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Equilibrium: A Note**

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# Public Input Competition under Stackelberg Equilibrium: A Note\*

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## Abstract

This paper examines the Stackelberg equilibrium for public input competition and compares it with the non-cooperative Nash equilibrium. Given two asymmetric regions, we show that under the Nash equilibrium, the more productive region tends to spend more on public input, which results in this region attracting more capital than the less productive region. The comparison of the two equilibria reveals that the leader region obtains a first-mover advantage under the Stackelberg setting. This suggests that if regions interact with each other sequentially as in the Stackelberg equilibrium, then the regional disparity that is due to the heterogeneity of productivity is likely to be mitigated or enlarged, depending on which region performs the leadership role in the competition process.

**Keywords:** Public input competition; Nash and Stackelberg equilibria; Comparison

**JEL Classifications:** H73, H87, C72.

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# 1 Introduction

The past several decades have witnessed a growing interest in the study of how competition for capital influences governments' choices of fiscal policies. The standard argument, which originates in the fundamental work of [Zodrow and Mieszkowski \(1986\)](#) and [Wilson \(1986\)](#), has been that competition through taxation leads to inefficiently low tax rates. On the contrary, if competition is conducted through the use of public input that enhances the productivity of private capital, an overemphasis on that policy is commonly expected to emerge ([Keen and Marchand, 1997](#); [Bayindir-Upmann, 1998](#); [Bucovetsky, 2005](#)).<sup>1</sup> Despite providing valuable insights into the nature of competition among governments, these results have been generally obtained under a non-cooperative game framework in which competing units move simultaneously. However, as challenged by [Wang \(1999\)](#) and [Kempf and Rota-Graziosi \(2010\)](#), the relevance of the non-cooperative hypothesis for the study of fiscal competition has not yet been established in reality.<sup>2</sup> Relaxing this hypothesis to investigate a scenario in which competition is conducted in a sequential game framework, both studies show that the downward pressure on tax rates is indeed less strong than predicted in the standard tax competition analysis—in a large part that is due to the property of strategic complementarity of tax rates across the competing units. More specifically, when the competing units follow a sequence of moves in setting their tax rates, the second moving region (the “Stackelberg follower”) will increase its tax rate if it observes a higher level of tax rate chosen by the first moving region (the “Stackelberg leader”); the leader anticipates this and consequently increases its tax rate. As a result, the selected tax rates in both regions in the

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<sup>1</sup>Numerous subsequent works have extended and refined these arguments in a variety of directions. See [Dembour \(2008\)](#) for a survey of literature on competitive location policies. For surveys of the tax competition literature in general, see [Wilson \(1999\)](#) and [Wilson and Wildasin \(2004\)](#).

<sup>2</sup>Due to the complexity of the strategic interaction of competing units, it has indeed never been clarified in the literature which game setting, either simultaneous or sequential, is a better approximation of reality. In some cases, it is conceivable that the smaller regions make their strategic responses after they observe the actions chosen by the larger regions. In other cases, the difference between core versus periphery regions may also translate into strategic asymmetries. The empirical literature, on the other hand, does provide some evidence on the presence of Stackelberg-type leaders in tax competition across regions and countries (e.g., [Altshuler and Goodspeed, 2002](#); [de Mello, 2008](#)).

Stackelberg equilibrium are higher than that in the non-cooperative Nash equilibrium.

This paper adds to this literature by asking whether the different outcomes implied by the varied game settings for tax rate setting can be generalized to the case of competition through public input. More specifically, we investigate the Stackelberg equilibrium for public input competition and compare it with the non-cooperative Nash equilibrium. For simplicity and tractability, our model assumes: (i) that regions that are heterogeneous in productivity compete for mobile capital by providing a productivity-enhancing public input; and (ii) that the capital tax rate is coordinated by the social planner and so it is no longer a policy instrument for competition. These two assumptions, which are similar to those of [Cai and Treisman \(2005\)](#), presents the advantage of focusing exclusively on the strategic interactions for public input among regions and enables us to simplify the comparison between the two equilibria. Given that the underlying mechanisms through which tax rates and public inputs are utilized to attract capital are different, our results reveal somewhat *non-comparable* outcomes between these two tools of competition. In particular, we show that the public input is a strategic substitute among the competing units in the public input competition model—a feature that differs from the case of tax competition, where tax rates are strategic complements. These different features of the two competition tools finally transform into a different comparison outcome between the Stackelberg equilibrium and the Nash equilibrium for public input competition and tax competition. More specifically, we find that in the case of public input competition under the Stackelberg equilibrium it is important to differentiate the leader region and the follower region—while the leader region tends to set a higher level of public input than what this region would select in the Nash equilibrium, the follower region does the opposite. This result differs from the case of tax competition found in the previous literature that suggests a consistent upward selection of tax rates in both types of region under the Stackelberg equilibrium.<sup>3</sup>

The rest of this note is organized as follows. Section 2 presents the basic model. Section

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<sup>3</sup>See [Kempf and Rota-Graziosi \(2010\)](#) for the comparison of the Stackelberg equilibrium and Nash equilibrium for competition through tax rates.

3 proceeds with the equilibrium analysis in both game settings and compares the equilibrium outcomes. Section 4 concludes.

## 2 The model

Consider an economy that consists of two regions,  $i = 1, 2$ . In each region, a numeraire output is produced under perfect competition, and this output can be used either for private consumption or government consumption. The production function in each region is given by  $F_i(L_i, K_i, I_i)$ , where  $K_i$  is the amount of perfectly mobile capital,  $I_i$  is the amount of public input provided by the regional government that enhances the productivity of domestic capital,<sup>4</sup> and  $L_i$  is the amount of a fixed production factor such as land or labor. For analytical convenience the fixed factor is normalized to unity and the production function can be rewritten as  $F_i(K_i, I_i)$ , which is increasing, twice continuously differentiable and concave in the level of capital  $K_i$ ; i.e.,  $\frac{\partial F_i}{\partial K_i} > 0 > \frac{\partial^2 F_i}{\partial K_i^2}$ . Domestic capital and public input are complements, so an increased provision of public input increases the marginal productivity of capital, i.e.,  $\frac{\partial^2 F_i}{\partial K_i \partial I_i} > 0$ . The cost of public input provision is given by the convex function  $C_i(I_i)$ , which, for analytical tractability, is assumed to be quadratic:  $C_i(I_i) = \frac{I_i^2}{2}$ .

In each region, public input is financed by a source-based specific tax on capital  $t$ , which is coordinated by the social planner and therefore cannot be a policy instrument for the regions. By assuming this we are able to focus exclusively on the nature of public input competition and its impact on public input provision. Private capital is perfectly mobile and the total fixed stock of private capital in the economy is assumed equal to  $\bar{K}$ ; the market clearing conditions imply that the allocation of capital across the regions equates its net return in

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<sup>4</sup>Although the magnitude of the output elasticity of public input is still under debate, the literature has reached a broad consensus on the argument that public input is truly productivity-enhancing; see [Duarte Bom and Ligthart \(2008\)](#), [Ligthart and Martin-Suarez \(2011\)](#) for a quantitative review of the literature on the productivity of public input.

the two regions; that is

$$\begin{cases} \frac{\partial F_1}{\partial K_1} - t = \frac{\partial F_2}{\partial K_2} - t \\ K_1 + K_2 = \bar{K} \end{cases} \quad (1)$$

where the net return of capital is assumed to be positive in order to ensure a non-zero allocation of capital in each region, i.e.  $\frac{\partial F_i}{\partial K_i} - t > 0$ . To complete the model, we assume that the objective of each region is to maximize the sum of the fixed factor income and capital tax revenue, net of the investment costs<sup>5</sup>

$$W_i(I_i, I_j) = F_i(K_i, I_i) - K_i \frac{\partial F_i}{\partial K_i} + tK_i - C_i(I_i), \quad j \neq i \quad (2)$$

In our model, the two regions are assumed to be asymmetric with respect to their initial productivity which, however, can be mitigated and possibly eliminated by the regions' choices of public input. More precisely, following [Bucovetsky \(1991\)](#), [Grazzini and Van Ypersele \(2003\)](#) and [Hindriks et al. \(2008\)](#), we assume a quadratic specification of the production function, which is well behaved over its increasing range and allows us to introduce several simplifications.<sup>6</sup> Specifically, the production functions are given by

$$\begin{cases} F_1(K_1, I_1) = (a + \delta + I_1)K_1 - \frac{b}{2}K_1^2 \\ F_2(K_2, I_2) = (a - \delta + I_2)K_2 - \frac{b}{2}K_2^2 \end{cases} \quad (3)$$

where  $b \geq 1$  is the rate of decline of the marginal product of capital with the amount of capital invested in the region; technology parameter  $a$  is assumed to be sufficient large relative to  $b$ , which ensures a positive level of production and the standard properties of the production function; and the parameter  $\delta \geq 0$  captures the degree of production asymmetry across regions, with region 1 assumed to have a superior production technology than region

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<sup>5</sup>We assume there is no domestic ownership of capital. This assumption, which is consistent with [Wildasin \(1988\)](#), has been used by [Hauptmeier et al. \(2008\)](#), [Hindriks et al. \(2008\)](#), [Kempf and Rota-Graziosi \(2010\)](#). As argued by [Laussel and Le Breton \(1998\)](#), this assumption can be justified as a partial equilibrium reflecting the high concentration of countries' capital distribution.

<sup>6</sup>In our simple context, there is little to be gained from using a more general production function form.

2.

From equations (1) and (3), we immediately get that

$$\begin{cases} K_1 = \frac{I_1 - I_2}{2b} + \frac{\bar{K}}{2} + \frac{\delta}{b} \\ K_2 = \frac{I_2 - I_1}{2b} + \frac{\bar{K}}{2} - \frac{\delta}{b} \end{cases} \quad (4)$$

Therefore, the stock of capital in each region is increasing in its own public input provision and decreasing in the public input provision of the other region. In particular, given equal provision of public input, i.e.  $I_1 = I_2$ , region 1 will attract more capital than its counterpart.

### 3 Nash equilibrium vs. Stackelberg equilibrium

In this section we examine the regions' equilibrium choices, depending on the sequence of government actions. We first analyze the Nash equilibrium where both regions simultaneously decide how much public input to provide. Then we derive the Stackelberg equilibrium by setting one region (the leader) to make the provision decision before the other (the follower) does. Finally, a comparison of the two equilibria follows.

#### 3.1 Nash equilibrium

In this case, each region chooses its own public input level independently. Given  $I_j$ , the problem of region  $i$  is to choose  $I_i$  in order to maximize its welfare function (2). The FOC yields

$$\frac{\partial W_i}{\partial I_i} = \frac{\partial F_i}{\partial I_i} + \left( \frac{\partial^2 F_j}{\partial K_j^2} K_i + t \right) \frac{\partial K_i}{\partial I_i} - \frac{\partial C_i}{\partial I_i} = 0, \quad j \neq i \quad (5)$$

With production functions (3), it is straightforward to show that the Nash equilibrium  $(I_1^N, I_2^N)$  is jointly determined by

$$\begin{cases} \frac{K_1}{2} - I_1 + \frac{t}{2b} = 0 \\ \frac{K_2}{2} - I_2 + \frac{t}{2b} = 0 \end{cases} \quad (6)$$

In addition, the second order condition is satisfied at  $(I_1^N, I_2^N)$ , i.e.  $-1 < \frac{\partial^2 W_i}{\partial I_i^2} = \frac{1}{4b} - 1 < 0$ , which guarantees the existence and the uniqueness of a Nash equilibrium.<sup>7</sup> Combining equations (4) and (6) to solve the equilibrium, we obtain the following proposition.

**Proposition 1.** *The Nash equilibrium requires a higher level of public input and capital in the more productive region:  $I_1^N = \frac{\bar{K}}{4} + \frac{t}{2b} + \frac{\delta}{2b-1} > I_2^N = \frac{\bar{K}}{4} + \frac{t}{2b} - \frac{\delta}{2b-1}$ ;  $K_1^N = \frac{\bar{K}}{2} + \frac{2\delta}{2b-1} > K_2^N = \frac{\bar{K}}{2} - \frac{2\delta}{2b-1}$ .*

The explanation is simple. Since the capital tax rate is fixed across regions, the Nash equilibrium requires allocating capital so as to equate the marginal product of capital across regions. Due to the heterogeneity of regional productivity and given other things being equal, the marginal product of capital is higher in the more productive region (i.e. region 1). Then the decline of marginal product of capital requires allocating more capital to the more productive region. Furthermore, the equilibrium level of investment in public input is determined by the equivalence between its marginal revenue and its marginal cost. Since the more productive region receives more capital, it also exhibits higher marginal value of investment, and thus also undertakes higher public input investment.

### 3.2 Stackelberg equilibrium

Let us consider the equilibrium under the Stackelberg game. Assuming that region  $i$  is the leader in the game, and region  $j$  is the follower, we solve this game backwards. Given the leader's choice  $I_i$ , the maximization problem of the follower  $j$  is similar to the case of a non-cooperative game, the usual FOC of the follower obtains

$$\frac{K_j}{2} - I_j(I_i) + \frac{t}{2b} = 0 \tag{7}$$

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<sup>7</sup>Note that it is assumed that  $b \geq 1$ .

where  $I_j(I_i)$  is the best response function of the follower with respect to the choice of the leader.

Now given the follower's best response function  $I_j(I_i)$ , the leader incorporates this reaction function into its maximization problem, and the corresponding FOC after simplification is given by

$$\frac{K_i}{2} - I_i + \frac{t}{2b} - \left(\frac{K_i}{2} + \frac{t}{2b}\right) \frac{\partial I_j}{\partial I_i} = 0 \quad (8)$$

Since the derivation of  $\frac{\partial W_j}{\partial I_j}$  with respect to  $I_i$  and  $I_j$  yields  $\frac{\partial^2 W_j}{\partial I_j \partial I_i} = -\frac{1}{4b}$  and  $\frac{\partial^2 W_j}{\partial I_j^2} = \frac{1}{4b} - 1$ , respectively, applying the Envelop Theorem to equation (7) we obtain

$$\frac{\partial I_j}{\partial I_i} = -\frac{\frac{\partial^2 W_j}{\partial I_j \partial I_i}}{\frac{\partial^2 W_j}{\partial I_j^2}} = \frac{1}{1 - 4b} < 0 \quad (9)$$

With (9), equation (8) can be further simplified to

$$\frac{2b}{4b - 1} K_i - I_i + \frac{2t}{4b - 1} = 0 \quad (10)$$

The Stackelberg equilibrium of public input  $(I_i^L, I_j^F)$  is therefore jointly determined by equations (7) and (10). Meanwhile, equation (9) implies the following Lemma.

**Lemma 1.** *Public input performs as a strategic substitute.*

This is so because when region  $i$  increases its level of public input, it increases the competitive pressure on region  $j$  as this decision increases the incentive of capital to relocate from  $j$  to  $i$ . The marginal benefit derived from an increase of public input set by region  $j$  is decreasing since it generates fewer revenues than the additional costs for providing it. Therefore, the optimal response for region  $j$  is to reduce its own level of public input. Mathematically, this is reflected by the negative sign of the second order cross-derivative, i.e.  $\frac{\partial^2 W_j}{\partial I_j \partial I_i} = -\frac{1}{4b} < 0$ , which implies that when region  $i$  increases its provision of public input, it

is optimal for region  $j$  to decrease its provision of public input in order to increase its overall welfare.

### 3.3 Comparison of the two equilibria

In this subsection, we compare the Stackelberg equilibrium to the Nash equilibrium and summarize our results in the following proposition.

**Proposition 2.** *The follower region selects a lower level of public input in the Stackelberg equilibrium than what this region would select in the Nash equilibrium, while the leader region does the opposite:  $I_j^F < I_j^N; I_i^L > I_i^N$ .*

**Proof.** From the definition of Stackelberg equilibrium, we have

$$W_i(I_i^L, I_j^F(I_i^L)) = \text{Max}_{I_i} W_i(I_i, I_j^F(I_i)) \geq W_i(I_i^N, I_j^F(I_i^N)) = W_i(I_i^N, I_j^N) \quad (11)$$

since  $\frac{\partial W_i}{\partial I_j} = -\frac{K_i}{2} - \frac{t}{2b} < 0$ , if we assume by contradiction that inequality  $I_j^F(I_i^L) \geq I_j^N$  holds, then we get

$$W_i(I_i^N, I_j^N) = \text{Max}_{I_i} W_i(I_i, I_j^N) \geq W_i(I_i^L, I_j^N) > W_i(I_i^L, I_j^F) \quad (12)$$

Obviously, inequality (12) contradicts to (11). That means  $I_j^F(I_i^L) \geq I_j^N$  cannot hold, and thus we have  $I_j^F < I_j^N$ .

Given that  $I_j^F < I_j^N$  and Lemma 1 (i.e.  $\frac{\partial I_j}{\partial I_i} < 0$ ), the comparison of the two equilibria  $(I_i^N, I_j^N)$  and  $(I_i^L, I_j^F)$  immediately concludes with  $I_i^L > I_i^N$ . ■

This proposition identifies the first-mover advantage of the leader region in the sense that a region will select a higher level of public input and end up with a higher level of payoff if it acts as the leader by comparison to the situation where the counterpart region acts as the leader.<sup>8</sup> Intuitively, this result can be explained as follows. In the Nash framework, each

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<sup>8</sup>As explicitly proven by Varian(1992, pp.297-298), under the conditions (which are satisfied in our model) that: (i) the objective function  $W_i(I_i, I_j)$  is a strictly decreasing function of  $I_j$  (i.e.  $\frac{\partial W_i}{\partial I_j} = (-\frac{\partial^2 F_i}{\partial K_i^2} + t)\frac{\partial K_i}{\partial I_j} < 0$ ), and (ii) the best response function of a region with respect to the other region is strictly decreasing

region chooses its level of public input independently, and tends to ignore the negative externality that it would cause on the tax base of the other region when it raises its public input. Thus, the Nash provision of public input in each region is determined by maximizing its own welfare without considering the other region's action. In contrast, under the Stackelberg framework, the follower will reduce its public input if it observes a higher public input level chosen by the leader;<sup>9</sup> the leader anticipates this and consequently increases its own public input. As a result, the leader's provision of public input in the Stackelberg equilibrium is higher than in the Nash equilibrium; while at the same time the follower selects a level of public input in the Stackelberg equilibrium that is lower than the level selected in the Nash equilibrium.

### 3.4 Policy implications and numerical solutions

Proposition 1 highlights an important result obtained by [Cai and Treisman \(2005\)](#). Due to the heterogeneity of regional productivity, competition for capital leads to an asymmetric outcome with the more productive region spending more on public input and attracting more capital than the less productive region. Consequently, any existing regional disparity is anticipated to get larger in a decentralized economy with heterogeneous competing regions. If the continued disadvantage in attracting capital is deemed undesirable in the less productive region, there is a need to consider some policies through which this situation can be mitigated or even reversed. In this regard, Proposition 2 suggests a possible solution. The less productive region may take advantage by trying to become the first mover in the public input competition, and so utilizing the first-mover advantage to offset some of

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(i.e. equation (9) ), a region's equilibrium payoff in the Stackelberg game is larger if it is the leader than if the counterpart region is the leader. The exact proof process is similar to what we provided as proof for proposition 2, thus it is not duplicated in this paper. However, this result is shown numerically in the next subsection.

<sup>9</sup>The reason for this reaction is due to the property of strategic substitution of public input between regions, which is given by Lemma 1. It should be noted that this is the key to drive asymmetric policy responses for the two regions in the Stackelberg game when public input is employed as the tool for competition. As a comparison, in the case of tax competition, tax rates are shown to be strategic complements, which implies that under the Stackelberg game the follower region will increase its tax rate if it observes a higher level of tax rate chosen by the leader region, leading to a similar policy response of the two regions.

the competitive disadvantage that is generated by the preexisting heterogeneity of regional productivity.

In order to illustrate this point more vividly, we conduct some numerical simulations, based on the following settings. The stock of total capital is fixed at 100, the technology parameter  $a$  is set at 50, the decline rate of marginal product of capital  $b$  is set at 2, and the capital tax rate  $t$  is set at 20%. Then, the degree of production asymmetry across regions  $\delta$  is increased in steps from 1 up to 10, and the two equilibria are computed for each case. The results are presented in Figure 1. As characterized in Proposition 1, the upper half of Figure 1 shows that under the Nash equilibrium, an increase in the degree of production asymmetry leads to an increase in the gap of investment in public input (and so capital allocation) between regions 1 and 2. Turning to the Stackelberg equilibrium, Figure 1 shows that for whichever a region is assumed to be the leader in the competition, its resulting selection of public input (and so capital received) are always higher than the corresponding levels under the Nash equilibrium, which reflects the outcomes summarized in Proposition 2. In support of our above policy suggestion, when region 2 is the leader (i.e. the upper half of Figure 1(b)), and the degree of production asymmetry is relatively low, i.e.  $\delta < 6$ , the competing disadvantage of region 2 in a non-cooperative competition framework is completely reversed; while in other cases with larger degrees of production asymmetry, the gap between regions 1 and 2's choices of public input and capital received is mitigated. Nevertheless, it should also be noted that if the opposite is observed—region 1 is the leader (i.e. the upper half of Figure 1(a)), then the effect of the heterogeneity of regional productivity will be strengthened, which eventually leads to an even larger regional gap in terms of the regions' choices of public input and capital received.

### 3.5 Further discussion

The previous results highlight the importance of identifying the potential leadership in the public input competition game, as it does not only matter for the policy choice of the regions

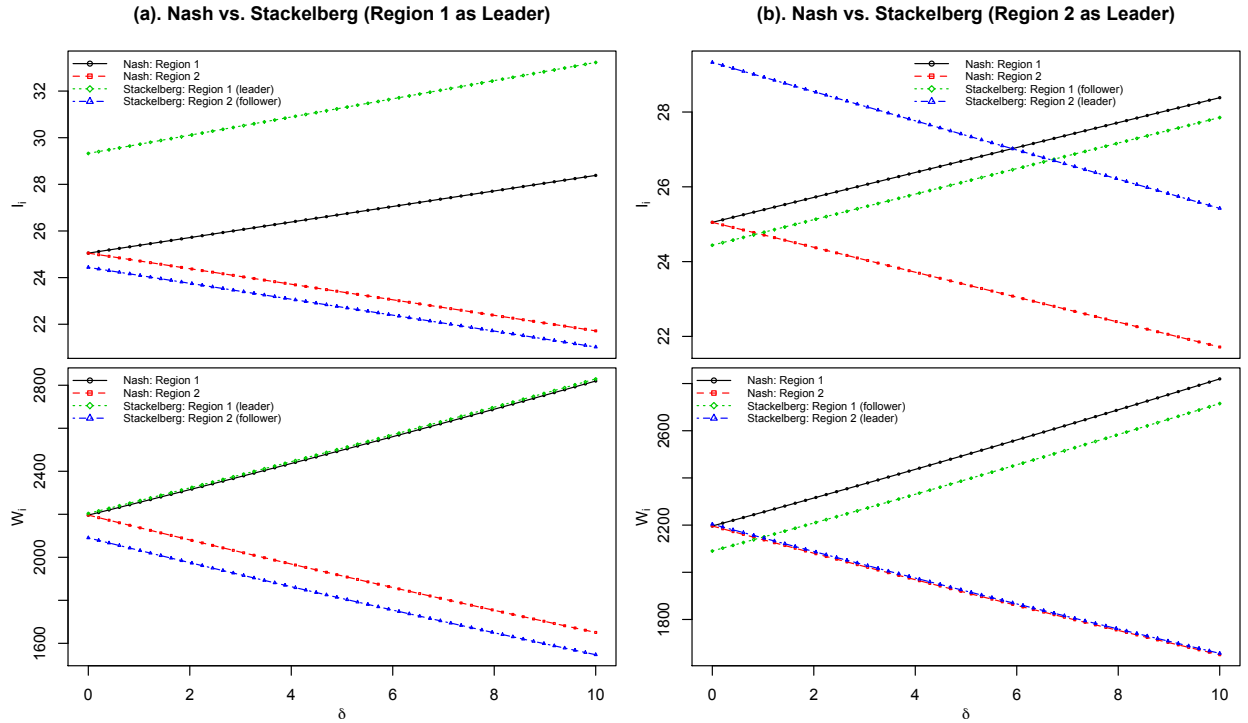


Figure 1: Basic Simulation Results

but also affect the ultimate pattern of regional development in the economy. Hence, it would be relevant to answer the following two questions. First, from a regional perspective, which region (the more productive region or the less productive region) has a larger incentive to become the leader? Second, from the social planner's perspective, is it necessary for the social planner to intervene the timing dimension of the game if a Stackelberg type of competition is in place?

### 3.5.1 Equilibrium payoff functions

Before we proceed to explore the above two questions more thoroughly, let us first derive the equilibrium payoff functions for both regions in both Nash and Stackelberg game settings, which will serve as the basis for our analysis.

Substituting the production functions (3), the cost function, and the corresponding Nash and Stackelberg equilibria of public input and capital into equation (2), we obtain the equi-

librium payoff functions

$$\begin{cases} W_1^N = \frac{4b-1}{2} \left( \frac{\bar{K}}{4} + \frac{t}{2b} + \frac{\delta}{2b-1} \right)^2 - \frac{t^2}{2b} \\ W_2^N = \frac{4b-1}{2} \left( \frac{\bar{K}}{4} + \frac{t}{2b} - \frac{\delta}{2b-1} \right)^2 - \frac{t^2}{2b} \end{cases} \quad (13)$$

and

$$\begin{cases} W_1^L = \frac{[(2-4b)(b\bar{K}+2t)-8b\delta]^2}{8b(16b^2-12b+1)} - \frac{t^2}{2b} \\ W_2^F = \frac{(4b-1)[(3-4b)(b\bar{K}+2t)+(4b-1)2\delta]^2}{2(16b^2-12b+1)^2} - \frac{t^2}{2b} \end{cases} \quad \text{or} \quad \begin{cases} W_1^F = \frac{(4b-1)[(3-4b)(b\bar{K}+2t)+(1-4b)2\delta]^2}{2(16b^2-12b+1)^2} - \frac{t^2}{2b} \\ W_2^L = \frac{[(2-4b)(b\bar{K}+2t)+8b\delta]^2}{8b(16b^2-12b+1)} - \frac{t^2}{2b} \end{cases} \quad (14)$$

where  $(W_1^N, W_2^N)$  is the Nash equilibrium payoff functions, and  $(W_1^L, W_2^F)$  and  $(W_1^F, W_2^L)$  are the Stackelberg equilibrium payoff functions for regions 1 and 2, each being alternatively the leader. Confirming what we found above regarding the effects of the heterogeneity of initial productivity and the first-mover advantage of the leader region in the Stackelberg setting, the simulated payoff functions in the bottom half of Figure 1 show that the larger is the heterogeneity of initial productivity,  $\delta$ , the more divergence is the regional payoffs; and for whichever region serves as the leader in the Stackelberg game, it obtains a higher payoff than what it would obtain under a Nash setting while the follower region achieves the opposite.<sup>10</sup>

### 3.5.2 Regions' choice

The answer to the first question regarding the regions' incentives to become a leader is directly related to the potential gains of being a leader or the potential losses of becoming a follower in the competition. Therefore, we define the "leader's premium" as the difference between the Stackelberg equilibrium payoff for region  $i$  being a leader and the Nash equi-

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<sup>10</sup>It is also noticeable from Figure 1 that the extra payoffs for a region to be a leader appears to be smaller in magnitude than the losses of the same region to be a follower in the competition.

librium payoff for the same region (i.e.  $W_i^L - W_i^N, i = 1, 2$ ), and we define the “follower’s loss” as the difference between the Nash equilibrium payoff for region  $j$  and the Stackelberg equilibrium payoff for the same region being a follower (i.e.  $W_j^N - W_j^F, j \neq i$ ). Next, based on the above assumed parameter values, we simulate both the “leader’s premium” and the “follower’s loss” by alternatively considering regions 1 and 2 as the leader. The results are depicted in Figure 2. As shown, the results clearly suggest that the premium for region 1 to be the leader is relatively larger than the corresponding premium that region 2 can obtain if it is the leader; at the same time, the potential loss for region 1 being a follower is also larger than what region 2 would lose if it is the follower. In addition, these disparities between the two regions are increasing in the regional heterogeneity of initial productivity. An important implication from these exercises is that region 1—the more productive region—would appear to have a relatively larger incentive to become the leader as it can obtain a higher level of premiums or avoid a larger loss of payoff. In an economy with potential intervention from the social planner, this also means that the more productive region would be willing to pay more to be the leader if that was required.

### 3.5.3 Social planner’s choice

As the main policy message conveyed by the analysis above, the selection of who becomes the leader may become a possible tool to remedy regional disparities that are caused by the heterogeneity in initial productivity. This can be achieved by ensuring that the less productive region moves first in the competition. However, which region actually is the leader would presumably depend on historical factors and the possible intervention from the social planner. This brings us to our second question regarding whether the social planner has the incentives to intervene the timing dimension of the competition game.

The answer to this question is at least partially related to the type of social planner we have—for example, in a broad sense, whether the social planner is a Utilitarian type or a Rawlsian type. Below, we consider these two extreme cases. We define the objective function

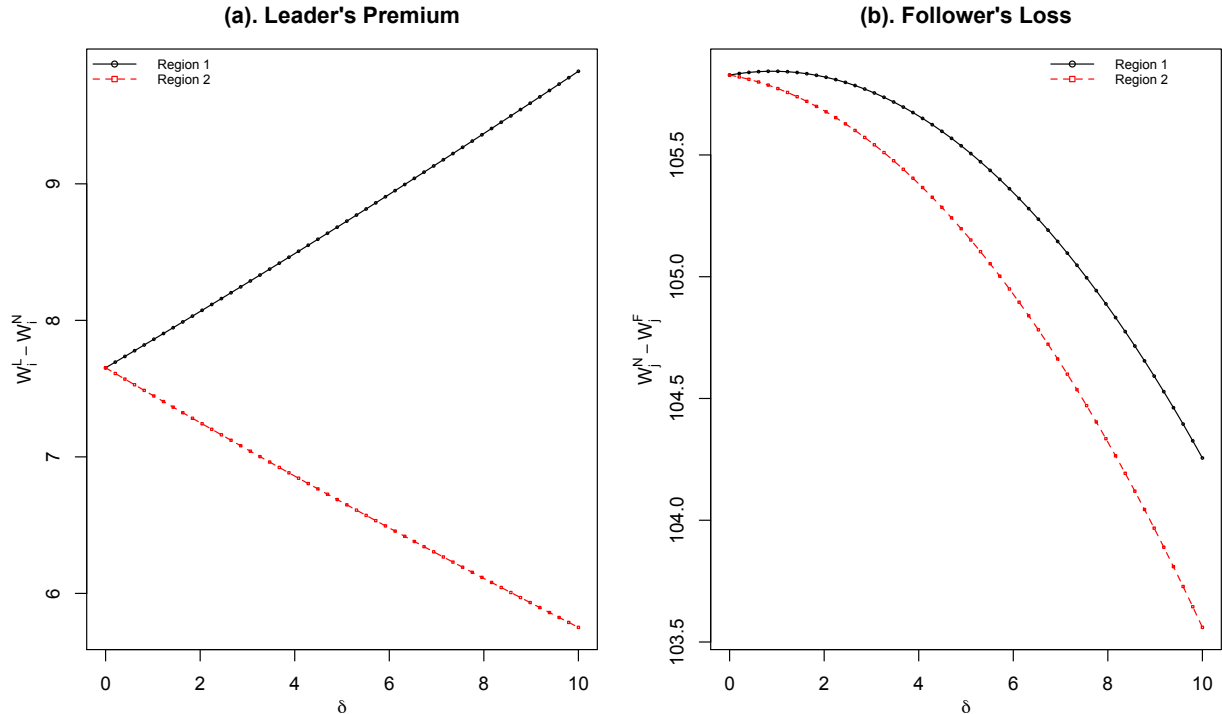


Figure 2: Leader's Premium and Follower's Loss

of a Utilitarian social planner as that maximizes the summation of the equilibrium payoff of both regions; and define the objective function of a Rawlsian social planner as one that minimizes the difference of the equilibrium payoff between the two regions. We present the simulated results for both Nash and Stackelberg equilibriums (considering regions 1 and 2 alternatively as the leader) in Figure 3. Focusing first on the Utilitarian social planner, Figure 3(a) indicates that in the Nash case, maintaining a mechanism to ensure both regions move simultaneously would achieve the highest social welfare; while provided that the Stackelberg type of competition is in place, ensuring region 1 to move first would lead to a better outcome as it induces more capital moving from the less productive region to the more productive region. On the contrary, as shown in Figure 3(b), the best choice for a Rawlsian type of social planner appears to ensure the less productive region to become the leader in the competition as it induces more capital to be allocated to the less productive regions, which ultimately reduces regional disparity.

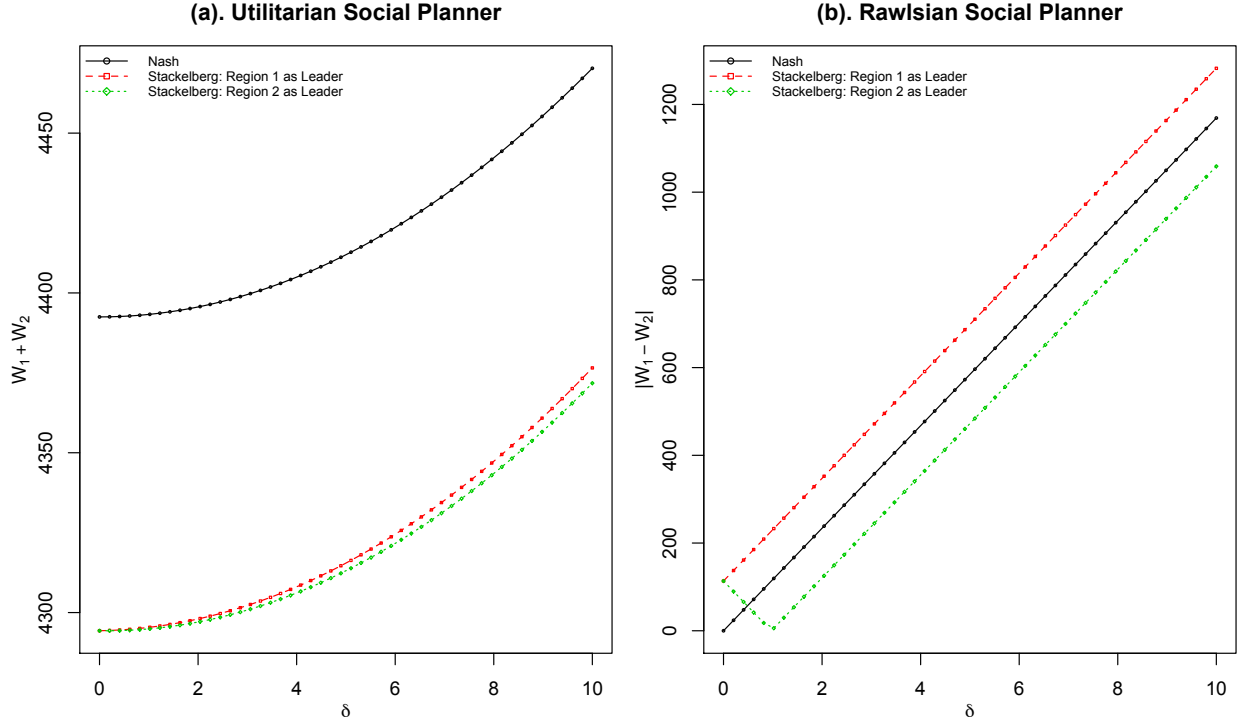


Figure 3: Utilitarian vs. Rawlsian Social Planners

## 4 Concluding remarks

Inspired by some recent work that revisited tax rate competition under a Stackelberg game framework, this paper extends the analysis to the case of competition through public input. Given two asymmetric regions, we show that public input is a strategic substitute among the competing regions in the public input competition model. A further comparison of the Stackelberg equilibrium and Nash equilibrium suggests an asymmetric outcome for the leader region and the follower region: while the leader region sets a higher level of public input under the former game setting than the latter, the follower region does the opposite. In addition, under a non-cooperative game framework, we echoed an important result found in some previous studies—the more productive region tends to select a higher level of public input, which results in attracting more capital than the less productive region. A key policy message that follows from our findings is that the competing disadvantage of the less productive region

can be mitigated (enlarged) when we allow regions to behave in a Stackelberg fashion and let the less productive region (the more productive region) to be the leader in the competition game.

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