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Dismantling a State Monopoly: Insight from Theory

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Abstract

We analyze competition with taxation as an alternative to state monopoly by highlighting the importance of the industry's cost structure and the external cost of consuming the good. Under government revenue maximization assumption, competition is a better alternative to state monopoly if and only if the state monopoly has diseconomies of scale or is producing in the range of output where there are diseconomies of scale. The result is unchanged even when the government also accounts for the social cost of consuming the good. However, in this case, total output will be higher than the monopoly output only if the social cost of consuming the good is too small, that is it is lower than a determined threshold value. Interestingly, the analysis also showed that under both assumptions, oligopoly is a better alternative to state monopoly than perfect competition.

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1 Introduction

The rules of regulation applied by governments most often vary both across and within industries. In some cases, regulation occurs through taxation in a private competitive market, while ownership and state-run enterprises apply in others. Alcohol distribution and sale, one of the most heavily regulated industries in North America, sharply exemplifies the dichotomy between these two types of regulation in practice.

Indeed, in Alberta, Canada, and in US 'license' states, alcohol sales and distribution occur through private licensing vendors. The use of a private competitive market plus taxation also prevails in Australia and Thailand.[1] Interestingly, besides alcohol, excise taxes are also enacted by governments both to collect revenue and to internalize the external costs associated with the consumption or production of many other products (e.g., tobacco, gambling, petroleum products, etc.). Alternatively, in US 'control' states and most of Canadian provinces, government monopolies somehow control the liquor industry and are responsible for the sale (retail, wholesale, or both) of alcoholic beverages.[2]

Regulation, either through taxation in a private market or through state monopolies, is mainly justified for two reasons. First, there are revenues (from monopoly rent or taxation) accruing to the government (e.g., Nelson, 2007; Seim & Waldfogel, 2013; Zullo, 2017). Second, there are various negative externalities associated with the consumption of some products (e.g., health issues, violence and traffic accidents associated to alcohol consumption). Clearly, alcohol consumption and alcohol-related externalities are affected by regulation and market structure (e.g., Miller et al., 2006; Norstrom et al., 2010; Patra et al., 2011; Tyrfingsson et al., 2015).

Assuming both revenue and social benefit maximization, we examine competition with taxation as alternatives to state monopoly.[3] We analyze perfect

[1] Doran et al. (2013) estimate the impact of alternative alcohol taxation structures on consumption, public health and government revenues in Australia while Sornpaisarn & Kaewmungkun (2014) examine alcohol taxation in Thailand.

[2] In all Canadian provinces, the wholesale distribution of alcohol is controlled by government monopolies which, except in Alberta, are also dominant retailers. Alberta is the only province with a fully privatized retail alcohol sales, whereas two provinces (Prince Edward Island and New Brunswick) operate full government retail monopolies; a mixed (public and private) system of retail alcohol sales prevail in the other seven provinces. More details on the regulatory structure of alcohol sales in Canada can be found in Thomas (2012).

[3] In addition to government revenue, the social benefit takes into account the external

competition, which leaves entry decisions to the market, and oligopoly with entry decisions decided by the government who can set an entry cost. Our analysis is different from Koziashvili et al. (2011) who compares monopoly and perfect competition and shows that the prevailing market structure can be determined by a government maximizing the extracted resources from the alternative market structures. Indeed, we consider two alternative market structures to monopoly and examine the consequence, not only on government revenue, but also on consumer surplus and social welfare. More precisely, any optimal alternative to the state monopoly must satisfy three conditions: (i) It must provide the government with revenues at least as large as dividends it collects under state monopoly; (ii) It must not reduce the social welfare prevailing under the state monopoly; (iii) It must ensure the participation of firms.

The paper is structured as follows. Section 2 presents the theoretical model. In Section 3 we derive the optimal mechanism to be implemented post-liberalization under the hypothesis of revenue-maximization. Section 4 discusses the optimal mechanism under the assumption that the regulator uses the tax revenue to offset the external costs of consuming the good. Section 5 concludes the paper.

2 The model

Consider a state-owned monopoly producing a homogeneous good. Let q be the output. Suppose the cost function $c(q)$ is twice differentiable and nondecreasing ($MC(q) = dc(q)/dq = c'(q) \geqslant 0$). We will distinguish later the cost function along the four well known cases described in the microeconomic literature on the geometry of cost (e.g., Mas-Colell et al., 1995). This classification that depends on the shape of the average cost function $AC(q) = c(q)/q$ is given below:

Case 1: The average cost function is strictly increasing. Formally, $dAC(q)/dq = (MC(q) - AC(q))/q > 0,\ \forall q > 0$. Thus, there are diseconomies of scale in all range of output.

Case 2: The average cost function is constant. That is, $\forall q \geq 0,\ AC(q) = k$ with $k > 0$. The technology presents constant returns to scale.

Case 3: The average cost function is U-shaped. Therefore, the average cost function exhibits a strictly positive efficient scale $\bar{q} > 0$, which is the min-

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costs of consuming the good. For instance external costs of alcohol consumption.

imum of the average total cost, satisfying $MC(\bar{q}) = AC(\bar{q})$. In this more general setting, there are economies of scale for low output levels and diseconomies of scale for higher levels.

Case 4: The average cost function is strictly decreasing. That means, $dAC(q)/dq = (MC(q) - AC(q))/q < 0,\ \forall q > 0$. Hence, there are economies of scale in all range of output.

Let $p(q)$ be the inverse demand function satisfying $p'(q) < 0$ and $\pi(q) = p(q)q - c(q)$ the profit of a firm. Denote by q^m, p^m, and π^m the monopoly optimal output, price and profit respectively. Recall that q^m solves $\max_{q\geq 0} \pi(q) = p(q)q - c(q)$, $p^m = p(q^m)$ and $\pi^m = \pi(q^m) > 0$.[4]

Let $n \geq 2$ be the total number of firms in the market after liberalization and entry.[5] Denote by $c_i(q_i)$ the cost function of firm i when it produces q_i. The industry total cost function is $c(Q) = \sum_{i=1}^{n} c_i(q_i)$, where $Q = \sum_{i=1}^{n} q_i$ is the aggregate output.

Post-liberalization, the government can implement a general class of linear mechanisms (τ, L), where $\tau \geq 0$ is the per-unit tax (a fixed dollar amount per unit of output) and $L = (l_i)_{1\leq i\leq n}$, l_i being a lump-sum transfer (license fee) from firm i. Hence, firm i total transfer is $G_i(\tau, l_i) = \tau q_i + l_i$. Accordingly, the total revenue accruing to the government is $G(\tau, L) = \sum_{i=1}^{n} G_i(\tau, l_i)$. Clearly, $L = (l_i)_{1\leq i\leq n}$ represents a barrier to entry. Thus, under perfect competition $L = \mathbf{0}$ (i.e., $l_i = 0$ for all i) and the government uses only a per-unit tax τ. To simplify, assume that firms are identical and that the $n-1$ other firms enter the market with the same cost function as the state monopoly. Thus, $Q = nq$ where $q = q_i,\ i = 1, ..., n$; $l_i = l$ for all i and $c_i(q_i) = c(q)$.

3 Market structure and optimal mechanism under revenue maximization

Let θ be a parameter defining the market structure, with $\theta = 0$ under perfect competition and $\theta = 1$ under oligopoly. To be an alternative to monopoly, the mechanism (τ, L) as well as the quantity q must satisfy the

[4]Hence, we assume that the state monopoly earns a positive profit. The amount π^m is the monopoly rent accruing to the government in the form of dividends.

[5]We consider both the case where the state monopoly continues to produce and the case where it is dismantled.

following conditions:

$$G(\tau, L) = n(\tau q + \theta l) \geq \pi^m \quad (1)$$
$$Q = nq \geq q^m \quad (2)$$
$$\pi^\tau(q, \tau, l) = p(Q)q - c(q) - \tau q - \theta l \geq 0 \quad (3)$$

Equation (1) says that (τ, L) must generate at least the same revenue to the government as the rent it collects under state monopoly. Equation (2) says that (τ, L) must not reduce the consumer surplus. Equation (3) says that the mechanism (τ, L) must be incentive compatible, i.e., firms should earn a nonnegative profit.

3.1 Optimal mechanism under imperfect competition: $\theta = 1$

To determine the optimal mechanism, a two-stage game is used. (i) First, the government sets the mechanism (τ, L) as well as the number of firms n so as to maximize its revenue $G(\tau, L) = n(\tau q + \theta l)$ subject to (1)-(3). Second, given (τ, L), each firm chooses its output $q \geq 0$ so as to maximize its profit $\pi^\tau(q, \tau, l) = p(Q)q - c(q) - \tau q - \theta l$. To solve the problem, we use a backward induction. Starting with the firms, the first order condition of profit maximization for an output $q > 0$ is given by

$$p'(Q)q + p(Q) - c'(q) - \tau = 0. \quad (4)$$

Now, let's turn to the government problem. The optimal solution requires to extract all of the firms' surplus. Thus, it follows from (3) that $\pi^\tau = 0$. Substituting $\tau q + l$ from this equation into the objective function we get that $G_o(q, n) = np(nq)q - nc(q) \equiv p(Q)Q - nc(Q/n)$, where $Q = nq$.[6] First, given n, we find Q. Then we determine the optimal number of firms that maximizes the government revenue.[7] The first order and the second order necessary conditions for an interior solution ($Q > 0$) are given by

$$p'(Q)Q + p(Q) - c'(Q/n) \;=\; 0 \quad (5)$$
$$np''(Q)Q + 2np'(Q) - c''(Q/n) \;\leq\; 0. \quad (6)$$

[6]The subscript o refers to the situation under oligopoly and later the subscript c will refer to the situation under perfect competition.

[7]It follows from Equation (4) that $\tau = \tau(Q, n)$. In fact, there is a one to one relationship between Q and τ. Therefore, it is equivalent and more convenient to solve for Q rather than τ.

Using the envelope theorem, n is implicitly determined by

$$\frac{dG_o}{dn} = q(c'(q) - c(q)/q) = q(MC(q) - AC(q)). \tag{7}$$

Equation (7) clearly shows that the result depends on the cost structure of the industry.

Case 1: The average cost function is strictly increasing. This implies that $MC(q) - AC(q) > 0$, $\forall q > 0$. It follows from Equation (7) that $dG_o/dn > 0$, $\forall q > 0$. Hence, the government revenue increases with the number of firms and the optimal number of firms is undetermined. Then, $\forall n \geq 2$, $G_o(q^*(n), n) > G_o(q^*(1), 1) = \pi^m$. Note that $q^*(n) = Q_o^*(n)/n$ is the optimal output per firm, where the optimal output of the industry, $Q_o^*(n)$, satisfies (5). Thus, for any given number of firms, the optimal output will induce the optimal mechanism to satisfy constraint (1). Second, totally differentiating (5) and using (6) we obtain

$$\frac{dQ_o^*}{dn} = -\frac{1}{n}\frac{Q_o^* c''(Q_o^*/n)}{np''(Q_o^*)Q_o^* + 2np'(Q_o^*) - c''(Q_o^*/n)} \geq 0. \tag{8}$$

Therefore, $Q_o^*(n)$ is increasing with n and for $n \geq 2$, $Q_o^*(n) \geq Q_o^*(1) = q^m$, then condition (2) is satisfied. We have thus shown that for $n \geq 2$, $Q_o^*(n)$ satisfies conditions (1)-(3). Moreover, because $\pi^\tau = 0$, it follows from (4) and (3) that for $n \geq 2$, the optimal mechanism is $\tau_o^*(n) = -(1-1/n)p'(Q_o^*)Q_o^* > 0$ and $l^*(n) = q^*[c'(q^*) - c(q^*)/q^* - p'(Q_o^*)q^*] > 0$. The previous result shows that when the cost function exhibits diseconomies of scale in all range of output, meaning that total cost of the industry decreases with the number of firms in the market, then imperfect competition yields much better outcome than monopoly.

Case 2: The average cost function is constant. It follows from (5) that Q_o^* satisfies $p'(Q_o^*)Q_o^* + p(Q_o^*) = k$ and thus, $Q_o^* = q^m$. We also have that $G_o(q^m, n) = G_o(q^m, k) = \pi^m$.[8] Therefore, $\tau_o^* = -(1 - 1/n)p'(q^m)q^m$ and $l^* = -p'(q^m)(q^m/n)^2 > 0$. We conclude that, when the technology has constant returns to scale, the government revenue is the same as under state monopoly. This revenue will be greater only if the average (and marginal)

[8] Recall that $G_o(q, n) = np(nq)q - nc(q) = p(Q)Q - kQ = G_o(Q, k)$ is independent of n.

cost of the entering firms is lower.[9]

Case 3: The average cost function is U-shaped. It follows from (7) that the optimal number of firms will induce each firm to produce $\bar{q}$. Therefore, Equation (5) becomes

$$p'(Q)Q + p(Q) - c'(\bar{q}) = 0. \tag{9}$$

Assuming that the marginal revenue function, $MR(Q) = p'(Q)Q + p(Q)$, is downward sloping, Equation (9) has a unique solution. Let's define $F(Q) = p'(Q)Q + p(Q) - c'(\bar{q}) = MR(Q) - c'(\bar{q})$. Clearly, $F(\cdot)$ is a strictly decreasing function and $F(Q_o^*) = 0$.

First, if $q^m > \bar{q}$, then $F(q^m) = MR(q^m) - c'(\bar{q}) = c'(q^m) - c'(\bar{q}) > 0$. Hence, $F(Q_o^*) < F(q^m)$, implying that $Q_o^* > q^m$, and condition (2) is satisfied. In addition, $n^* = Q_o^*/\bar{q} > q^m/\bar{q} > 1$. Ignoring integer constraint, we also have that $G_o(\bar{q}, n^*) > \pi^m$ and thus, (1)-(3) are satisfied.[10] Therefore, oligopoly is more profitable than monopoly. Finally, the optimal per unit tax and the optimal transfer per firm are respectively given by $\tau^* = -(1 - 1/n^*)p'(Q_o^*)Q_o^* > 0$ and $l^* = -p'(Q_o^*)(Q_o^*/n^*)^2 > 0$.

Second, if $q^m \leq \bar{q}$, then $F(q^m) = c'(q^m) - c'(\bar{q}) \leq 0$ and $0 = F(Q_o^*) \geq F(q^m)$. This implies that $Q_o^* \leq q^m$ such that condition (2) is not satisfied. In addition, $n^* = Q_o^*/\bar{q} \leq q^m/\bar{q} \leq 1$. Therefore, liberalization is not profitable and it is optimal to have only one firm in the market.

Case 4: The average cost function is strictly decreasing. This implies that $MC(q) - AC(q) < 0$, $\forall q > 0$. It follows from Equation (7) that $dG_o/dn < 0$, $\forall q > 0$. Hence, the government revenue decreases with the number of firms. Therefore, the production efficiency requires a single firm in the market, a so-called "natural monopoly".

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[9] This would likely be the case as it is well known that the average cost under monopoly is typically higher than under competition (all else equal) due to X-inefficiency.

[10] If n^* is not an integer, let $\bar{n}$ be the integer part of n^* such that $\bar{n} \leq n^* < \bar{n}+1$. Then, the optimal number of firms $n^{**} = argmax_{n \in \{\bar{n},\, \bar{n}+1\}} G_o(\bar{q(n)}, n)$. In addition, $\pi^m = G_o(q^m, 1) \leq \max_{q>0,\, n>0} G_o(q, n) = G_o(\bar{q}, n^*)$. The couple $(q^m, 1)$ satisfies Equation (5) but is not the zero of Equation (7) which is $\bar{q}$. Therefore, $(q^m, 1)$ is not an optimal point and $G_o(\bar{q}, n^*) > \pi^m$.

3.2 Optimal mechanism under perfect competition: $\theta = 0$

The government problem is to choose (τ, n, q) so as to maximize $G_c(\tau) = n\tau q$ subject to (1)-(4). Substituting τ from (4) into (3) and G_c, the firm's profit and the government revenue can be written respectively as $\pi^\tau(q) = q(c'(q) - c(q)/q) = q(MC(q) - AC(q))$ and $G_c(Q, n) = Q(p(Q) - c'(Q/n))$. Let's discuss the result by considering the four cases of the cost structure.

Case 1: The average cost function is strictly increasing. This implies that $\pi^\tau > 0$. Moreover, we show in the Appendix that there exists $n_0 > 1$ such that $G_c(q^m, n_0) = \pi^m$ and $\forall n > n_0,\ G_c(q^m, n) > \pi^m$. Therefore, $\forall n > n_0,\ \max_{Q \geq 0} G_c(Q, n) \geq G_c(q^m, n) > \pi^m$. This also proves that the industry output under competition is higher than under monopoly, i.e., $Q^*_c \geq q^m$. Therefore, if the number of firms is sufficiently large, the government will raise more revenue than what it collects under state monopoly. This will occur because a positive profit will be an incentive for new firms to enter the market.

Case 2: The average cost function is constant. In this case, we know from Equation (10) that $\forall q \geq 0,\ \forall n > 1,\ G_o(q, n) = G_c(q, n)$. Consequently, the solution is the same as under imperfect competition.

Case 3: The average cost function is U-shaped. Here, $\pi^\tau = q(MC(q) - AC(q)) = 0$ (profit in the long-run equilibrium is zero). Thus, $q^* = \bar{q}$ and the government will find n to maximize $G_c(\bar{q}, n) = n[P(n\bar{q})\bar{q} - \bar{q}c'(\bar{q})]$. The first order condition implies that $p'(Q)Q + p(Q) - c'(\bar{q}) = 0$, where $Q = n\bar{q}$. This equation is identical to (9). Therefore, $Q^*_c = Q^*_o$ and the conclusion is the same as under imperfect competition. Especially, perfect competition would be preferable to monopoly if and only if $q^m > \bar{q}$.

Case 4: The average cost function is strictly decreasing. This implies that $MC(q) - AC(q) < 0,\ \forall q > 0$. And, for any given value of n, $\pi^\tau = q(MC(q) - AC(q)) < 0$. Therefore, the participation constraint of firms (3) fails. The monopoly is then preferable to perfect competition. This result is not surprising because we are in the presence of a natural monopoly. The following proposition summarizes the previous results.

Proposition 1 *(i) If the state monopoly has diseconomies of scale or is producing in the range of output where there are diseconomies of scale, then*

implementing the optimal tax system (τ^*, L^*) under competition will generate more revenue to the government and higher consumer surplus than the state monopoly.[11]
(ii) In the case of constant returns to scale, implementing the optimal tax system (τ^*, L^*) under competition yields the same outcome as the state monopoly.
(iii) If the state monopoly has economies of scale or is producing in the range of output where there are economies of scale, then it is optimal for the government to maintain it.

It is also interesting to compare the solution under perfect competition with the one under imperfect competition. To do this, note that:

$$\forall q \geq 0,\ \forall n > 1,\ G_o(q,n) - G_c(q,n) = nq(MC(q) - AC(q)). \tag{10}$$

Consequently, we can state the following proposition.

Proposition 2 *Imperfect competition is a better alternative to the state monopoly than perfect competition if the state monopoly has either diseconomies of scale or is producing in the range of output where there are diseconomies of scale.*

Proof. If the technology has diseconomies of scale, then, $MC(q) > AC(q) > 0,\ \forall q > 0$. It immediately follows from Equation (10) that $G_o(q,n) > G_c(q,n),\ \forall q > 0$. Alternatively, if the monopoly is producing in the range of output where there are diseconomies of scale, then, $q^m > \bar{q}$. We also know that $MC(q) > AC(q) > 0,\ \forall q > \bar{q}$. Therefore, we can conclude from Equation (10) that $G_o(q,n) > G_c(q,n),\ \forall q > \bar{q}$. Clearly, we know from proposition 1 that $Q_o^* > q^m$ and $Q_c^* > q^m$. Finally, we show in the Appendix that $Q_o^* > Q_c^*$. Thus, we can conclude that both the government revenue and the market output are higher under imperfect competition than under perfect competition. ■

The intuition behind this proposition is as follows. When the state monopoly has either diseconomies of scale or is producing in the range of output where there are diseconomies of scale, liberalization induces the government to use the optimal taxation consisting of a per-unit tax and a lump-sum

[11] We ignore the integer constraint when the cost function is U-shaped. However if we take into account the integer constraint, then it may be profitable for the government to maintain the state monopoly. For example, let's assume that $p(q) = 70 - q$ and $c(q) = q^2 + 20q + 100$. Then, $\bar{q} = 10$. Let's consider the oligopoly case. It follows from Equation (9) that $Q_o^* = 15$, and $n^* = 1.5$. Using the integer constraint, we get from footnote 10 that $\bar{n} = 1$. Then, $q(1) = 12.5$ and $q(2) = 20$, $G_o(q(\bar{1}), 1) = 212.5 = \pi^m > G_o(q(\bar{2}), 2) = 200$ implying that the optimal solution is to maintain the state monopoly.

transfer to extract all the firms' surplus in the case of imperfect competition. In a perfectly competitive market, the government can only use a per-unit tax, which enables firms to have a positive profit. Therefore, the government in its attempt to increase its shares of the remaining profit must set a higher per-unit tax which has the effect of increasing the market price and lowering the market output.[12]

4 Social benefit

Post-liberalization, the industry total production would be above the monopoly quantity. This extra consumption will generate additional costs to the society (this is likely the case for alcohol and marijuana). In this section, we assume that in addition to revenue, the government incorporates the external costs of consuming the good. Because imperfect competition yields much better outcome than perfect competition, we will focus only on imperfect competition, i.e., $\theta = 1$.

For simplicity, let's assume that the external cost of consuming the good is linear in the quantity and denote by $s > 0$ the marginal external cost. The additional external cost of producing a quantity $Q \geq q^m$ is $s(Q - q^m)$. Then, the government problem is to choose (τ, l, n, q) so as to maximize the social benefit, namely its net revenue, $G_o(\tau, L) = n(\tau q + l) - s(Q - q^m)$, subject to (2)-(4) along with the following condition

$$G_o(\tau, L) = n(\tau q + l) - s(Q - q^m) \geq \pi^m. \tag{11}$$

Condition (11) is simply condition (1) adjusted to account for the external cost. The optimal solution requires to extract all of the firm's surplus. Thus, the government maximizes $G_o(Q, n) = p(Q)Q - nc(Q/n) - s(Q - q^m)$ subject to (2), (4) and (11). Ignoring the constraints, the first order condition for an interior solution $Q > 0$ is given by:

$$p'(Q)Q + p(Q) - c'(Q/n) = s, \tag{12}$$

while the second order condition is given by (6) and the optimal number of firms in the market is still determined by (7). Denoting by $Q_o^e = Q_o^e(n, s)$

[12]Notice that the per-unit tax in perfect competition is actually greater than in oligopoly. Indeed, it is straightforward to show that $\tau_c^* - \tau_o^* = c'(q_o^*) - c'(q_c^*) + P(Q_c^*) - P(Q_o^*) - P'(Q_o^*)q_o^* > 0$, where τ_c^* and τ_o^* are respectively the optimal per-unit tax in perfect competition and oligopoly. Also, it is important to note that in the long run equilibrium both markets will generate the same outcome.

the solution to equation (12) and Q_o^{e*} the optimal output, let's discuss by distinguishing the four cases of the cost structure.

Case 1: The average cost function is strictly increasing. We prove in the Appendix that there exists a threshold external marginal cost $\hat{s}$ such that $Q_o^e > q^m$, if and only if $s < \hat{s}$. Thus,

$$Q_o^{e*} = \begin{cases} Q_o^e & \text{if } s < \hat{s} \\ q^m & \text{if } s \geq \hat{s} \end{cases}$$

Because according to Equation (7), the government net revenue increases with the number of firms, we obtain that, for any $n \geq 2$, $G_o(q^m, n) > G_o(q^m, 1) = \pi^m$. Moreover, for any $n \geq 2$, $G_o(Q_o^{e*}, n) = \max_{Q>0} G_o(Q, n) \geq G_o(q^m, n) > \pi^m$. Hence, $G_o(Q_o^{e*}, n) > \pi^m$ and condition (11) is satisfied. Thus, for any $s > 0$, constraints (2), (3) and (11) are satisfied. Furthermore, it follows from Equations (3) and (4) that the optimal unit tax and the transfer per firm are respectively given by $\tau^*(n, s) = -(1 - 1/n)p'(Q_o^{e*})Q_o^e + [c'(Q_o^{e*}) - nc'(Q_o^{e*}/n)] > 0$ and $l^*(n, s) = q_o^{e*}[c'(q_o^{e*}) - c(q_o^{e*})/q_o^{e*} - p'(Q_o^{e*})q_o^{e*}] > 0$, where $q_o^{e*} = Q_o^{e*}/n$.

Case 2: The average cost function is constant. Note that $MR(q^m) = k$ and from (12), Q_o^e satisfies $MR(Q_o^e) = k + s$. Therefore, th government will set $\tau^m = -(1 - 1/n)p'(q^m)q^m > 0$ and $l^m = -p'(q^m)(q^m/n)^2 > 0$ to induce the market to produce $Q_o^{e*} = q^m$.

Case 3: The average cost function is U-shaped. We showed in the previous section that under government revenue maximization ($s = 0$), it is optimal to maintain the state monopoly if $q^m < \bar{q}$. This result also holds when $s > 0$. Now assume that $q^m > \bar{q}$. It is shown in the Appendix that there exists $\hat{s}$ such that $Q_o^e > q^m$ if and only if $s < \hat{s}$. Thus,

$$Q_o^{e*} = \begin{cases} Q_o^e & \text{if } s < \hat{s} \\ q^m & \text{if } s \geq \hat{s} \end{cases}$$

In addition, $G_o(Q_o^{e*}, n^{e*}) = \max_{Q>0,\, n\geq 1} G_o(Q, n) > G_o(q^m, n^o) = \pi^m$, where $n^o = q^m/\bar{q}$, $n^e = Q_o^e/\bar{q}$ and $n^{e*} = n^o$ if $Q_o^{e*} = q^m$ or $n^{e*} = n^e$ if $Q_o^{e*} = Q_o^e$.

Case 4: The average cost function is strictly decreasing. We are in the presence of a natural monopoly, meaning the state monopoly is the better alternative.

Previous results clearly show that liberalization does not depend on the external cost of consuming the good. Indeed, even when the social cost of consuming the good is high, the regulator can still use a system of taxation to induce the state monopoly's output post-liberalization. We can thus state the following proposition.

Proposition 3 *Integrating the external cost of consuming the good does not affect the decision of market liberalization. That is, competition is still preferable to the state monopoly if and only if there are diseconomies of scale or the monopoly is producing in the range of output where there are diseconomies of scale. However, market output will increase if and only if the social cost of consuming the good is below a threshold value.*

5 Concluding Remarks

This paper provided a theoretical analysis to examine whether a competitive market regulated with taxation can be a better alternative to a state monopoly which is mainly justified by the maximization of either the government revenue or the social benefit.

First, assuming revenue maximization, we derived the optimal tax mechanism under oligopoly and perfect competition. Competition is better than the state monopoly, meaning that it generates more revenue to the government and increases consumer surplus, if and only if the state monopoly has diseconomies of scale or is producing in the range of output where there are diseconomies of scale. This result is unsurprising because diseconomies of scale imply the industry total cost decreases with the number of firms. When there are constant returns to scale, the outcome under competition is identical to that under state monopoly, unless competition fosters innovation and allows new firms to enter the market with lower marginal cost.

Second, the results are unchanged even when the government also accounts for the social cost of consuming the good. However, total output will be higher only if the social cost of consuming the good is too small, that is it is lower than a determined threshold value. Interestingly, the analysis also showed that under both assumptions, imperfect competition is a better alternative to the state monopoly than perfect competition.

The paper highlights the importance of the industry's technology and the external costs of consuming the good. Most importantly, it contributes to the new debate regarding the liberalization of cannabis since its recent legalization for recreational purpose in Canada. For instance, even if the external cost of marijuana consumption is high, our results suggest that consumption can still be controlled in a competitive market through a tax system.

Appendix

A1: There exists $\mathbf{n_0} > \mathbf{1}$ such that $\mathbf{G_c(q^m, n_0)} = \pi^{\mathbf{m}}$ and $\forall \mathbf{n} > \mathbf{n_0},\ \mathbf{G_c(q^m, n)} > \pi^{\mathbf{m}}$.

Proof. $G_c(Q,n) = p(Q)Q - Qc'(Q/n) = \pi(Q) + c(Q) - Qc'(Q/n)$. Therefore, $G_c(q^m, n) = \pi^m + c(q^m) - q^m c'(q^m/n)$. Let $f(n) = c(q^m) - q^m c'(q^m/n)$. $f'(n) = (q^m/n)^2 c''(q^m/n) > 0$; thus, $f(n)$ is increasing with n. Moreover, $f(1) = c(q^m) - q^m c'(q^m) = q^m(c(q^m)/q^m - c'(q^m)) < 0$ and $\lim_{n\to+\infty} f(n) = c(q^m) - q^m c'(0) = q^m(AC(q^m) - AC(0)) > 0$, since $AC(q) = c(q)/q$ is strictly increasing. Hence, by the intermediate value theorem, there exists $n_0 > 1$ such that $f(n_0) = 0$. Because $f(n)$ is strictly increasing with n, $f(n) > 0,\ \forall n > n_0$ and thus, $G_c(q^m, n) > \pi^m$. ■

A2: $\mathbf{Q_o^*} > \mathbf{Q_c^*}$

Proof. Note that Q_c^* satisfies, $p'(Q_c^*)Q_c^* + p(Q_c^*) - c'(Q_c^*/n) - Q_c^* c''(Q_c^*/n)/n = 0$. Denote by $L(Q) = p'(Q)Q + p(Q) - c'(Q/n)$. Clearly, from Equation (6), this function is strictly decreasing in Q. In addition, it follows from (5) that $L(Q_o^*) = 0$ and $L(Q_c^*) = Q_c^* c''(Q_c^*/n)/n > 0$. Thus, $L(Q_o^*) < L(Q_c^*)$, implying that $Q_o^* > Q_c^*$. ■

A3: There exists $\hat{\mathbf{s}}$ such that, $\mathbf{Q_o^e} > \mathbf{q^m}$, for $\mathbf{s} < \hat{\mathbf{s}}$.

Proof. (i) First let assume Case 1 where the average cost function is strictly increasing. Implying that the marginal cost function is increasing with the level of output. Define $L(Q,s) = MR(Q) - c'(Q/n) - s$, which is continuous and differentiable in $Q \geq 0$ and $s \geq 0$. From Equation (12), $L(Q_o^e, s) = 0$. Assuming a decreasing marginal revenue function, for a given value of s, $L(Q,s)$ is strictly decreasing in Q. Hence, $Q_o^e > q^m$ if and only if $L(q^m, s) > 0$. We have that, $L(q^m, s) = MR(q^m) - c'(q^m/n) - s = c'(q^m) - c'(q^m/n) - s$, and then $L(q^m, 0) = c'(q^m) - c'(q^m/n) > 0$. Let $\bar{s} = c'(q^m) - c'(0) > 0$, then

$L(q^m, \bar{s}) = c'(0) - c'(q^m/n) < 0$. The intermediate value theorem implies that there exists $0 < \hat{s} < \bar{s}$ such that $L(q^m, \hat{s}) = 0$. Because $L(q^m, \cdot)$ is strictly decreasing in s, then $L(q^m, s) > 0$ for all $0 < s < \hat{s}$. (ii) second let assume Case 3 where the average cost function is U-shaped. Therefore the optimal output Q_o^e that depends on s is given by $F(Q_o^e, s) = 0$ where $F(Q, s) = MR(Q) - c'(\bar{q}) - s$. This function is twice differentiable and both decreasing in Q and s. Because the liberalization occurs only if $q^m > \bar{q}$, thus $Q_o^e > q^m$ if and only if $F(q^m, s) > 0$. Or $F(q^m, s) = MR(q^m) - c'(\bar{q}) - s = c'(q^m) - c'(\bar{q}) - s$, implying that $F(q^m, s) > 0 \Leftrightarrow s < c'(q^m) - c'(\bar{q})$. Hence denote $\hat{s} = c'(q^m) - c'(\bar{q}) > 0$ since $q^m > \bar{q}$. ■

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