equity--tangible [11]; common equity--total [60]; common shares outstanding [25]; common stock [85]; cost of goods sold [41]; current assets--total [4]; current liabilities--total
[5]; debt--due in one year [44]; deferred taxes and investment tax credit [35]; depreciation and amortization [14]; dividends--common [21]; dividends--preferred [19]; dividends per share--ex date [26]; income taxes--total [16]; income taxes payable [71]; interest expense [15]; inventories--total [3]; investment tax credit [208]; liabilities--total [181]; long-term debt--total [9]; net income (loss) [172]; operating income after depreciation [178]; operating income before depreciation [13]; preferred stock--carrying value [130]; pretax income [170]; price (close) [24]; property, plant and equipment--capital expenditures [30]; property, plant and equipment--total (gross) [7]; property, plant and equipment--total (net) [8]; retained earnings [36]; sales (net) [12]; and working capital [179].

The 50 selected firms were divided in four broad industrial activity groups for the purposes of constructing industry group dummies and other analyses: resource [IND1]--8 firms; manufacturing and processing [IND2]--23 firms; utilities, transportation and communications [IND3]--6 firms; and "other", including construction, services and trades [IND4]--13 firms. Each of the four industry groups includes at least 10% of the firms.

The National Finances, published every year by the Canadian Tax Foundation, provides combined federal-provincial top corporate tax rates (u) for each province and territory, and investment tax credit rates (φ). Separate tax rates are available for manufacturing and processing, and "other", the former being a lower rate. The construction of a coherent series required extra calculations and effort, especially in the early years of the sample. In addition, this source offers details on changes in the tax system (e.g. tax and investment tax credit rates) from year to year. Changes in the tax system which occur outside reforms are incorporated to the extent possible. One-time and phased-in changes caused by the 1987-88 reform of the Canadian corporate tax system are incorporated in the construction of the present data set to the extent that it is possible to do so with a reasonable level of accuracy. In all cases of tax parameter changes, expectations are treated as static when calculating the cost of capital.

In the resource sector, mining taxes and royalties which are above and beyond the corporate income tax are ignored. On the one hand, one could argue that royalties can be ignored in constructing the cost of capital because they are a payment for the use of a public resource. On the other hand, royalties and mining taxes do interact, theoretically speaking,
they would both end up affecting the cost of capital.

The *Historical Reports*, which are published and updated periodically by the Financial Post Datagroup, provide detailed information on the firms’ history. This information was analyzed carefully in order to determine the nature and location of companies’ productive operations, their history with respect to openings and closures, and their ownership status. The main output from this analysis was a breakdown of operations on a province by province basis.

Firms were first matched to their relevant tax rate from *The National Finances* (see above) depending on whether they are engaged into manufacturing and processing activities or not. Then, the rate and location data (provincial dummies) were combined with the relevant top corporate tax rates to calculate firm-specific weighted average federal-provincial corporate tax rates. The federal rate always enters the calculation, while provincial rates enter it if a firm has significant business operations in that province. The Northwest Territories and Yukon are included in those calculations. Accounting for the territories turned out to be important to measure corporate tax rates accurately for resource firms. Within a given year, the tax rates as calculated exploit the inter-provincial variation in corporate tax rates. Note that capital taxes are ignored since available information does not allow for a precise estimate of the contribution of capital taxes to each firm’s cost of capital.

Jung (1989) reports average effective investment tax credit rates, capital stock weights, and economic depreciation rates (اة) for large corporations. Each of the above is disaggregated into 11 identical industry groups and 28 identical asset classes. Jung also reports capital cost allowance (CCA) rates (ؤ) disaggregated into the same 28 asset classes. The capital stock weights and the CCA rates are used to calculate average CCA rates which are weighted by asset class and industry group. This results in 11 weighted average CCA rates, one for each industry group. CCA rates for firms in the sample are determined by matching each firm to its industry group. Jung’s data are appropriate for the pre-reform period which covers 1976 to 1988 inclusive. Chen and Mintz (1995) provide updates to Jung’s numbers for the post-reform period of 1989 to 1994 inclusive, with a couple of industrial sectors combined. Pre and post-reform data remain compatible with Jung’s.
The database of the Canadian Financial Markets Research Center provides daily data on the Toronto Stock Exchange (TSE) 300 price index, and TSE group indices for 14 industrial groups. In addition, it provides the return on 91-day treasury bills over 1 month. First, the stock price data are used to estimate daily stock returns for each industrial group. Second, the calculated returns are converted into annual figures. Third, the data are used to estimate CAPM betas by OLS regression. In order to obtain a complete and variable annual beta series for the full sample, the estimation of the betas is done on the basis of two-year rolling averages. Finally, estimated betas are used to compute annual series for CAPM-based equity returns ($\rho$) by industrial sector. Equity returns are matched to firms in the sample according to their industrial sector.

Statistics Canada's CANSIM database is used to obtain economy-wide interest rates and price indices. The raw series retrieved from CANSIM are: consumer price index [D44957]; implicit price index for business fixed investment [D14486]; Scotia-McLeod average weighted long-term corporate bond yield [B14048]; and treasury bills yield--3 months [B14060]. Numbers in square brackets denote the series' CANSIM label. Interest rate series are expressed in percent and are converted to annual values when required. The base year for price indices is 1986.

Dummies for recession years of 1982, 1983, and 1990 are constructed. Finally, a dummy for foreign ownership is also constructed, although this is definitely not a reliable indicator since it is based upon the last few years of the sample period. Ownership was determined according to the Historical Reports. The problem with this source is that old reports are discarded as updated ones are published. The foreign ownership dummy is included in the analysis for exploratory purposes but can be ignored.

What follows explains the construction of new variables (as required) which have not been described yet. Series identifiers and variable symbols are used when relevant.

- Book value of debt: $[70] + [44] + [9]$.
- Book value of equity: $[85] + [130]$.
- Market value of debt: $[70] + ([15]/([B14048]/100))$.
- Price of capital goods ($p^1$): $[D14486]/100$. 
Price of output (p): \([D44957]/100\).
Real assets: \([6]/p^I\).
Real capital stock: \([7]/p^I\).
Real inventories: \([3]/p\).
Real investment (I): \([30]/p^I\).
Real output (Q): \([12]/p\).
Real profits: \([13]/p\).
Relative price of capital goods (q): \(p^I/p\).

The determination of the marginal financing regime under the pecking-order model is made by comparing \([30]\) to the following: \([36]\), the one-period change in the book value of debt, and the one-period change in the book value of equity net of retained earnings.

The study does not use the replacement cost value of the capital stock as usually calculated using the perpetual inventory method. First, the economic depreciation rate that comes out of the application of the method is not needed. The cost of capital constructed here incorporates economic depreciation rates that vary by industry group and over time (pre and post-reform). Second, the method would call for the deletion of a couple of years of data at the beginning of the sample. This would be highly undesirable given the dynamics embodied in the cost of capital. Third, replacement value will be highly correlated to the book value anyway. In a related vein, preliminary OLS regression analysis (whose results are not presented here) shows that the cost of capital calculated using the static trade-off model of financing with book values of financial assets exhibits a stronger correlation with investment than any other version of the cost of capital. The other versions are static trade-off with market values, pecking-order with book values, and pecking-order with market values). Bartholdy, Fisher and Mintz (1989) also find that book values outperform market values in their empirical work. The better performance of the static trade-off model \textit{per se} appears to come from the variation over time and across firms in debt-asset ratios which are used to construct the weighted average cost of finance. This variation outweighs the variation obtained by computing the marginal cost of finance under the pecking-order model.
NOTES

1. See Appendix A for those expressions.

2. See Mintz (1995b) for a discussion of the tax loss model and other static trade-off models which yield interior debt ratios.

3. This expression incorporates well-known special cases: Cobb-Douglas ($\sigma = 1$), constant returns to scale ($\nu = 1$), and the flexible accelerator ($\sigma = 0$). For further details, see Jorgenson (1972). Also, see Chirinko (1993) for a discussion of models with implicit dynamics.

4. This and all subsequent tables appear at the end of the paper.

5. Under the pecking order’s hierarchy, one would observe one of the following three cases for each observation: (i) 100% financing through retained earnings; (ii) financing through a combination of retained earnings and debt; or (iii) financing through a combination of retained earnings, debt and new equity. Refer to (A.3) again.

6. There will be no further discussion of the pecking-order model from this point on. In preliminary empirical work, the static trade-off model yielded better results (more variability in the cost of capital) than the pecking-order model. Hence, (5) is calculated using (A.2) in the empirical analysis of Section 5.0.

7. Unless the researchers have access to corporation-specific tax return data, as in Altshuler and Auerbach (1990).

8. One may take issue with this interpretation by providing a story. An example would be that discretionary CCA may be largest for firms with permitted CCA for fast write-offs. In other words, firms with lower CCA rates would be more likely to claim losses and therefore be tax-exhausted.

9. See Maddala (1983) and the references cited therein for a discussion and other economic applications of the switching regression.

10. See the Appendix on truncated distributions in Maddala (1983).


12. The seminal contributions are Jorgenson (1963, 1967), and Hall and Jorgenson (1967). For detailed explanations and modern derivations of the user cost of capital, see Boadway, Bruce and Mintz (1987), and McKenzie and Mintz (1992).

13. The presentation follows Mintz (1995b). The reader should refer to that paper for more details on the economic content and interpretation of those models.
REFERENCES


### Table 1

**Descriptive Statistics of 1977-94 Sample (Millions of 1986 Dollars)**

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Median</th>
<th>Std. Dev.</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assets</td>
<td>1806.266</td>
<td>578.772</td>
<td>2707.349</td>
<td>20.592</td>
<td>16952.739</td>
</tr>
<tr>
<td>I/K</td>
<td>0.106</td>
<td>0.089</td>
<td>0.077</td>
<td>0.002</td>
<td>0.590</td>
</tr>
<tr>
<td>Output</td>
<td>1715.820</td>
<td>618.605</td>
<td>2335.815</td>
<td>16.925</td>
<td>10749.574</td>
</tr>
<tr>
<td>Profits</td>
<td>217.026</td>
<td>77.479</td>
<td>327.436</td>
<td>-155.103</td>
<td>2099.688</td>
</tr>
</tbody>
</table>
Table 2

Poisson Regression Results: Full Sample, 1977-94

Dependent Variable: $Y = T^*-t$

<table>
<thead>
<tr>
<th>Explanatory Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>Asy. t stat.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource Dummy</td>
<td>0.2196</td>
<td>0.4100</td>
<td>0.5356</td>
</tr>
<tr>
<td>M&amp;P Dummy</td>
<td>-0.1130</td>
<td>0.4150</td>
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</tr>
<tr>
<td>UT&amp;C Dummy</td>
<td>-3.0173</td>
<td>0.8298</td>
<td>-3.6360</td>
</tr>
<tr>
<td>&quot;Other&quot; Dummy</td>
<td>-0.8309</td>
<td>0.4236</td>
<td>-1.9617</td>
</tr>
<tr>
<td>Foreign Dummy</td>
<td>-0.8861</td>
<td>0.2492</td>
<td>-3.5557</td>
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<tr>
<td>1982 Dummy</td>
<td>0.7553</td>
<td>0.2096</td>
<td>3.6040</td>
</tr>
<tr>
<td>1983 Dummy</td>
<td>0.7572</td>
<td>0.2373</td>
<td>3.1911</td>
</tr>
<tr>
<td>1990 Dummy</td>
<td>0.6271</td>
<td>0.2198</td>
<td>2.8525</td>
</tr>
<tr>
<td>Lagged Real Inventories</td>
<td>1.9326</td>
<td>0.7252</td>
<td>2.6648</td>
</tr>
<tr>
<td>Lagged Real Investment</td>
<td>1.8036</td>
<td>1.1959</td>
<td>1.5082</td>
</tr>
<tr>
<td>Real Output</td>
<td>-0.5506</td>
<td>0.1520</td>
<td>-3.6232</td>
</tr>
<tr>
<td>Real Profits</td>
<td>-13.6505</td>
<td>0.9706</td>
<td>-14.0648</td>
</tr>
<tr>
<td>Deferred Taxes and ITC</td>
<td>4.2517</td>
<td>1.4883</td>
<td>2.8567</td>
</tr>
<tr>
<td>CCA Rate</td>
<td>-4.7603</td>
<td>0.9589</td>
<td>-4.9641</td>
</tr>
<tr>
<td>Prop. of Debt Financing</td>
<td>1.9552</td>
<td>0.4739</td>
<td>4.1259</td>
</tr>
</tbody>
</table>

Observations: 900; log likelihood = -1833.62.
Table 3

Poisson Regression Results: 1977-87 Subsample

Dependent Variable: $Y = T^* - t$

<table>
<thead>
<tr>
<th>Explanatory Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>Asy. t stat.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource Dummy</td>
<td>-0.3187</td>
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<td>-0.3145</td>
</tr>
<tr>
<td>M&amp;P Dummy</td>
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<td>-0.7683</td>
</tr>
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<td>UT&amp;C Dummy</td>
<td>-6.5513</td>
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<td>&quot;Other&quot; Dummy</td>
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<tr>
<td>Foreign Dummy</td>
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<td>-1.1466</td>
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<tr>
<td>Lagged Real Inventories</td>
<td>1.7098</td>
<td>1.2020</td>
<td>1.4224</td>
</tr>
<tr>
<td>Lagged Real Investment</td>
<td>-0.3032</td>
<td>1.6758</td>
<td>-0.1809</td>
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<tr>
<td>Real Output</td>
<td>-0.3918</td>
<td>0.2108</td>
<td>-1.8581</td>
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<tr>
<td>Real Profits</td>
<td>-20.4558</td>
<td>1.8507</td>
<td>-11.0531</td>
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<tr>
<td>Deferred Taxes and ITC</td>
<td>6.1559</td>
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<td>2.7445</td>
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<tr>
<td>CCA Rate</td>
<td>-2.1512</td>
<td>1.9385</td>
<td>-1.1097</td>
</tr>
<tr>
<td>Prop. of Debt Financing</td>
<td>3.1968</td>
<td>0.9468</td>
<td>3.3765</td>
</tr>
</tbody>
</table>

Observations: 550; log likelihood = -1013.93.
Table 4

Poisson Regression Results: 1988-94 Subsample

Dependent Variable: $Y = T^*-t$

<table>
<thead>
<tr>
<th>Explanatory Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>Asy. t stat.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource Dummy</td>
<td>-2.4481</td>
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<td>M&amp;P Dummy</td>
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<tr>
<td>UT&amp;C Dummy</td>
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<tr>
<td>&quot;Other&quot; Dummy</td>
<td>-1.8390</td>
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<td>-2.5421</td>
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<td>Foreign Dummy</td>
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<td>Lagged Real Investment</td>
<td>4.2739</td>
<td>1.9217</td>
<td>2.2240</td>
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<tr>
<td>Real Output</td>
<td>-0.3737</td>
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<td>Real Profits</td>
<td>-14.7605</td>
<td>1.3842</td>
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<tr>
<td>Deferred Taxes and ITC</td>
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<tr>
<td>CCA Rate</td>
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<tr>
<td>Prop. of Debt Financing</td>
<td>0.9923</td>
<td>0.5964</td>
<td>1.6640</td>
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</table>

Table 5

Poisson Regression Results: Independent Subsample, 1977-94

Dependent Variable: $Y = T^{-t}$

<table>
<thead>
<tr>
<th>Explanatory Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>Asy. t stat.</th>
</tr>
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<tbody>
<tr>
<td>Resource Dummy</td>
<td>-0.7571</td>
<td>0.5392</td>
<td>-1.4040</td>
</tr>
<tr>
<td>M&amp;P Dummy</td>
<td>-0.7291</td>
<td>0.5560</td>
<td>-1.3115</td>
</tr>
<tr>
<td>UT&amp;C Dummy</td>
<td>-3.4096</td>
<td>0.9223</td>
<td>-3.6968</td>
</tr>
<tr>
<td>&quot;Other&quot; Dummy</td>
<td>-1.7080</td>
<td>0.5830</td>
<td>-2.9299</td>
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<tr>
<td>Foreign Dummy</td>
<td>-0.7615</td>
<td>0.3160</td>
<td>-2.4098</td>
</tr>
<tr>
<td>1982 Dummy</td>
<td>1.0626</td>
<td>0.2457</td>
<td>4.3249</td>
</tr>
<tr>
<td>1983 Dummy</td>
<td>0.1602</td>
<td>0.4715</td>
<td>0.3397</td>
</tr>
<tr>
<td>1990 Dummy</td>
<td>0.7678</td>
<td>0.2714</td>
<td>2.8291</td>
</tr>
<tr>
<td>Lagged Real Inventories</td>
<td>2.6494</td>
<td>0.9254</td>
<td>2.8631</td>
</tr>
<tr>
<td>Lagged Real Investment</td>
<td>3.4582</td>
<td>1.4212</td>
<td>2.4333</td>
</tr>
<tr>
<td>Real Output</td>
<td>-0.4932</td>
<td>0.1816</td>
<td>-2.7153</td>
</tr>
<tr>
<td>Real Profits</td>
<td>-14.4942</td>
<td>1.2417</td>
<td>-11.6727</td>
</tr>
<tr>
<td>Deferred Taxes and ITC</td>
<td>5.9295</td>
<td>1.8812</td>
<td>3.1520</td>
</tr>
<tr>
<td>CCA Rate</td>
<td>-5.3388</td>
<td>1.2290</td>
<td>-4.3440</td>
</tr>
<tr>
<td>Prop. of Debt Financing</td>
<td>2.0199</td>
<td>0.6379</td>
<td>3.1667</td>
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</table>

Observations: 838; log likelihood = -1556.10.
Table 6

Switching Regression Results: Full Sample, 1977-94, Unrestricted

Dependent Variable: ln K

<table>
<thead>
<tr>
<th>Explanatory Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>Asy. t stat.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource Dummy</td>
<td>0.0508</td>
<td>0.0161</td>
<td>3.1551</td>
</tr>
<tr>
<td>M&amp;P Dummy</td>
<td>0.0384</td>
<td>0.0136</td>
<td>2.8305</td>
</tr>
<tr>
<td>UT&amp;C Dummy</td>
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<td>0.0163</td>
<td>3.8817</td>
</tr>
<tr>
<td>&quot;Other&quot; Dummy</td>
<td>0.0191</td>
<td>0.0147</td>
<td>1.3059</td>
</tr>
<tr>
<td>Foreign Dummy</td>
<td>0.0102</td>
<td>0.0099</td>
<td>1.0357</td>
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<td>1982 Dummy</td>
<td>0.0551</td>
<td>0.0151</td>
<td>3.6411</td>
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<td>1983 Dummy</td>
<td>0.0005</td>
<td>0.0155</td>
<td>0.0305</td>
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<td>1990 Dummy</td>
<td>0.0473</td>
<td>0.0163</td>
<td>2.9062</td>
</tr>
<tr>
<td>Ln Lagged Capital Stock</td>
<td>0.9652</td>
<td>0.0084</td>
<td>115.1010</td>
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<tr>
<td>Ln Relative Prices</td>
<td>0.0017</td>
<td>0.0019</td>
<td>0.8802</td>
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<td></td>
<td>[0.0489]</td>
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<tr>
<td>Ln Output</td>
<td>-0.0001</td>
<td>0.0062</td>
<td>-0.0090</td>
</tr>
<tr>
<td></td>
<td>[-0.0029]</td>
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</tr>
<tr>
<td>-1/Prob(tax exhaustion)</td>
<td>-0.0001</td>
<td>0.0009</td>
<td>-0.1305</td>
</tr>
<tr>
<td>1/Prob(taxpaying)</td>
<td>-0.0416</td>
<td>0.0077</td>
<td>-5.3952</td>
</tr>
</tbody>
</table>

Observations: 900; SEE = 0.9426; SSR = 799.719. Numbers in square brackets are long-run elasticities.
Switching Regression Results: Full Sample, 1977-94, Restricted

Dependent Variable: ln K

<table>
<thead>
<tr>
<th>Explanatory Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>Asy. t stat.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource Dummy</td>
<td>0.0148</td>
<td>0.0142</td>
<td>1.0448</td>
</tr>
<tr>
<td>M&amp;P Dummy</td>
<td>-0.0023</td>
<td>0.0111</td>
<td>-0.2025</td>
</tr>
<tr>
<td>UT&amp;C Dummy</td>
<td>0.0209</td>
<td>0.0134</td>
<td>1.5631</td>
</tr>
<tr>
<td>&quot;Other&quot; Dummy</td>
<td>-0.0196</td>
<td>0.0126</td>
<td>-1.5556</td>
</tr>
<tr>
<td>Foreign Dummy</td>
<td>0.0112</td>
<td>0.0095</td>
<td>1.1715</td>
</tr>
<tr>
<td>1982 Dummy</td>
<td>0.0587</td>
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<td>3.8796</td>
</tr>
<tr>
<td>1983 Dummy</td>
<td>0.0059</td>
<td>0.0152</td>
<td>0.3885</td>
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<tr>
<td>1990 Dummy</td>
<td>0.0414</td>
<td>0.0159</td>
<td>2.6127</td>
</tr>
<tr>
<td>Ln Lagged Capital Stock</td>
<td>0.9694</td>
<td>0.0080</td>
<td>120.6950</td>
</tr>
<tr>
<td>Ln Relative Prices</td>
<td>0.0015</td>
<td>0.0018</td>
<td>0.8031</td>
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<td></td>
<td>[0.0490]</td>
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<td>Ln Output</td>
<td>0.0011</td>
<td>0.0059</td>
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</table>

Observations: 900; SEE = 0.9980; SSR = 896.337. Numbers in square brackets are long-run elasticities.
Table 8

Switching Regression Results: Full Sample, 1977-94, Unrestricted

Dependent Variable: ln I

<table>
<thead>
<tr>
<th>Explanatory Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>Asy. t stat.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ln(I,1)*Resource Dummy</td>
<td>-0.0477</td>
<td>0.0265</td>
<td>-1.8025</td>
</tr>
<tr>
<td>Ln(I,1)*UT&amp;C Dummy</td>
<td>-0.0574</td>
<td>0.0303</td>
<td>-1.8961</td>
</tr>
<tr>
<td>Ln(I,1)*Other Dummy</td>
<td>0.0463</td>
<td>0.0179</td>
<td>2.5876</td>
</tr>
<tr>
<td>Foreign Dummy</td>
<td>-0.0240</td>
<td>0.0556</td>
<td>-0.4320</td>
</tr>
<tr>
<td>1982 Dummy</td>
<td>-0.4178</td>
<td>0.0927</td>
<td>-4.5098</td>
</tr>
<tr>
<td>1983 Dummy</td>
<td>-0.3029</td>
<td>0.0925</td>
<td>-3.2763</td>
</tr>
<tr>
<td>1990 Dummy</td>
<td>-0.3368</td>
<td>0.0943</td>
<td>-3.5729</td>
</tr>
<tr>
<td>Ln Lagged Investment (I,1)</td>
<td>0.8397</td>
<td>0.0208</td>
<td>40.4121</td>
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<tr>
<td>Ln Relative Prices</td>
<td>0.0468</td>
<td>0.0096</td>
<td>4.8599</td>
</tr>
<tr>
<td>[0.2920]</td>
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<tr>
<td>Ln Output</td>
<td>0.0273</td>
<td>0.0335</td>
<td>0.8139</td>
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<tr>
<td>[0.1703]</td>
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</tr>
<tr>
<td>-1/Prob(tax exhaustion)</td>
<td>0.0151</td>
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<td>2.4700</td>
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<tr>
<td>1/Prob(taxpaying)</td>
<td>-0.1379</td>
<td>0.0446</td>
<td>-3.0903</td>
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</table>

Observations: 900; SEE = 0.9884; SSR = 879.320.
Numbers in square brackets are long-run elasticities.
### Table 9

Switching Regression Results: Full Sample, 1977-94, Restricted

Dependent Variable: $\ln I$

<table>
<thead>
<tr>
<th>Explanatory Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>Asy. t stat.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\ln(I_{-1}) \times \text{Resource Dummy}$</td>
<td>-0.0492</td>
<td>0.0264</td>
<td>-1.8624</td>
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<tr>
<td>$\ln(I_{-1}) \times \text{UT&amp;C Dummy}$</td>
<td>-0.0441</td>
<td>0.0300</td>
<td>-1.4690</td>
</tr>
<tr>
<td>$\ln(I_{-1}) \times \text{Other Dummy}$</td>
<td>0.0447</td>
<td>0.0179</td>
<td>2.5004</td>
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<tr>
<td>Foreign Dummy</td>
<td>-0.0361</td>
<td>0.0555</td>
<td>-0.6503</td>
</tr>
<tr>
<td>1982 Dummy</td>
<td>-0.4425</td>
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<td>1983 Dummy</td>
<td>-0.2943</td>
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<td>-3.2019</td>
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<tr>
<td>1990 Dummy</td>
<td>-0.3990</td>
<td>0.0918</td>
<td>-4.3486</td>
</tr>
<tr>
<td>$\ln \text{Lagged Investment (I}_{-1})$</td>
<td>0.8737</td>
<td>0.0180</td>
<td>48.6590</td>
</tr>
<tr>
<td>$\ln \text{Relative Prices}$</td>
<td>0.0553</td>
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</tr>
<tr>
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</tr>
<tr>
<td>$\ln \text{Output}$</td>
<td>0.0324</td>
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Observations: 900; SEE = 0.9969; SSR = 894.389.
Numbers in square brackets are long-run elasticities.