Department of Economics
and
Institute for Policy Analysis
University of Toronto
150 St. George Street
Toronto, Ontario M5S 3G7
Canada

WORKING PAPER
NUMBER UT-ECIPA-ECPAP-96-04

CORPORATION TAX ASYMMETRIES: AN OLIGOPOLISTIC SUPERGAME ANALYSIS

by

Pierre-Pascal Gendron

June 24, 1996

Latest Version: July 8, 1996

ISSN 0829-4909

On-line Version: http://www.chass.utoronto.ca:8080/ecipa/wpa.html
Author's e-mail: pgendron@chass.utoronto.ca

Corporation Tax Asymmetries:

An Oligopolistic Supergame Analysis*

Pierre-Pascal Gendron

June 24, 1996

Abstract

Corporation tax systems around the world treat gains and losses asymmetrically. This paper examines the impact of changing the refundability of tax losses in a cash flow tax system. A dynamic game of complete information is used to analyse refund policies in an imperfectly competitive setting. In this supergame, firms produce a homogeneous good and sustain tacit collusion by using credible and severe punishments of deviations. The analysis of the most collusive equilibrium with losses indicates that a tax policy which increases refundability has the following impacts: it reduces collusive industry output, increases market price, and therefore enhances tacit collusion. This policy also reduces social welfare even though refunds are never given in equilibrium.

JEL classification: C72 and H25.

---

* I am grateful to Jack Mintz, Michael Peters, and Michael Smart for useful discussions and suggestions. Their invaluable comments on the previous drafts of this paper are greatly appreciated. My thanks also go to Frank Mathewson for suggesting examples. The usual disclaimer applies. Mailing address is Department of Economics, University of Toronto, 150 St. George Street, Toronto, Ontario, Canada M5S 3G7; e-mail address is pgendron@chass.utoronto.ca

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 theoretical studies such as Edwards and Keen (1985) and Auerbach (1986), and in empirical work such as that of Auerbach and Poterba (1987), Mintz (1988) and Altshuler and Auerbach (1990). This empirical work also underscores the economic significance of tax losses. The appropriate modelling strategy to study the impact of tax losses and their non-refundability must be dynamic in nature.

A common feature of tax systems around the world is the non-refundability of tax losses. Those systems, however, generally allow tax losses to be carried back against taxes paid in the past or carried forward to reduce future tax liabilities. For example, corporate tax systems in Canada, the U.K. and the U.S. allow firms to carry back losses for a limited number of years, thereby claiming a refund of past taxes paid. They also allow firms to carry such losses forward at no interest but for longer periods. The corporate tax system in Canada includes limited instances of refundability such as carrybacks, the refundable scientific research and development tax credit, and the refundable small business tax credit.

Those measures constitute an attempt to move towards a neutral tax system. Mintz (1991) points out that tax losses and their lack of refundability 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.

The present paper explores a different justification for the non- refundability of tax losses. The framework is one in which oligopolistic firms interact repeatedly and collusive behaviour may be supported by non-cooperative equilibria. In contrast to the traditional supergame literature, this model allows for punishments that are more severe than the Cournot-Nash reversion in order to support tacit collusion. The Cournot-Nash reversion is a punishment mechanism which specifies that all industry members revert to Cournot competition once any individual firm deviates from its collusive output share. The most collusive equilibrium 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.[1]

In this paper, 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 can be made in a very simple way 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 such punishments are a generalization of punishments based on Cournot reversions as in Friedman (1971). 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 basic model. Section 3.0 presents a description of the tax treatment of losses and characterizes the outcome paths and equilibria with a cash flow tax. Section 4.0 analyses the effects of changes in refundability on profits, output and welfare. Finally, Section 5.0 concludes the paper by a summary and a discussion of interesting extensions to the present work.

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.[2]

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 $\pi^d(x) = \max_y P(y + (n-1)x)y - C(y)$ 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. What follows summarizes the assumptions needed to proceed.

Assumption 1. The functions $\pi(x)$ and $\pi^d(x)$ satisfy:

(a) $\pi(x)$ is strictly concave;

(b) $\pi^d(x)$ is nonnegative, continuous, convex, nonincreasing, and satisfies $\pi^d(0) > 0$;

(c) there exists a unique x^n such that $\pi(x^n) = \pi^d(x^n)$.

Denote the action set of firm i by $S_i = [0,x^s(\delta)]$, where $\delta \in (0,1)$ is the discount factor common to all firms. Let $\delta \equiv 1/(1+r)$ where r is the firms' fixed one-period discount rate. Output $x^s(\delta)$ satisfies $-\pi(x^s(\delta),0,...,0) > \delta/(1-\delta)\sup_x \pi(x,0,...,0)$. The above inequality says that it is never in a firm's interest to produce output beyond $x^s(\delta)$. If a 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, $\mathrm{argmax}\{\pi(x) | x \in S_i\}$ is a singleton whose unique element is x^m.

Let $G = (S_i,\pi;i=1,...,n)$ denote the one-shot Cournot game. Assumption 1 implies that G has a unique symmetric pure-strategy Nash equilibrium. Let $x^L \in S_i$ be the output per firm such that $\pi(x^L) = 0$. The supergame with discounting is obtained by repeating G infinitely often and evaluating profits using the discount factor δ. 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 or do not necessarily expect collusive interaction to last forever, the presence of incentive constraints rules 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) $x^s > x^L > x^n > x^m$;

(b) $\pi(x^m) > \pi(x^n) > 0 > \pi(x^s)$;

(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.

I further characterize the supergame environment as follows. A tacitly collusive agreement is one in which individual firms jointly maximize profits by restricting industry output.[3] Each individual firm within the cartel can, however, increase its one-period profits by producing a higher output 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 $x \in (x^m, x^n)$.

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, I will assume that the punishment is symmetric in the sense of Abreu (1986).[4] 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) 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 :

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

$$\pi^d(x^p) + \delta\pi(x^p) \leq \pi(x^p) + \delta\pi(x). \qquad (2)$$

Proof. See Abreu (1986).

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 to 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.[5]

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 does 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. Under Assumption 1, there exists a δ 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^r 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 $x^m < x^r < x^n$. 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^r, and is upward-sloping when collusive output is near x^n.

Proof. Let $x \in [x^m,x^r]$. I shall show that there exists an x^p such that $x^p > x^n$ and (x,x^p) is on NDL. Point (x^r,x^n) is on NDL by definition, and so is point (x^n,x^n). Thus, the following two equations hold:

$$\pi^d(x^r) - \pi(x^r) = \delta[\pi(x^r) - \pi(x^n)]. \tag{3}$$

$$\pi^d(x^n) - \pi(x^n) = \delta[\pi(x^n) - \pi(x^n)]. \tag{4}$$

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

$$-\int_{x^r}^{x^n}[\pi^{d/}(x) - \pi^{/}(x)]\,dx \;=\; -\delta\int_{x^r}^{x^n}\pi^{/}(x)\,dx. \qquad (5)$$

Now, take any $x < x^r$. The change in the left-hand side of NDL that takes place when output is reduced from x^n to x is given by:

$$-\int_{x^r}^{x^n}[\pi^{d/}(x) - \pi^{/}(x)]\,dx \;-\; \int_{x}^{x^r}[\pi^{d/}(x) - \pi^{/}(x)]\,dx. \qquad (6)$$

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

$$-\delta\int_{x^r}^{x^n}\pi^{/}(x)\,dx \;-\delta\int_{x}^{x^r}\pi^{/}(x)\,dx. \qquad (7)$$

By Assumption 1, the function $[\pi^d(x)-\pi(x)]$ is convex while $\pi(x)$ 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 such that $x^m < x < x^n$ and write PAL as $\pi^d(x^p) - (1-\delta)\pi(x^p) = \delta\pi(x)$. When $x^p = x^n$, 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 $\pi^d(x^p)$. Thus, by the mean-value theorem, there exists an 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^m, 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^f. 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^n, 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 $y^p > x^p$ because of 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 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. In order to keep the corporation tax system simple, I ignore the issues of investment and financial policy. Losses arise in the model due to severe punishments of deviations. I therefore ignore losses caused by tax incentives such as generous investment tax credits and capital cost allowances.[6] Taxation is initially asymmetric since gains are not treated in the same way as losses. Positive profits are taxed at a constant rate τ 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.

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 π_t in period t simply receives a lump-sum refund of $\rho\tau\pi_t$ in period t + 1. Let factor ρ 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 that $\delta \equiv 1/(1+r)$. Now assume that the government pays interest on carryforwards. Then, ρ 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 (i.e. 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.[7] I assume in what follows that ρ is included in the interval [1,1+r].

Apart from my treatment of investment, the present exposition closely follows Auerbach (1986). He finds that asymmetries in the cash flow tax have complicated impacts on firm behaviour. While there are 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.[8]

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 to period t where $L_t \geq 0$ for all t. For a firm which is not taxable at the margin, current after-tax profits are π_t and the accumulated 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 $\pi(\bullet)$ is the pre-tax profit function satisfying Assumption 1, then the after-tax profit function is:

$$\boldsymbol{\pi}(\bullet) = \begin{cases} (1-\tau)\,\pi(\bullet) \;\; if \;\; \pi(\bullet) \geq 0, \\ (1-\delta\rho\tau)\,\pi(\bullet) \;\; if \;\; \pi(\bullet) < 0. \end{cases} \tag{8}$$

Let after-tax best-response profit function simply be $\boldsymbol{\pi}^d(\bullet) = (1-\tau)\pi^d(\bullet)$ since $\pi^d(\bullet) \geq 0$ for outputs in S_i.

Two comments are in order. Firstly, it is straightforward to show that the after-tax profit functions $\boldsymbol{\pi}(\bullet)$ and $\boldsymbol{\pi}^d(\bullet)$ 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 $\boldsymbol{\pi}(\bullet)$ and $\boldsymbol{\pi}^d(\bullet)$ 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:

$$\boldsymbol{\pi}^d(x) \; + \; \delta\,\boldsymbol{\pi}(x^p) \; \leq \; (1+\delta)\,\boldsymbol{\pi}(x). \tag{9}$$

$$\boldsymbol{\pi}^d(x^p) \; + \; \delta\,\boldsymbol{\pi}(x^p) \; \leq \; \boldsymbol{\pi}(x^p) + \delta\,\boldsymbol{\pi}(x). \tag{10}$$

4.0 EFFECTS OF CHANGING REFUNDABILITY

In this Section, I examine the impact of changes to the extent of refundability on the most collusive equilibrium. Following Proposition 5 and the fact that the equivalent of 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. Recall that parameter ρ is an increasing index of refundability.

The direct approach, which consists in solving for comparative static impacts of changing ρ on x and x^p, is not informative.[9] The difficulty is that the change in ρ shifts both NDL and PAL in the same direction in output space. This makes it impossible to determine what happens to collusive output.

One approach to resolve this ambiguity 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 $b(\hat{\pi}) = \{\pi^d(\bullet) : \pi(\bullet) = \hat{\pi}\}$. 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 equivalent 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:

$$b(\boldsymbol{\pi}^c) + \delta\,\boldsymbol{\pi}^p \leq (1+\delta)\,\boldsymbol{\pi}^c. \tag{11}$$

$$b(\boldsymbol{\pi}^p,\rho) + \delta\,\boldsymbol{\pi}^p \leq \boldsymbol{\pi}^p + \delta\,\boldsymbol{\pi}^c. \tag{12}$$

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 ρ might affect this calculation. Firstly, the deviation profit might be negative so that changing ρ will change after-tax profits directly. To keep the analysis simple, I assume that fixed costs are zero. In that case, deviation profits cannot be negative since the firm can always produce nothing during that period. Hence, ρ cannot have any direct effect on deviation profits. Secondly, there is a more complicated possibility that ρ might affect deviation profits indirectly by changing the level of output that supports profits per firm of $\hat{\pi}$. In that case, changing ρ 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 ρ has no effect on b($\hat{\pi}^c$). In a punishment phase with losses, however, changing ρ will reduce losses associated with any level of output. Hence, 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. In short, b($\hat{\pi}^p$,ρ) is a nonincreasing function of ρ. The foregoing analysis is illustrated in Figure 3. The equilibrium output pair prior to the change in ρ is (x_1,x_1^p).

When ρ is increased from ρ_1 to ρ_2, after-tax profits in the punishment phase rise for any level of output. The punishment output necessary to support $\hat{\pi}^p$ must then increase from x_1^p to x_2^p. Deviation profits are such that $b(\hat{\pi}^p,\rho_2) < b(\hat{\pi}^p,\rho_1)$.

The main result of this Section is summarized in what follows.

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 ρ 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:

$$b(\boldsymbol{\pi}^c) \; + \; \delta\,\boldsymbol{\pi}^p \; = \; (1+\delta)\,\boldsymbol{\pi}^c. \tag{13}$$

$$b(\boldsymbol{\pi}^p,\rho) \; + \; \delta\,\boldsymbol{\pi}^p \; = \; \boldsymbol{\pi}^p \; + \; \delta\,\boldsymbol{\pi}^c. \tag{14}$$

The first term on the left-hand side of (14) is the only one that is affected by a change in ρ. For any given punishment output, increasing ρ 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 $b(\hat{\pi}^p,\rho)$ 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 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.

I shall show that NDL cuts PAL from above in after-tax profit space. Pick a point $(\hat{\tilde{\pi}}^c,\hat{\tilde{\pi}}^p)$ on NDL near the most collusive equilibrium $(\hat{\tilde{\pi}}_1^c,\hat{\tilde{\pi}}_1^p)$ satisfying $\hat{\tilde{\pi}}^c < \hat{\tilde{\pi}}_1^c$ as well as $\hat{\tilde{\pi}}^p > \hat{\tilde{\pi}}_1^p$. 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 satisfied by raising collusive output.

In after-tax profit space, holding x^p constant amounts to holding $\hat{\tilde{\pi}}^p$ constant. Increasing collusive output amounts to reducing $\hat{\tilde{\pi}}^c$. Thus, PAL lies to the left of the above point $(\hat{\tilde{\pi}}^c,\hat{\tilde{\pi}}^p)$ 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 $(\hat{\tilde{\pi}}_1^c,\hat{\tilde{\pi}}_1^p)$. At that point, NDL and PAL intersect. Increasing refundability rotates the segment of PAL in the loss region; the rotation takes place on the horizontal axis and in a southwesterly direction. The new segment is labelled PAL′. Since NDL does not move, the new most collusive equilibrium is determined by the position of PAL′ and is thus given by the pair $(\hat{\tilde{\pi}}_2^c,\hat{\tilde{\pi}}_2^p)$. This point is characterized by lower (more negative) punishment profits and higher collusive profits. For ease of comparison with Figure 2, $\hat{\tilde{\pi}}^n$ denote after-tax Cournot profits.

Proposition 6 goes against the intuition according to which increasing refundability makes the punishment easier to bear. In conclusion, the policy serves to enhance 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, and therefore that both incentive constraints (11) and (12) hold with equality at that point. In that case, 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.

For the purposes of welfare analysis, it follows immediately that collusive output is the only measure of production that matters. By reducing that output, the refundability policy 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.[11] 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 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 finds 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 also reduces welfare.

This new framework to analyse taxes could be made 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. The welfare conclusions in the uncertainty case appear to be much less clear-cut since the behaviour of output in actual punishment phases must be taken into account in that case. The appropriate framework for this analysis would be inspired by the work of Abreu et al. (1986 and 1990).

Figure 1

Pre-Tax and Best-Response Profit Functions

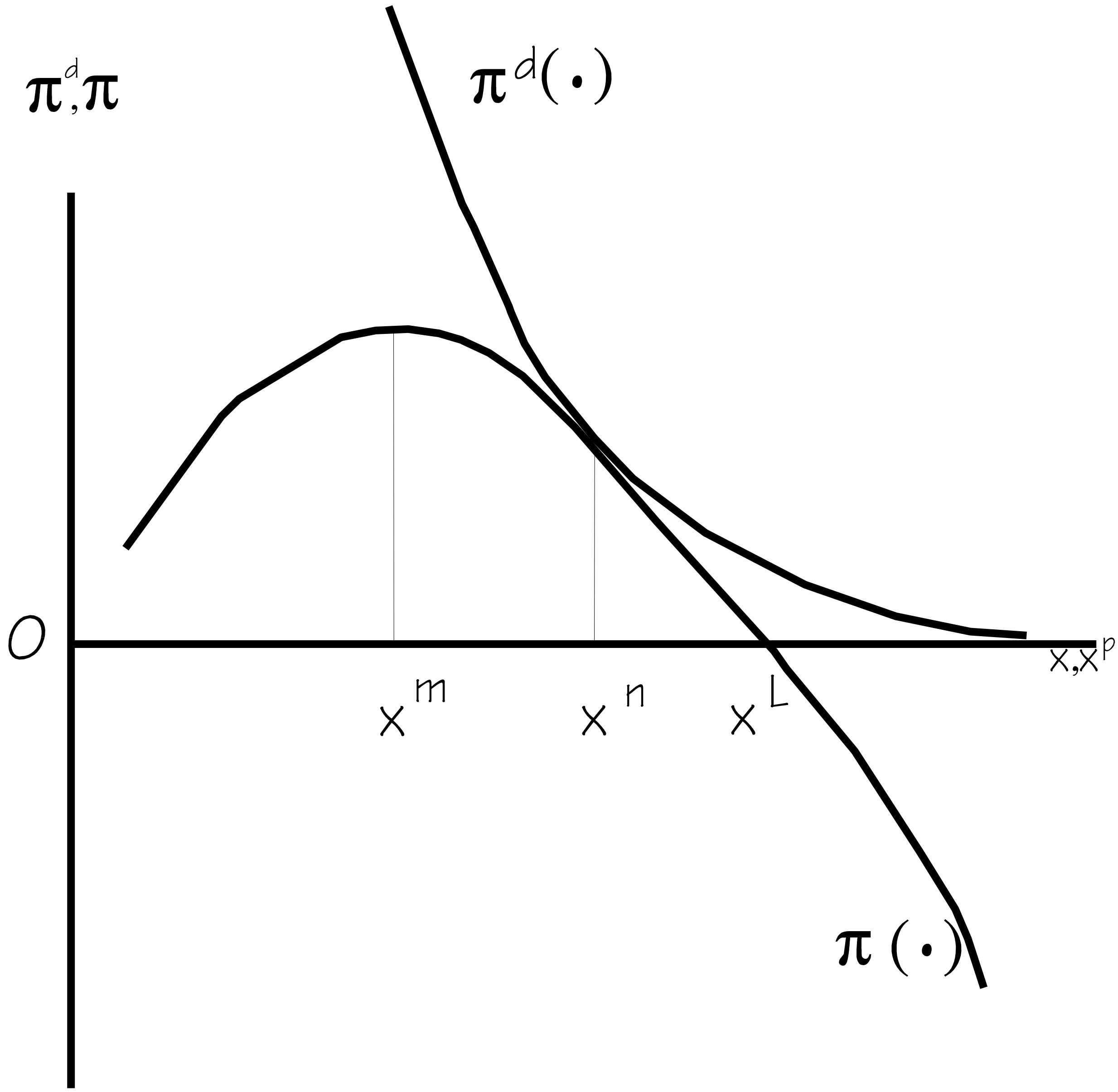


Figure 2

Most Collusive Equilibrium in Output Space

Figure 3

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

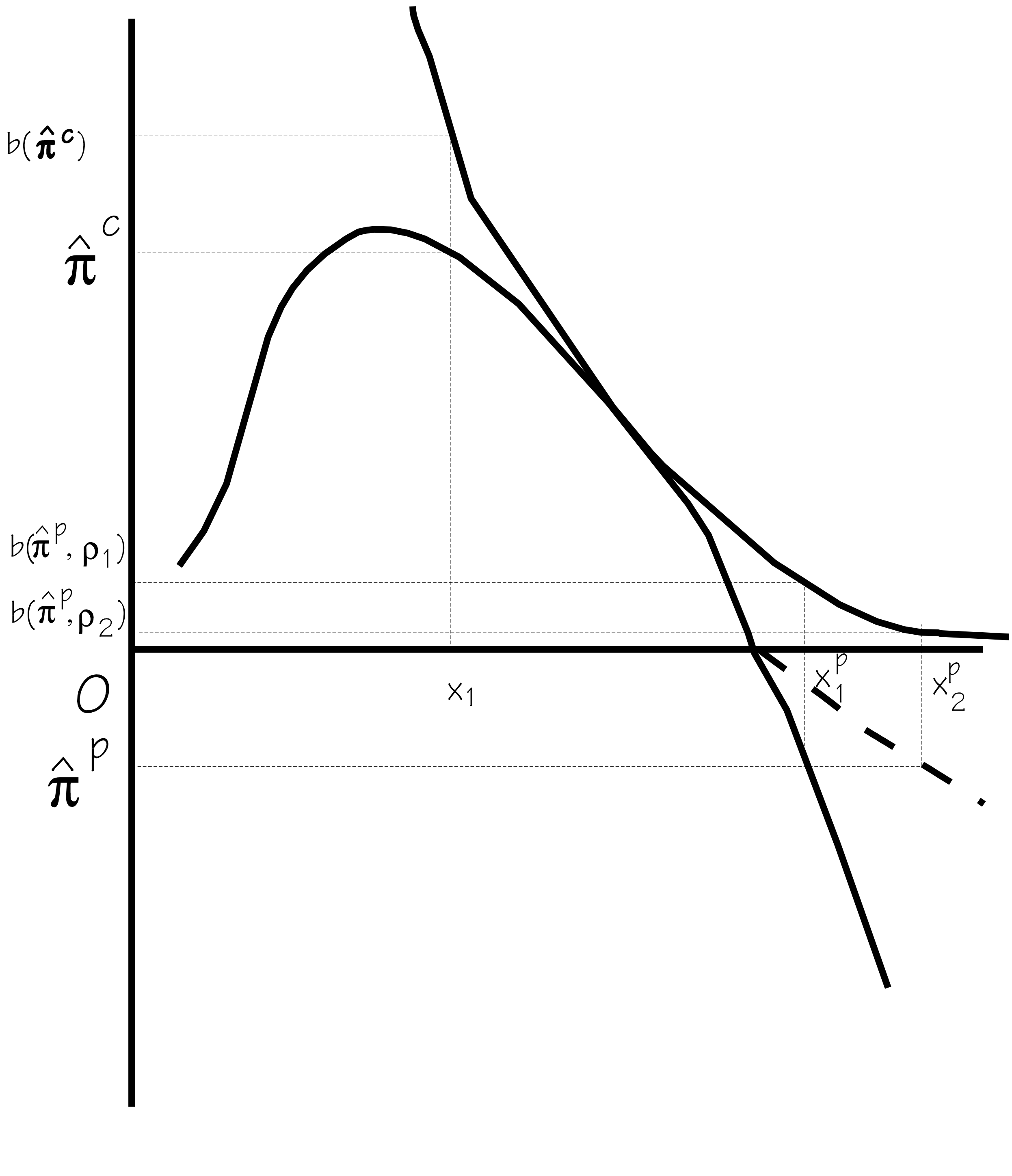
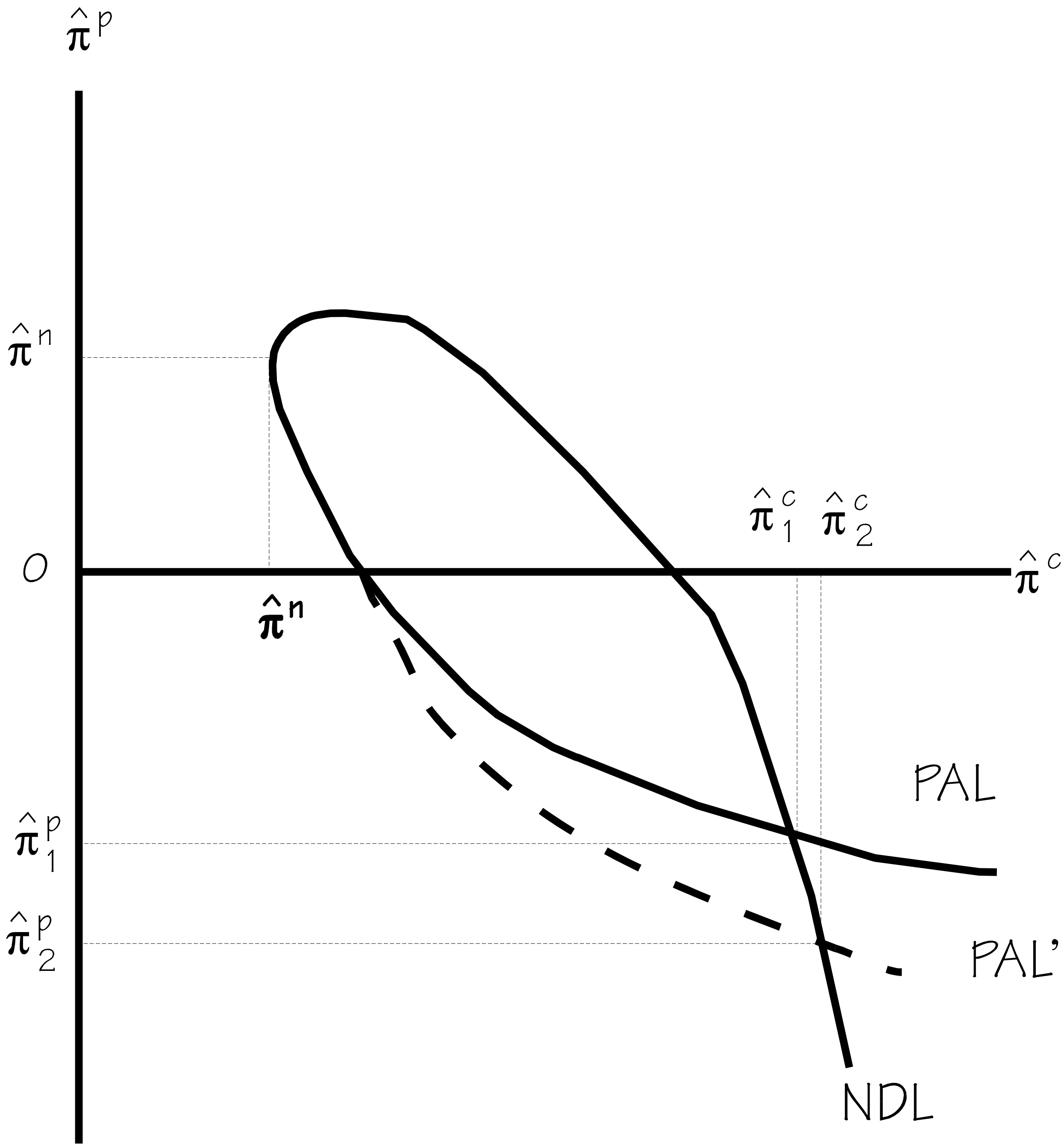


Figure 4

Effects of Increasing Refundability II: After-Tax Profits



NOTES

1. See Abreu (1986).

2. In that respect, this 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 brief summary in Myles (1995). As will be shown below, refundability matters, even without uncertainty. To anticipate Section 3.0 below, the fact that refundability matters under perfect certainty may also be used to justify a cash flow tax.

3. Recent examples of industries that have been studied using the supergame approach include retail-gasoline in Canada (Slade [1992]) and salt in the U.K. (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 (U.S.), 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.

4. As shown by Abreu (1986), asymmetric punishments generally yield more collusive outcomes. Such punishments, however, are not as neatly characterized as symmetric ones.

5. 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.

6. See Glenday and Mintz (1991) for a discussion of losses that arise from tax incentives. One cannot strictly talk about economic profit losses in the present model unless there is a full loss offset (full refundability).

7. Of course, intermediate situations characterized by $\rho < 1 + r$ also reflect a tax asymmetry.

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

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

10. See Myles (1995) for a brief summary, and Boadway et al. (1989) for specific proposals.

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

REFERENCES

Abreu, Dilip. 1986. "Extremal Equilibria of Oligopolistic Supergames." *Journal of Economic Theory* 39: 191-225.

---. 1988. "On the Theory of Infinitely Repeated Games with Discounting." *Econometrica* 56: 383-96.

---, David Pearce, and Ennio Stacchetti. 1986. "Optimal Cartel Equilibria with Imperfect Monitoring." *Journal of Economic Theory* 39: 251-69.

---, David Pearce, and Ennio Stacchetti. 1990. "Toward a Theory of Discounted Repeated Games with Imperfect Monitoring." *Econometrica* 58: 1041-63.

Altshuler, Rosanne, and Alan J. Auerbach. 1990. "The Significance of Tax Law Asymmetries: An Empirical Investigation." *Quarterly Journal of Economics* 105: 61-86.

Auerbach, Alan J. 1986. "The Dynamic Effects of Tax Law Asymmetries." *Review of Economic Studies* 53: 205-25.

---, and James M. Poterba. 1987. "Tax-Loss Carryforwards and Corporate Tax Incentives." *The Effects of Taxation on Capital Accumulation*. Ed. Martin Feldstein. Chicago: University of Chicago Press.

Boadway, Robin W., Neil Bruce, and Jack M. Mintz. 1987. "Taxes on Capital Income in Canada: Analysis and Policy." Canadian Tax Paper No. 80, Canadian Tax Foundation.

---, Kenneth J. McKenzie, and Jack M. Mintz. 1989. "Federal and Provincial Taxation of the Canadian Mining Industry: Impact and Implications for Reform." Monograph No. 24, Centre for Resource Studies, Queen's University.

Davidson, Carl, and Lawrence W. Martin. 1985. "General Equilibrium Tax Incidence under Imperfect Competition: A Quantity-Setting Supergame Analysis." *Journal of Political Economy* 93: 1212-23.

---. 1991. "Tax Incidence in a Simple General Equilibrium Model with Collusion and Entry." *Journal of Public Economics* 45: 161-90.

Domar, Evsey D., and Richard A. Musgrave. 1944. "Proportional Income Taxation and Risk-Taking." *Quarterly Journal of Economics* 58: 388-422.

Edwards, J.S.S., and M.J. Keen. 1985. "Inflation and Non-Neutralities in the Taxation of Corporate

Source Income." *Oxford Economic Papers* 37: 552-75.

Friedman, James W. 1971. "A Non-Cooperative Equilibrium for Supergames." *Review of Economic Studies* 38: 1-12.

Fudenberg, Drew, and Jean Tirole. 1989. "Noncooperative Game Theory for Industrial Organization: An Introduction and Overview." *Handbook of Industrial Organization*. vol. I. Eds. Richard Schmalensee and Robert D. Willig. Amsterdam: North-Holland.

---. 1991. *Game Theory*. Cambridge, MA: MIT Press.

Glenday, Graham, and Jack M. Mintz. 1991. "The Nature and Magnitude of Tax Losses ofCanadian Corporations." *Policy Options for the Treatment of Tax Losses in Canada*. Toronto: Clarkson Gordon Foundation.

Halpern, Paul, and Jack Mintz. 1992. "Taxation and its Impact on Market Structure." *Taxation to 2000 and Beyond*. Eds. Richard M. Bird and Jack M. Mintz. Toronto, Ontario: Canadian Tax Foundation.

Mintz, Jack M. 1981. "Some Additional Results on Investment, Risk Taking, and Full Loss Offset Corporate Taxation with Interest Deductibility." *Quarterly Journal of Economics* 96: 631-42.

---. 1988. "An Empirical Estimate of Corporate Tax Refundability and Effective Tax Rates." *Quarterly Journal of Economics* 103: 225-31.

---. 1991. "Economic Implications of Non-Refundability of Tax Losses." *Policy Options for the Treatment of Tax Losses in Canada*. Toronto: Clarkson Gordon Foundation.

Mossin, Jan. 1968. "Taxation and Risk-Taking: An Expected Utility Approach." *Economica* 35: 74-82.

Myles, Gareth D. 1995. *Public Economics*. Cambridge: Cambridge University Press.

Poddar, Satya. 1991. "Refunding the Tax Value of Unutilized Losses." *Policy Options for the Treatment of Tax Losses in Canada*. Toronto: Clarkson Gordon Foundation.

Rees, Ray. 1993a. "Collusive Equilibrium in the Great Salt Duopoly." *Economic Journal* 103: 833-48.

---. 1993b. "Tacit Collusion." *Oxford Review of Economic Policy* 9: 27-40.

Shapiro, Carl. 1989. "Theories of Oligopoly Behavior." *Handbook of Industrial Organization*. vol. I. Eds. Richard Schmalensee and Robert D. Willig. Amsterdam: North-Holland.

Slade, Margaret E. 1992. "Vacouver's Gasoline-Price Wars: An Empirical Exercise in Uncovering Supergame Strategies." *Review of Economic Studies* 59: 257-76.

---. 1995. "Empirical Games: The Oligopoly Case." *Canadian Journal of Economics* 28: 368-402.

Stangeland, Doug. 1995. "British Columbia Mineral Tax: A Tax on Resource Rent." *Natural Resources Tax Review* 8: 471-81.

Stiglitz, J. E. 1969. "The Effects of Income, Wealth, and Capital Gains Taxation on Risk-Taking." *Quarterly Journal of Economics* 83: 263-83.

Tirole, Jean. 1988. *The Theory of Industrial Organization*. Cambridge, MA: MIT Press.

Verboven, Frank. 1993. "Theoretical and Empirical Essays in Oligopoly Behavior." Unpublished Ph.D. Dissertation, Department of Economics, University of Toronto.