Follow you, Follow me in tax and investment competition models*

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December 16, 2015

Abstract

We study a model in which asymmetric regions compete for capital, using both public investments and taxes. Public investments increase the productivity of capital and they also serve to stake out a positive advantage in the tax competition stage. We show that, under sufficient asymmetry, sequential choice of taxes achieves higher public investments by both regions over the simultaneous tax game. We also show that regions prefer to choose investment before taxes. Investment game displays the negative externalities and strategic substitutability, and regions prefer the simultaneous choice of investment. Relative to efficiency criterion, the small region may overinvest to acquire mobile capital, and the large region may overtax due to tax leadership.

JEL Classification: H30, H87, C72
Keywords: Endogenous timing, Tax competition, Public investments

*We would like to thank the Co-Editor (Kai Konrad) and the referees for their useful comments. An earlier version of this paper was circulated as "On the timing of tax and investment in fiscal competition models". We acknowledge helpful comments from audience and participants at the Welfare Economics Workshop at CORE (Louvain-la-Neuve, 2014), the 14th Journees Louis-Andre Gerard-Varet Conference in Public Economics (Aix-en-Provence, 2015), the 71th Annual Meeting of International Institute of Public Finance (Dublin, 2015), and the 30th Annual Congress of the European Economic Association (Mannheim, 2015). Nishimura acknowledges the financial support from the Grants-in-Aid for Scientific Research (C) (the Ministry of Education, Culture, Sports, Science, and Technology, 24530348, 15K03511) and Strategic Young Researcher Overseas Visits Program for Accelerating Brain Circulation (Japan Society for the Promotion of Science, J2402).

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1 Introduction

Many developing countries rely heavily on corporate income tax (CIT), both as a proportion of GDP and as a proportion of tax revenue (Abramovsky et al. 2014).[1] Whereas CIT is important for the mobilization of tax revenue in developing countries, these countries face a globalised world with competition to acquire mobile capital. As a result of the tax competition, firms are able to extract rents in the form of tax incentives from competing jurisdictions. However, by providing tax incentives, governments in low-income countries forego substantial revenue that instead could be used to foster the elements that really drive foreign investment (for example, human capital, infrastructure and electricity).[2] Indeed, evidence shows that, instead of tax incentives, investors are more likely to be driven into a country by a stable economic and political environment, good infrastructure and availability of basic services (see Besley and Persson 2011, IMF 2011).[3]

In this paper, we highlight the international competition for capital and firms as the driving forces of public investment. We point to the feedback loop from public investment to taxation in the context of intergovernmental competition between developing and developed countries. When the government invests in productivity-enhancing infrastructure, it increases its fiscal capacity. This complementarity can create virtuous circle between taxation and public investment. Therefore, one interesting option for developing countries to reduce offering tax incentives in equilibrium is to use public investment to increase their fiscal capacity.

To make this point, we use a simple framework with the following elements: (1) two countries of different size compete for firms and capital, the smaller country being a developing country with less market power on the global capital market; (2) the smaller country offers tax incentive to compensate for its smaller market; (3) each country undertakes public investment that drives foreign investment and promotes economic growth; (4) public investment also has a positive effect on the government's ability to raise tax revenue; (5) private capital is owned (mostly) by non-residents; (6) there is low appropriability of the investment benefits for the residents when countries

[1]In 2010, CIT revenues represented about 20 per cent of revenues in low-income countries compared with 15 per cent in high-income countries.

[2]Keen and Simone (2004) argue that international competition for capital is more damaging for developing countries which are typically constrained to offer tax incentives to attract (or retain) capital and firms.

[3]Besley and Persson (2011, 2013) develop a general framework to study the equilibrium interaction between taxation and investments in fiscal capacity. They highlight the political forces as the key driver of investment in fiscal capacity.

compete for capital.

Considering the choice of public investment prior to tax competition, we show that it is always preferable for the smaller (developing) country to set its tax in response to the tax chosen by the larger (developed) country, even under endogenous investments; that is to say, the smaller country should let the tax initiative to the larger country. This tax-matching strategy not only raises equilibrium taxes of both countries, but also, under sufficient asymmetry, induces higher public investments in the developing country, than it would otherwise. So the developing country ends up with more tax revenue and more public investment than it would obtain otherwise. We then show the commitment value of investment in the sense that both countries prefer to make irrevocable investment decisions before choosing taxes. We also examine the investment game closely. We show that investments are strategic substitutes, and that there exists a first-mover incentive for both countries. Therefore, no country can take the leadership in the investment game (in contrast to the tax game).

1.1 Background

There is a vast literature on commitment and leadership in Industrial Organisation. Von Stackelberg (1934) shows that the leading firm in a Cournot duopoly can obtain higher profit than the follower by committing to a high production quantity. Gal-Or (1985) and Dowrick (1986) show that the first-mover (the leader) gains higher payoff only if the actions of the leader and the follower are strategic substitutes. In order to induce a reduction in the rival's output, the leader produces more than in any Cournot equilibrium. Bulow et al. (1985) give the exact definition of the terms strategic substitutes and strategic complements. Milgrom and Roberts (1990) study a rich class of noncooperative games with strategic complementarities. More recently, a new development emerged based on endogenous timing. Hamilton and Slutsky (1990) propose the endogenous timing game in which both players decide in a preliminary stage between sequential move or simultaneous move. Using this construct, Amir and Grilo (1999) show that Cournot solution always emerges as the solution of the endogenous timing game when quantities are strategic substitutes for both firms. Amir and Stepanova (2006) show that for price competition there is a second-mover advantage when the unit costs of the two firms are sufficiently close.[4] In contrast, for the quantity competition, there is a first-mover advantage. Drawing a parallel between price

[4] However, for sufficient asymmetry in the unit costs of production, the dominant (low cost) firm has a first-mover advantage.

competition and tax competition, Wang (1999) and Baldwin and Krugman (2004) were the first to study a sequential tax competition model between countries of different size assuming that the dominant country takes the initiative. Kempf and Rota Graziosi (2010) show that sequential tax play will emerge from the endogenous timing game, and that the risk-dominant outcome is the leadership by the small region. Hindriks and Nishimura (2015a) show that defining size in terms of market dominance leads to the endogenous leadership by the large region. There are some empirical evidence on tax leadership. Altshuler and Goodspeed (2015), Chatelais and Peyrat (2008), and Redoano (2007) provide some evidence for the US and the European tax competition.[5] In a broader sense, tax leadership could be interpreted as any tax commitments susceptible to influence tax choices (such as the most-favored-nations rule in international tax laws, fiscal ruling agreement and tax delegation).[6] Hoffmann and Rota Graziosi (2010) and Eichner (2014) provide a useful analysis that relates the sequential and simultaneous play to the sign of the interregional externalites and to the sign of the slopes of the reaction function. Keen and Konrad (2013) provide a good discussion of tax leadership with a useful graphical illustration.

The main novelty of our approach is to study purposeful and forward-looking decisions to invest in public infrastructure shaping the creation of fiscal capacity. We study how the timing of taxes governs the investment decisions, and how these relate to exogenous economic difference.

Strategic effects do not only result from being the (price or tax) leader in the market, but also from investing in R&D, investing in production capacity, investing in productivity enhancing technology. The goal of such type of commitment strategies is to influence the future behavior of its rival and to improve its own competitive position. Brander and Spencer (1983) and Fudenberg and Tirole (1984) introduce a duopoly model where both firms can invest in R&D reducing unit cost of production, before the firms compete in quantities or in prices in the market. They show that firms have incentives to overinvest or to underinvest to induce a favorable reaction from the rival. On the strategic effect of investment on tax decisions, Besley and Persson (2011, 2013) concentrate on state-building investment to improve fiscal capacity under the constraint of political competition. They show that political competition induces under-investment. Hindriks et al. (2008) and Pieretti and Zanaj (2011) concentrate on state-building investment to improve fiscal capacity under the constraint of international tax competition. They also ob-

[5] In industrial organisation, price leadership is well documented: see Seaton and Waterson (2013) for recent empirical evidence of price leadership in British supermarkets.

[6] Hines and Logue (2015) provide several arguments for delegating tax.

tain under-investment. Keen and Marchand (1997) and Bucovetsky (2005) show that tax competition will distort the pattern of public expenditures, with a relative overprovision of public input against public consumption.[7] Our contribution to the tax-investment literature is to endogenize the timing structure instead of assuming a specific timing.

2 The model

We will use the linear model as a vehicle to make our point clearer.[8] As we will show throughout the paper, the simple model used does not compromise the generality of our main results. Indeed, most of the reasoning is performed without assuming the specific model. There are two regions $i = 1, 2$. The regional governments choose the tax on mobile capital t_i, and a level of public investment g_i. Under free mobility of capital, $t = (t_1, t_2)$ and $g = (g_1, g_2)$ determine the allocation of capital x_1 and x_2 across regions. In the linear model, production in each region is:

$$F^1(x_1; g_1) = \left(\gamma + g_1 + \frac{\delta\epsilon}{2}\right) x_1 - \delta\frac{x_1^2}{2},\ F^2(x_2; g_2) = \left(\gamma + g_2 - \frac{\delta\epsilon}{2}\right) x_2 - \delta\frac{x_2^2}{2}, \tag{1}$$

for constants $\gamma > 0$, $\delta > 0$, and $\epsilon \geq 0$. Let the subscripts denote the partial derivatives of the production function (e.g., $F_g^i(x_i; g_i) \equiv \partial F^i/\partial g_i$ and $F_{xx}^i(x_i; g_i) \equiv \partial^2 F^i/\partial(x_i)^2$). Our main assumptions are $F_g^i > 0$, $F_x^i > 0 > F_{xx}^i$ and $F_{xg}^i > 0$. It is also assumed that there is no investment spillover, that is, $\partial F^i/\partial g_j = 0$ for $i \neq j$. However, public investment enables each region to expand its tax base at the expense of the other. This negative externality creates incentives for possibly excessive investment. We consider both symmetric regions ($\epsilon = 0$) and asymmetric regions ($\epsilon > 0$). For the linear model, we make specific assumptions to guarantee a positive amount of capital in equilibrium in each region.

Assumption 1 *(For the linear model)* $\delta > \frac{1}{1-\epsilon}$, $\gamma \geq \frac{65}{50}\delta$.

[7] Aronsson and Wehke (2008) showed that the relative overprovision of the public input good derived by Keen and Marchand (1997) may no longer hold in the presence of unemployment.

[8] Most papers on leadership games use the linear model. The same is true about papers on strategic commitments. The reason is that with the linear model we are assured that the welfare function is concave, hence single peaked. The linear model also helps making the analysis of the multi-stage game of investment and tax more manageable, without sacrificing the economic insights.

Note that the first condition is equivalent to assume that $\epsilon < \frac{\delta-1}{\delta}$ where $\delta > 1$ ensures decreasing returns to scale. The second condition requires γ to be sufficiently high to assure positive net return of capital in both regions.

In this model, g_i can represent public infrastructure, business public services, human-capital investment, R&D investments. The key point is that this public investment enhances the regional productivity of capital (and labor). In the linear model, similar to Hindriks and Nishimura (2015a), we model the exogenous regional economic difference by a parallel shift of the linear inverse demand of capital.[9]

Capital is owned by non-residents.[10] The regional firm purchases the capital x_i from abroad at a competitive price equals to the marginal productivity of capital $\partial F^i/\partial x_i \equiv F_x^i(x_i; g_i)$. The source based unit tax t_i is levied, so $F_x^i(x_i; g_i) - t_i$ is the net return of capital which is a function of tax and investment choices. For convenience, the cost of investment g_i is given by the function

$$c_i(g_i) = \frac{g_i^2}{2}. \tag{2}$$

Each region i maximizes its welfare function:

$$\begin{aligned} W_i(t, g) &= F^i(x_i; g_i) - F_x^i(x_i; g_i)x_i + t_i x_i - c_i(g_i) \\ &= \delta\frac{x_i^2}{2} + t_i x_i - \frac{g_i^2}{2}. \end{aligned} \tag{3}$$

The second equation is specific to the linear model and will only be used to compute closed form solutions. We assume that investment cost is not financed by capital income tax, so that public investment is an independent policy instrument that is not tied down to tax rate by the budget constraint.[11]

The capital is perfectly mobile between regions. Normalizing to unity the total supply of capital, the arbitrage and the market clearing conditions involve:

$$F_x^1(x_1; g_1) - t_1 = F_x^2(x_2; g_2) - t_2, \;\; x_1 + x_2 = 1.$$

[9] Alternative modelling of the linear demand model would consider different slopes with the same vertical intercept (as in Kempf and Rota-Graziosi, 2010). This will not change our main findings.

[10] This assumption is stronger than what is required to obtain our main findings. In fact, what is needed is the positive tax externality (i.e., each region benefits from a tax increase in the other region). With full regional ownership of capital, the tax externality becomes negative for the capital exporting region (see Ogawa 2013). Using a continuity argument, Hindriks and Nishimura (2015b) showed that there exists a threshold in capital ownership such that preferences over taxation will switch over. Hence, our main findings carry over for any degree of capital ownership below that threshold.

[11] The previous studies of tax competition with public inputs consider that public inputs are entirely financed by capital income tax (see Zodrow and Mieszkowski (1986), Keen and Marchand (1997), Bucovetsky (2005), and Aronsson and Wehke (2008)).

For the linear specification, we can express the equilibrium distribution of capital in a convenient and readily interpretable form:

$$x_1 = \frac{1+\epsilon}{2} + \frac{(g_1 - g_2) - (t_1 - t_2)}{2\delta}, \quad x_2 = \frac{1-\epsilon}{2} - \frac{(g_1 - g_2) - (t_1 - t_2)}{2\delta}. \quad (4)$$

Thus the equilibrium distribution of capital depends on the exogenous economic difference (ϵ), the endogenous economic difference in investment levels ($g_1 - g_2$), and tax rates ($t_1 - t_2$).

As a benchmark we first describe the efficient outcome that maximizes total welfare under full coordination on taxes and investments. The efficient outcome, denoted by the superscript o, requires

$$\begin{aligned} F_g^i(x_i^o; g_i^o) &= c_i'(g_i^o) \ (i = 1, 2), \\ t_1^o &= t_2^o = F_x^i(x_i^o; g_i^o) \end{aligned}$$

These conditions are the Diamond-Mirrlees (1971) rule of the desirability of productive efficiency. Efficient taxation requires to extract the full rent from the capital owners ($t_i^o = F_x^i(x_i^o; g_i^o)$).[12] Even though public investments do not change the allocation of capital, it is efficient to choose positive amount of investment because it increases the productivity of capital which is then fully taxed.[13] In the following sections we examine departure from efficiency when rents cannot be fully taxed. We consider a two-stage game in which regions first make irrevocable investments, and then they compete in taxes. Tax game can either be Nash or Stackelberg competition.

3 Investment choices for different tax competitions

3.1 Nash tax competition

In the first stage, regions simultaneously make public investments. Then in the second stage, regions simultaneously make tax decisions. In this two-stage model, public investment has three effects. The first effect is to raise the productivity of capital and thus the regional output. The second effect

[12]This is because capital owners are non residents. We would get the same result if capital owners were residents and the government does not care about their welfare.

[13]For the linear model, the first conditions imply $g_i^o = x_i^o$ $(i = 1, 2)$. Then using the second conditions together with the resource constraint give the efficient investment levels $g_1^o = \frac{1}{2}\left(1 + \frac{\delta\epsilon}{\delta-1}\right) \geq g_2^o = \frac{1}{2}\left(1 - \frac{\delta\epsilon}{\delta-1}\right)$.

is to attract capital from the other region which increases both the regional output and the tax base. This is a negative investment externality for the other region. The third effect is the strategic effect of investment on tax choices. It is the interaction of these three effects that will determine how equilibrium investments compare with the first best levels.

The game is solved backwards. For the tax choices, taking $g = (g_1, g_2)$ as given, each region i simultaneously and independently chooses t_i so as to maximize $W_i(t, g)$. The tax reaction functions $t_i = \tau_i(t_j; g)$ (for $i = 1, 2$) are implicitly defined by[14]

$$t_i = -F^j_{xx} \cdot x_i(t, g), \; j \neq i. \tag{5}$$

Totally differentiating (5) with respect to taxes, it is readily seen that tax reaction functions are upward sloping with gradients less than one when $F^j_{xxx} \geq 0$ (with for the linear model, $F^j_{xxx} = 0$). Hence taxes are strategic complements.[15]

Solving the system of equations (5) yields the solution of the Nash tax game, $t^N(g)= (t^N_1(g), t^N_2(g))$. It has the feature that $\frac{\partial t^N_i}{\partial g_j} < 0$ for $i = 1,\ 2$ and $i \neq j$, which is the negative strategic effect of investment (investment in one region reduces the tax rate in the other region). The reason is best seen from (5) and the fact that x_i is decreasing in g_j: investment enables a region to expand its tax base at the expense of the other which then has lower incentive to tax.[16] On the other hand, domestic tax is increasing with own investment ($\frac{\partial t^N_i}{\partial g_i} > 0$ for $i = 1,\ 2$). Higher public investment expands the tax base and enhances the ability to tax. This creates a complementarity between public investment and taxation.

Moving backwards, public investment in region i maximizes $V^N_i(g_1, g_2) \equiv W_i(t^N(g), g)$ $(i = 1,\ 2)$. The first-order condition for investment in region i is

$$\frac{\partial V^N_i}{\partial g_i} = \frac{\partial W_i}{\partial g_i} + \frac{\partial W_i}{\partial t_i}\frac{\partial t^N_i}{\partial g_i} + \frac{\partial W_i}{\partial t_j}\frac{\partial t^N_j}{\partial g_i} = 0.$$

[14] See, e.g., Kempf and Rota-Graziosi (2010), equation (8).

[15] Note that in Zodrow and Mieszkowski (1986) type of tax competition, higher tax induces higher public investment which would increase the productivity of capital. As a result, tax reaction functions may slope up or down.

[16] In the linear model, $\tau_1(t_2; g) = \delta\left(\frac{1+\epsilon}{3} + \frac{g_1-g_2}{3\delta}\right)+\frac{t_2}{3}$, $\tau_2(t_1; g) = \delta\left(\frac{1-\epsilon}{3} - \frac{g_1-g_2}{3\delta}\right)+\frac{t_1}{3}$. The Nash equilibrium is $t^N_1(g) = \frac{\delta(2+\epsilon)+(g_1-g_2)}{4}$, $t^N_2(g) = \frac{\delta(2-\epsilon)-(g_1-g_2)}{4}$, so $\frac{\partial t^N_i}{\partial g_j} = -\frac{1}{4}$ and $\frac{\partial t^N_i}{\partial g_i} = \frac{1}{4}$. For a more general production function, we can show that $\frac{\partial t^N_i}{\partial g_j} < 0$ and $\frac{\partial t^N_i}{\partial g_i} > 0$ if $F^i_{xxx} \geq 0$ and $F^i_{xxg} = 0$.

Using the envelope theorem to eliminate the second term given optimal tax choice, it is shown in the Appendix that,

$$\frac{\partial V_i^N}{\partial g_i} = \frac{\partial W_i}{\partial g_i} + \frac{\partial W_i}{\partial t_j}\frac{\partial t_j^N}{\partial g_i} = F_g^i(x_i(t,g);g_i) - c_i'(g_i) + \frac{\partial t_j^N}{\partial g_i}x_i(t,g) = 0. \quad (6)$$

Given the negative strategic effect of investment ($\frac{\partial t_j^N}{\partial g_i} < 0$), the last term is negative so that investment is inefficient ($F_g^i(x_i;g_i) > c'(g_i)$). In particular for the linear model, we obtain $g_i^N = \frac{3}{4}x_i^N$ ($i = 1,2$) in the equilibrium, whereas efficient investment is $g_i^o = x_i^o$ ($i = 1,2$). Moreover, the large region taxes higher than the small region ($t_1^N \geq t_2^N$, with strict inequality when $\epsilon > 0$) so that equilibrium allocation of capital is inefficient: $x_1^N < x_1^o$ and $x_2^N > x_2^o$ when $\epsilon > 0$. Therefore, there is underinvestment for the large region ($g_1^N < g_1^o$) but there is ambiguity for the small region ($g_2^N \gtrless g_2^o$). In the earlier version (Hindriks and Nishimura (2014)), we show that $g_2^N < g_2^o$ if and only if $\epsilon < \left(\frac{\delta-1}{\delta}\right)\left(\frac{8\delta-3}{20\delta}\right)$. Also, because regions do not cooperate on tax rates, they will choose too little taxation of capital, from the perspective of their residents ($t_i^N < t_i^o,\ i = 1,2$).

3.2 Stackelberg tax competition

We now turn to the Stackelberg tax game. We focus on the tax leadership by the large region 1. In Hindriks and Nishimura (2015a) we provide argument for this form of tax leadership to emerge endogenously in a game without investment. The leadership argument is based on market power. Extending that argument in a model with endogenous investment requires that region 1 remains the large region (in terms of market power) in equilibrium. We will show that this holds true in equilibrium.

Proceeding backwards, we first solve the Stackelberg tax game. Given $g = (g_1, g_2)$, the follower (region 2) will choose t_2 so as to maximize $W_2(t_1, t_2, g)$, yielding the tax reaction function $\tau_2(t_1; g)$ as in (5). The tax leader will maximize $W_1(t_1, \tau_2(t_1; g), g)$ with respect to t_1 by moving along $\tau_2(t_1; g)$. The first-order condition yields[17]

$$t_1 = \frac{-F_{xx}^2 - \tau_2' F_{xx}^1}{1 - \tau_2'} x_1(t, g),$$

where $\tau_2' = \frac{\partial \tau_2(t_1;g)}{\partial t_1} \in (0,1)$ measures the influence of t_1 on t_2. The Stackelberg tax equilibrium is denoted by $t_1^S(g)$ and $t_2^S(g) \equiv \tau_2(t_1^S(g); g)$. Given

[17] See, e.g., Kempf and Rota-Graziosi (2010), equation (10).

g, one can apply Kempf and Rota-Graziosi (2010, Lemma 2) to show that $t_1^S(g) > t_1^N(g)$ and $t_2^S(g) > t_2^N(g)$: Stackelberg taxes are higher than Nash taxes in games with strategic complementarities.[18] The negative strategic effect of investment continues to hold in the Stackelberg game ($\frac{\partial t_i^S}{\partial g_j} < 0,\ i \neq j$).[19]

Moving backwards, public investment in region i maximizes $V_i^S(g_1, g_2) \equiv W_i(t^S(g), g)$ $(i = 1,\ 2)$. The following first-order conditions are shown in the Appendix:[20]

$$\begin{aligned} \frac{\partial V_2^S}{\partial g_2} &= \frac{\partial W_2}{\partial g_2} + \frac{\partial W_1}{\partial t_2}\frac{\partial t_1^S}{\partial g_2} = F_g^2(x_2(t,g);g_2) - c_2'(g_2) + \frac{\partial t_1^S}{\partial g_2}x_2(t,g) \quad (7) \\ &= 0. \\ \frac{\partial V_1^S}{\partial g_1} &= F_g^1(x_1(t,g);g_1) - c_1'(g_1) = 0. \quad (8) \end{aligned}$$

For the tax leader (region 1), it is worth noting that the efficiency condition $F_g^1(x_1(t,g);g_1) = c_1'(g_1)$ holds. For the tax follower (region 2), the formula is similar to (6). In the linear model, we obtain $g_2^S = \frac{3}{5}x_2^S$ and $g_1^S = x_1^S$. Compared with the Nash outcome, $g_i^N = \frac{3}{4}x_i^N$ $(i = 1, 2)$, for the same distribution of capital, the Stackelberg outcome involves more investment by the leading region and less investment by the following region. However, the distribution of capital is different and we need to compare explicitly the Nash and Stackelberg outcomes. The following is shown in the Appendix:

Proposition 3.1 *(i) $g_1^S > g_1^N$ for all parameter values: the Stackelberg leader invests more than in the Nash equilibrium.*

(ii) There exists $\epsilon^* \in (0,1)$ such that $g_2^S \leq g_2^N$ for $\epsilon \leq \epsilon^*$ and $g_2^S > g_2^N$ otherwise.

(iii) $t_1^S > t_1^N$ and $t_2^S > t_2^N$ for all parameter values.

The reason for the tax leader to invest more (compared to Nash) is that by investing more, the leader commits to tax more, which in turn induces a favorable increase in tax from the follower. Therefore, there is an additional benefit of investment for the tax leader.

Comparing the Stackelberg outcome with the efficient outcome, we get the following proposition.

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[18] See also Milgrom and Roberts (1990).

[19] In the linear model, the Stackelberg equilibrium is $t_1^S(g) = \frac{\delta(4+2\epsilon)+2(g_1-g_2)}{5}$, $t_2^S(g) = \frac{\delta(3-\epsilon)-(g_1-g_2)}{5}$, so $\frac{\partial t_1^S}{\partial g_2} < \frac{\partial t_2^S}{\partial g_1} < 0$.

[20] It may be worth noting that (7) and (8) do not make use of the linear specification. (8) is shown if $F_{xxx}^i \geq 0$ and $F_{xxg}^i = 0$. The first condition is required for taxes to be strategic complement. The second condition requires (for convenience) that the slope of the demand for capital is independent of the investment level.

Proposition 3.2 *(i) $g_1^S < g_1^o$ for all parameter values: the Stackelberg leader under-invests relative to efficiency.*

(ii) There exists $\epsilon^\circ \in \left(0, \frac{\delta-1}{\delta}\right)$ such that $g_2^S \leq g_2^o$ for $\epsilon \leq \epsilon^\circ$ and $g_2^S > g_2^o$ otherwise.

(iii) The follower region always under-taxes and the leader region may over-tax when γ is sufficiently small and ϵ is sufficiently high.

It is interesting to note that the tax leader may actually overtax under sufficient asymmetry. However, for $\epsilon = 0$, the leader always undertaxes. For sufficiently high γ, the tax leader also undertaxes.

4 The value of commitment

We now perform a welfare comparison between the Nash and Stackelberg outcomes to derive the possible benefit of tax commitment. We also extend this welfare comparison to the fully simultaneous choice of taxes and investment in which there is no investment commitment. Let the equilibrium outcome of the fully simultaneous game be (t^A, g^A). Plugging the equilibrium outcome in the welfare function gives $W_i(t^A, g^A)$ for $i = 1,\ 2$. The welfare ranking with and without commitment is the following:

Proposition 4.1 $W_i(t^S, g^S) > W_i(t^N, g^N) > W_i(t^A, g^A)$ *for* $i = 1,\ 2$. *Namely, (i) both regions are better off in choosing investment before taxes, and (ii) both regions are better off in choosing taxes sequentially rather than simultaneously.*

Part (i) of the proposition establishes the value of commitment for investment. This is illustrated in Figure 1 representing the investment game with and without commitment. At (t^N, g^N), when making irrevocable investment decisions before choosing taxes, both regions understand how those investment decisions influence tax choices. In contrast, when regions choose investments and taxes simultaneously, at (t^A, g^A), the investment strategic effect in (6) disappears which yields the efficient investment condition, $F_g^i - c_i'(g_i) = 0$ $(i = 1, 2)$. Noting that (5) is also satisfied at (t^A, g^A), we have $t^A = t^N(g^A)$. Then from $F_g^i(x_i(t^N(g), g); g) - c_i'(g_i) = 0$ at $g = g^A$, we derive the reaction function $g_i = g_i^A(g_j)$. Alternatively, let $g_i = g_i^N(g_j)$ be the investment-reaction function derived from (6). Since the strategic effect is negative in both regions, $g_i^N(g_j) < g_i^A(g_j)$ $(i = 1, 2)$ for all g_j. As a result, investment commitment leads each region to invest less: $(g_1^N, g_1^N) < (g_1^A, g_2^A)$. We now show that each region benefits from this joint investment reduction. Let $V_i^N(g_1, g_2) = W_i(t^N(g), g)$. Notice that

$W_i(t^A, g^A) = W_i(t^N(g^A), g^A) = V_i^N(g_1^A, g_2^A)$. Also, let $x_i^N(g) \equiv x_i(t^N(g), g)$. Then:

$$\frac{\partial V_i^N}{\partial g_j} = (-F_{xx}^i x_i + t_i)\frac{\partial x_i^N}{\partial g_j} + \frac{\partial t_i^N}{\partial g_j} x_i < 0. \tag{9}$$

In the first term, public investment in region j reduces the tax base of region i ($\frac{\partial x_i^N}{\partial g_j} < 0$),[21] with a marginal welfare loss in region i of $-F_{xx}^i x_i + t_i > 0$. In the second term, public investment in region j induces region i to lower its tax rate, reducing its tax revenue by the amount $\frac{\partial t_i^N}{\partial g_j} x_i < 0$. Hence, investment externalities are negative (unlike tax externalities). Given that result, the indifference curves in Figure 1 passing through (g_1^N, g_2^N) are such that $W_i(t^N, g^N) = V_i^N(g_1^N, g_2^N) > V_i^N(g_1^A, g_2^A) = W_i(t^A, g^A)$ $(i = 1, 2)$. That is, both regions are better off by making commitment on investment.[22] This strategic commitment is similar to the "puppy-dog ploy" strategy in industrial organisation in which firms choose to underinvest in cost-reducing technology to look inoffensive so as to trigger a favourable response from the rival (see Fudenberg and Tirole, 1984). In a nutshell, commitment on investment mitigates the harmful tax competition, and both regions prefer to pre-commit on investment in the context of low appropriability of the investment benefits for the residents.

Part (ii) of the proposition extends the arguments by Kempf and Rota-Graziosi (2010) and Hindriks and Nishimura (2015a) to a model in which governments make both tax and investment decisions. As we have discussed, strategic complementarity and positive tax externalities imply $t_i^S(g) > t_i^N(g)$ $(i = 1, 2)$. Moreover, endogenous investments involves $g_1^S > g_1^N$ for the tax leader. There is ambiguity for the tax follower $g_2^S \gtreqless g_2^N$, but tax leadership always Pareto dominates the simultaneous tax choices.

[INSERT FIGURE 1 ABOUT HERE]

5 Endogenous timing decision

We now analyse the endogenous timing decision to enhance the relevance of our commitment analysis. In particular, we have assumed so far that in-

[21] In the linear model, $\frac{\partial x_i^N}{\partial g_j} = -\frac{1}{4\delta} < 0$.

[22] To see this more clearly, consider $\epsilon = 0$. As long as public investments are set equal, they do not influence either the allocation of capital or the tax rates in equilibrium. The full benefit of investment is then expropriated by the capital owner. Notice that this *over*provision of the public investments is relative to the non-cooperative tax choices. As mentioned above, relative to the efficient outcome (with cooperative taxes) there is *under*investment ($g_1^N < g_1^o$, and $g_2^N < g_2^o$ for $\epsilon < \left(\frac{\delta-1}{\delta}\right)\left(\frac{8\delta-3}{20\delta}\right)$).

vestment decisions are simultaneous, and that only tax choices in the second stage can be sequential. To this end, we use the endogenous timing model of Hamilton and Slutsky (1990). In a pre-play stage, the regions simultaneously decide whether to move *Early* or *Late* in the following investment-tax competition game. In our extended version with the commitment on investment choices, we have separate stages for investments and taxes, with each stage consisting of the substages of announcement and policy choices. For each policy instrument (either investment or tax), if both regions choose the same timing, the instrument is chosen simultaneously. If both regions choose different timing, the policy instrument is chosen sequentially, according to the order of moves decided by the regions. So the timing of the game emerges endogenously as the subgame perfect equilibrium of the timing game.

There are many possible timing games to consider and it would be tedious to cover them all. In this section, we will study only the possibility of sequential investment in the first stage, assuming tax leadership in the second stage (i.e. the Stackelberg tax game described earlier). The motivation to restrict attention to this specific timing is based on the analysis in Kempf and Rota-Graziosi (2010) and Hindriks and Nishimura (2015a) showing that tax leadership is the equilibrium timing.[23] Also, following Hindriks and Nishimura (2005a), we consider that the tax leader is the large region.[24]

Considering the timing of investment, if both regions choose the same timing (either to move *Early* or *Late*) in the pre-play substage, both regions play as in Section 3.2 maximizing $W_i(t^S(g), g) \equiv V_i^S(g)$ with respect to g_i, anticipating the Stackelberg tax competition. The regions choose (g_1^S, g_2^S), and the resulting welfare level is $V_i^S(g_1^S, g_2^S) \equiv V_i^{NS}$, where the superscript *NS* refers to the Nash investment and Stackelberg taxation. On the other hand, if both regions choose different timing, they will play the investment game sequentially, and then they will play Stackelberg tax competition. Suppose that region i chooses *Early* and region j chooses *Late*. Then the follower solves $\max_{g_j} V_j^S(g_1, g_2)$, yielding the reaction function $r_j(g_i)$, and the leader chooses g_i so as to maximize $V_i^S(g_i, r_j(g_i))$. Let equilibrium welfare be V_i^{LS} for the investment leader, and V_i^{FS} for the investment follower. Therefore,

[23] Namely, given the investment choice $g = (g_1, g_2)$, region 1 chooses *Early* and region 2 chooses *Late* in the pre-play substage for taxes. Subsequently, regions choose $(t_1, t_2) = (t_1^S(g), t_2^S(g))$ as in Section 3.2. This equilibrium timing is induced by the strategic complementarity and positive tax externalities as discussed above. See also Eichner (2014, Proposition 1) and Hoffmann and Rota-Graziosi (2010, Theorem 1).

[24] This timing choice uses a risk dominance criterion to solve the coordination issue involved in the tax timing. Indeed, each region prefers to be the follower rather than the leader. But each region also prefers the sequential tax choice to the simultaneous tax choice (see Proposition 4.1). We come back to this coordination issue shortly.

the investment timing reduces to the following normal-form game:

		Region 2 (small)	
		Early	*Late*
Region 1 (large)	*Early*	V_1^{NS}, V_2^{NS}	V_1^{LS}, V_2^{FS}
	Late	V_1^{FS}, V_2^{LS}	V_1^{NS}, V_2^{NS}

Table 1: Investment Timing Game

We now show that there is a first-mover advantage in this investment game. First notice that the investment reaction functions slope down as illustrated in Figure 2 (i.e., strategic substitutability). Let $x_i^S(g) \equiv x_i(t^S(g), g)$ and let $r_i(g_j)$ denote the investment reaction functions. Differentiating the first-order conditions (7) and (8) totally, we have

$$\frac{dr_1}{dg_2} = \frac{-F_{xg}^1 \frac{\partial x_1^S}{\partial g_2}}{\partial^2 V_1^S / \partial(g_1)^2} < 0, \; \frac{dr_2}{dg_1} = \frac{-(F_{xg}^2 + \frac{\partial t_1^S}{\partial g_2}) \frac{\partial x_2^S}{\partial g_1}}{\partial^2 V_2^S / \partial(g_2)^2} < 0$$

where both denominators are negative by the second order conditions. The first inequality follows from $F_{xg}^1 > 0$ and $\frac{\partial x_1^S}{\partial g_2} < 0$.[25] The second inequality follows from $\frac{\partial x_2^S}{\partial g_1} < 0$ and $F_{xg}^2 > -\frac{\partial t_1^S}{\partial g_2}$ (i.e., the investment productivity effect dominates the investment strategic effect). The last condition holds for the linear model,[26] but it also holds in general. Indeed, suppose otherwise. Then investment would increase the productivity of capital to a lesser extent than it decreases the other regional tax, driving out capital as a result. Consequently there would be no incentive to invest in the first place. We have thus demonstrated that the investment-reaction functions are decreasing. The negative investment externalities are similar to (9) in the Nash tax game, replacing $x_i^N(g)$ by $x_i^S(g)$. Therefore, each region prefers the other to reduce its investment. The investment reaction functions and the iso-welfare functions are represented in Figure 2. The equilibrium investment choice is $E^0 = (g_1^S, g_2^S)$ when both regions play the investment game simultaneously. If they play investment sequentially, then the equilibrium investment choice is E^i ($i = 1$ or 2) depending on who is taking the leadership. The investment leader (say region i) chooses higher investment than in E^0 and due to strategic substitutability, the investment follower (region j) chooses lower investment than in E^0. The following proposition states that the dominant strategy equilibrium of the investment timing game is the simultaneous play.

[25] In the linear model, $\frac{\partial x_i^S}{\partial g_j} = -\frac{1}{5\delta} < 0$.

[26] In the linear model, $F_{xg}^2 + \frac{\partial t_1^S}{\partial g_2} = 1 - \frac{2}{5} > 0$.

Proposition 5.1 *There exists* $\underline{\epsilon} \geq 0$ *such that for* $\epsilon > \underline{\epsilon}$*, given the choices of* $(t_1^S(g), t_2^S(g))$ *in the tax game, when playing investment timing game, the choice of (Early, Early) constitutes the dominant strategy equilibrium.*

Due to the strategic substitutability mentioned above, the investment leader stakes out a positive advantage in the investment game.[27] As a result, the extra investment leads to more productive capital, which in turn leads to a positive advantage in the tax competition subgame. Hence, as shown in Figure 2, the investment leader (say region i) strictly prefers E^i to E^0 ($V_i^{LS} > V_i^{NS}$). However, the investment follower (region j) strictly prefers E^0 to E^i ($V_j^{FS} < V_j^{NS}$). Since the follower will always seek to match the timing of the leader, only the simultaneous investment choice can prevail in equilibrium. In fact, for the sequential play to emerge as the equilibrium timing, the investment reaction function of at least one region must pass through the Pareto set defined relative to E^0. As illustrated in Figure 2, this is not possible in this game, given the combination of decreasing reaction functions and negative investment externalities.

We finally comment on the minimal asymmetry requirement in Proposition 5.1. We assume throughout tax leadership by the large region 1. However, tax leadership by region 1 requires no reversal in market power. That is, for each investment timing, the equilibrium levels of investment in the linear model satisfy

$$g_1 + \delta\epsilon/2 > g_2 - \delta\epsilon/2, \tag{10}$$

so that the endogenous economic difference does not outweigh the exogenous economic difference (i.e., the productivity of capital remains higher in region 1 at the equilibrium levels of investment). For equilibrium E^1 where region 1 leads, the above condition (10) is always satisfied since $g_1 > g_2$. However, for equilibrium E^2 where region 2 leads, there are offsetting effects between the investment leadership of region 2 and the exogenous competitive advantage of region 1. Here we impose a minimal threshold value of $\epsilon > \underline{\epsilon}$, under which we show that condition (10) still holds, and the tax leadership by region 1 remains the relevant tax timing for all configurations of equilibrium investment choices. This restriction is made explicit in the Appendix where it is also shown that $\underline{\epsilon} = 0$ for $\delta \geq 2$.

Given the coordination issues inherent to the tax timing game pointed out in Keen and Konrad (2013, p.280), we have also checked the investment game under simultaneous tax choices (assuming there is no solution to the coordination issues so that the fall back option is the simultaneous tax play).

[27] See also Gal-Or (1985) who shows that the first-mover (the leader) gains higher payoff only if the actions of the leader and the follower are strategic substitutes.

The result, available upon request, is that the simultaneous investment timing still emerges as the dominant strategy equilibrium.

[INSERT FIGURE 2 ABOUT HERE]

6 Conclusion

We have developed a model of tax competition in which countries can choose investments that enhance the productivity of capital so as to stake out some positive advantage in the tax competition stage. It is demonstrated that the pre-commitment on investment brings a Pareto superior outcome. Given this investment commitment benefit, it is shown that countries prefer to play taxes sequentially. Lastly concentrating on the investment game, it is shown that countries also prefer to play investment in the preliminary stage simultaneously (provided there is enough exogenous asymmetry among them). For the rest, we obtain the general undertaxation and underinvestment, relative to the efficiency criterion, when the exogenous asymmetry is small. However, when the exogenous asymmetry is high, (i) the small country may overinvest to acquire mobile capital, and (ii) the large country may overtax due to tax leadership.

In terms of policy recommendations, the message is twofold. First, in an open economy with an international market for capital, public investment (in infrastructure, education, R&D), unlike public consumption (such as public wages and transfers), can greatly influence the nature of competition. As a result, governments should look forward and anticipate the consequences of their commitment to public investment for competition. Second, public investment is not a reversible decision as are tax choices, it has long-lasting effects, and it displays strong commitment benefits. For that reason, it is recommended that the investment decision be delegated to a separate governmental agency and not be associated with the fiscal authority. Furthermore, when receiving foreign aid, the government may consider spending that transfer into public investment (rather than public consumption) in order to boost its future capacity to tax capital and profit. In that sense, public investment is a potential instrument for tax-revenue mobilization in developing countries.

Appendix

Derivation of Equations (6) and (7):

For the direct effect ($\frac{\partial W_i}{\partial g_i}$) in (6), we have

$$\frac{\partial W_i}{\partial g_i} = F_g^i - F_{xg}^i x_i - F_{xx}^i \frac{\partial x_i}{\partial g_i} x_i + t_i \frac{\partial x_i}{\partial g_i} - c_i'(g_i).$$

Differentiating the arbitrage condition $F_x^i(x_i(t,g);g_i) - t_i = F_x^j(1-x_i(t,g);g_j) - t_j$ with respect to g_i, we obtain $F_{xg}^i + F_{xx}^i \frac{\partial x_i}{\partial g_i} = -F_{xx}^j \frac{\partial x_i}{\partial g_i}$. We therefore have $-F_{xg}^i x_i - F_{xx}^i \frac{\partial x_i}{\partial g_i} x_i + t_i \frac{\partial x_i}{\partial g_i} = (F_{xx}^j x_i + t_i)\frac{\partial x_i}{\partial g_i} = 0$, where the last equality comes from (5). Thus, we have

$$\frac{\partial W_i}{\partial g_i} = F_g^i - c_i'(g_i). \tag{11}$$

The tax externality is given by

$$\frac{\partial W_i}{\partial t_j} = -F_{xx}^i \frac{\partial x_i}{\partial t_j} x_i + t_i \frac{\partial x_i}{\partial t_j} = (-F_{xx}^i - F_{xx}^j)\frac{\partial x_i}{\partial t_j} x_i = x_i, \tag{12}$$

where we used (5) again, and $\frac{\partial x_i}{\partial t_j} = \frac{-1}{F_{xx}^i + F_{xx}^j}$. Hence, the tax externality is proportional to the tax base. From (11) and (12), we obtain (6) and (7). *Q.E.D.*

Derivation of Equation (8):

We prove (8) under $F_{xxx}^i \geq 0$ and F_{xxg}^i=0. Let $V_1^S(g) = W_1(t_1^S(g), \tau_2(t_1^S(g);g), g)$, then using the envelope theorem

$$\frac{\partial V_1^S}{\partial g_1} = \frac{\partial W_1}{\partial g_1} + \frac{\partial W_1}{\partial t_2}\frac{\partial \tau_2}{\partial g_1}. \tag{13}$$

The first term in (13) is given by

$$\begin{aligned} \frac{\partial W_1}{\partial g_1} &= F_g^1 - F_{xg}^1 x_1 - F_{xx}^1 \frac{\partial x_1}{\partial g_1} x_1 + t_1 \frac{\partial x_1}{\partial g_1} - c_1'(g_1) \\ &= F_g^1 - c_1'(g_1) + (F_{xx}^2 x_1 + t_1)\frac{\partial x_1}{\partial g_1} \\ &= F_g^1 - c_1'(g_1) + (-F_{xx}^1 x_1 + t_1)\frac{\partial x_1}{\partial g_1}\frac{\partial \tau_2}{\partial t_1}, \end{aligned} \tag{14}$$

where we use the arbitrage condition to derive $F_{xg}^1 + F_{xx}^1 \frac{\partial x_1}{\partial g_1} = -F_{xx}^2 \frac{\partial x_1}{\partial g_1}$, and the first-order condition on t_1 to obtain $F_{xx}^2 x_1 + t_1 = (-F_{xx}^1 x_1 + t_1)\frac{\partial \tau_2}{\partial t_1}$.

The second term in (13) is given by

$$\frac{\partial W_1}{\partial t_2}\frac{\partial \tau_2}{\partial g_1} = (-F_{xx}^1 x_1 + t_1)\frac{\partial x_1}{\partial t_2}\frac{\partial \tau_2}{\partial g_1} \tag{15}$$

where we use $\frac{\partial W_1}{\partial t_2} = (-F^1_{xx}x_1 + t_1)\frac{\partial x_1}{\partial t_2}$.

To prove (8) it remains to prove that $\frac{\partial x_1}{\partial g_1}\frac{\partial \tau_2}{\partial t_1} = -\frac{\partial x_1}{\partial t_2}\frac{\partial \tau_2}{\partial g_1}$ so that adding up (14) and (15) gives (8) which is $\frac{\partial V^S_1}{\partial g_1} = F^1_g - c'_1(g_1)$. From $F^1_{xg} + F^1_{xx}\frac{\partial x_1}{\partial g_1} = -F^2_{xx}\frac{\partial x_1}{\partial g_1}$, we obtain:

$$\frac{\partial x_1}{\partial g_1} = \frac{F^1_{xg}}{-F^1_{xx} - F^2_{xx}} = F^1_{xg}\frac{\partial x_1}{\partial t_2}. \tag{16}$$

Next, let $x^F(t_1, g) \equiv x_2(t_1, \tau_2(t_1; g), g)$. From (5) we obtain $\tau_2(t_1; g) = -F^1_{xx}(1-x^F(t_1, g); g)\cdot x^F(t_1, g)$, so we obtain $\frac{\partial \tau_2}{\partial g_1} = (F^1_{xxx}\cdot x_2 - F^1_{xx})\frac{\partial x^F}{\partial g_1}$. Differentiating the arbitrage condition $F^1_x(1-x^F(t_1, g); g_1) - t_1 = F^2_x(x^F(t_1, g); g_2) - \tau_2(t_1; g)$ with respect to g_1, we obtain:

$$F^1_{xg} - F^1_{xx}\frac{\partial x^F}{\partial g_1} = F^2_{xx}\frac{\partial x^F}{\partial g_1} - (F^1_{xxx}\cdot x_2 - F^1_{xx})\frac{\partial x^F}{\partial g_1},$$

so that $\frac{\partial x^F}{\partial g_1} = \frac{F^1_{xg}}{F^1_{xx} + F^2_{xx} - F^1_{xxx}\cdot x_2 + F^1_{xx}}$ and therefore:

$$\begin{aligned}\frac{\partial \tau_2}{\partial g_1} &= F^1_{xg}\cdot\frac{F^1_{xxx}\cdot x_2 - F^1_{xx}}{F^1_{xx} + F^2_{xx} - F^1_{xxx}\cdot x_2 + F^1_{xx}} \\ &= -F^1_{xg}\cdot\frac{(F^1_{xxx}\cdot x_2 - F^1_{xx})\frac{\partial x_2}{\partial t_1}}{1 + (-F^1_{xxx}\cdot x_2 + F^1_{xx})\frac{\partial x_2}{\partial t_2}} \\ &= -F^1_{xg}\frac{\partial \tau_2}{\partial t_1},\end{aligned} \tag{17}$$

where the second equality uses $\frac{\partial x_2}{\partial t_2} = -\frac{\partial x_2}{\partial t_1} = \frac{1}{F^1_{xx} + F^2_{xx}}$ and the last equality uses $\tau_2(t_1; g) = -F^1_{xx}(1-x_2(t, g); g)x_2(t, g)$. Combining (16) and (17) implies that $\frac{\partial x_1}{\partial g_1}\frac{\partial \tau_2}{\partial t_1} = -\frac{\partial x_1}{\partial t_2}\frac{\partial \tau_2}{\partial g_1}$, which completes the proof. *Q.E.D.*

Proof of Proposition 3.1: As noted in the text, under (1) and (2), (7) and (8) give $g^S_2 = \frac{3}{5}x^S_2$ and $g^S_1 = x^S_1$ respectively. Combining with the Stackelberg leader's (region 1) formula $t_1 = \frac{-F^2_{xx} - \tau'_2 F^1_{xx}}{1-\tau'_2}x_1(t, g)$, $t_2 = -F^1_{xx}\cdot x_2(t, g)$ and (4) yields the unique equilibrium as follows. Let $\underline{\delta} = 3/8$ and $\Delta = \frac{1+8\epsilon}{25\delta - 8} > 0$:

$$\begin{aligned} g^S_1 &= \left(1 + \frac{5}{3}\delta\Delta\right)\underline{\delta}, \quad g^S_2 = (1 - \delta\Delta)\,\underline{\delta}, \\ t^S_1 &= \left(\frac{4 + 2\epsilon}{5} + \frac{2}{5}\Delta\right)\delta, \quad t^S_2 = \left(\frac{3 - \epsilon}{5} - \frac{1}{5}\Delta\right)\delta. \end{aligned}$$

We now compare these values with the Nash equilibrium levels given by

$$g_1^N = \left(1 + \frac{\delta\epsilon}{2(\delta - \underline{\delta})}\right)\underline{\delta}, \quad g_2^N = \left(1 - \frac{\delta\epsilon}{2(\delta - \underline{\delta})}\right)\underline{\delta},$$
$$t_1^N = \left(\frac{1}{2} + \frac{\delta\epsilon}{4(\delta - \underline{\delta})}\right)\delta, \quad t_2^N = \left(\frac{1}{2} - \frac{\delta\epsilon}{4(\delta - \underline{\delta})}\right)\delta.$$

Notice that $g_1^S - g_2^S = \delta\Delta > 0$ as well as $g_1^N - g_2^N \geq 0$, so that region 1 remains the large region in equilibrium.

(i) $g_1^S - g_1^N = \frac{1}{8}\frac{\delta(-15 + 40\delta - 24\epsilon + 20\delta\epsilon)}{(-8 + 25\delta)(-3 + 8\delta)} > \frac{1}{8}\frac{\delta(\delta + 20\delta\epsilon)}{(-8 + 25\delta)(-3 + 8\delta)} > 0.$

(ii) $g_2^S - g_2^N = \frac{1}{8}\frac{\delta(3 - 8\delta - 4\epsilon(2 - 9\delta))}{(-8 + 25\delta)(-3 + 8\delta)} \gtrless 0 \iff \epsilon \gtrless \epsilon^* \equiv \frac{1}{4}\frac{8\delta - 3}{9\delta - 2} < 1.$

(iii) $t_1^S - t_1^N = \frac{1}{2}\frac{\delta((15\delta - 4)(-3 + 8\delta) - 28\delta\epsilon + 60\delta^2\epsilon)}{(-8 + 25\delta)(-3 + 8\delta)} > 0$. $t_2^S - t_2^N = \frac{1}{2}\frac{\delta((5\delta - 2)(-3 + 8\delta) - 2\delta\epsilon + 20\delta^2\epsilon)}{(-8 + 25\delta)(-3 + 8\delta)} > 0$. *Q.E.D.*

Proof of Proposition 3.2: (i), (ii) $g_1^o = \frac{1}{2}\left(1 + \frac{\delta\epsilon}{\delta - 1}\right)$ and $g_2^o = \frac{1}{2}\left(1 - \frac{\delta\epsilon}{\delta - 1}\right)$. $g_1^o - g_1^S = \frac{1}{2(25\delta - 8)}\left(5\delta - 2 + \frac{\delta\epsilon(15\delta + 2)}{-1 + \delta}\right) > 0$. $g_2^o - g_2^S = \frac{1}{2(25\delta - 8)}\left(7\delta - 2 - \frac{\delta\epsilon(19\delta - 2)}{-1 + \delta}\right) \gtrless 0 \iff \epsilon \lessgtr \epsilon^\circ \equiv \frac{(\delta - 1)(7\delta - 2)}{\delta(19\delta - 2)} < \frac{\delta - 1}{\delta}$.

(iii) $F_x^i(x_i^S; g_i^S) - t_i^S > 0$ if $\gamma > \frac{-38\delta + 60\delta^2 + 6 - 2\delta\epsilon + 5\delta^2\epsilon}{2(25\delta - 8)}$. Assumption 1 assures this condition. $t_i^o = \gamma - \frac{\delta - 1}{2}$ $(i = 1, 2)$, so $t_2^o - t_2^S = \gamma + \frac{43\delta - 55\delta^2 - 8 + 10\delta^2\epsilon}{2(25\delta - 8)} \geq \frac{65}{50}\delta + \frac{43\delta - 55\delta^2 - 8 + 10\delta^2\epsilon}{2(25\delta - 8)} = \frac{111\delta + 50\delta^2 - 40 + 150\delta^2\epsilon}{10(25\delta - 8)} > 0$. On the other hand, $t_1^o - t_1^S = \gamma - \frac{65}{50}\delta - \frac{40 - 121\delta + 100\delta^2\epsilon}{10(25\delta - 8)} \equiv \gamma - \frac{65}{50}\delta - \eta(\delta, \epsilon)$. For $\epsilon > \frac{-40 + 121\delta}{100\delta^2}$, $\eta(\delta, \epsilon) > 0$, so that there is a range of $\gamma \in \left(\frac{65}{50}\delta, \frac{65}{50}\delta + \eta(\delta, \epsilon)\right)$ such that $t_1^o - t_1^S < 0$. *Q.E.D.*

Proof of Proposition 4.1: (i) In the fully simultaneous outcome, regions choose investments and taxes simultaneously. The first-order conditions are given by $\frac{\partial W_i}{\partial g_i} = F_g^i - c_i'(g_i) = 0$ as in (11), and $\frac{\partial W_i}{\partial t_i} = 0$ leads to (5) for $i = 1, 2$. The equilibrium outcome is given by $(t_1^A, t_2^A, g_1^A, g_2^A) =$

$\left(\frac{\delta(-1+2\delta+\delta\epsilon)}{2(-1+2\delta)}, \frac{\delta(-1+2\delta-\delta\epsilon)}{2(-1+2\delta)}, \frac{-1+2\delta+\delta\epsilon}{2(-1+2\delta)}, \frac{-1+2\delta-\delta\epsilon}{2(-1+2\delta)}\right)$. $W_1(t^A, g^A) = \frac{(-1+2\delta+\delta\epsilon)^2(-1+3\delta)}{8(-1+2\delta)^2}$, $W_1(t^N, g^N) = \frac{3(4\delta\epsilon+8\delta-3)^2(-3+16\delta)}{128(-3+8\delta)^2}$. $W_1(t^N, g^N) - W_1(t^A, g^A) = \frac{7}{128} + \frac{\delta\epsilon}{16}\frac{(-9+48\delta-76\delta^2+32\delta^3+18\delta^2\epsilon-40\delta^3\epsilon)}{(-3+8\delta)^2(-1+2\delta)^2}$. For $\epsilon \in \left[0, \frac{\delta-1}{\delta}\right)$, $W_1(t^N, g^N) - W_1(t^A, g^A)$ takes the lowest value either at $\epsilon = 0$ or at $\epsilon = \frac{\delta-1}{\delta}$. Clearly the value is positive when $\epsilon = 0$. When $\epsilon = \frac{\delta-1}{\delta}$, $W_1(t^N, g^N) - W_1(t^A, g^A) = \frac{-3216\delta^3+1728\delta^4+2428\delta^2-900\delta+135}{128(-3+8\delta)^2(-1+2\delta)^2} > 0$ for $\delta > 1$. $W_2(t^A, g^A) = \frac{(-1+2\delta-\delta\epsilon)^2(-1+3\delta)}{8(-1+2\delta)^2}$, $W_2(t^N, g^N) = \frac{3(-4\delta\epsilon+8\delta-3)^2(-3+16\delta)}{128(-3+8\delta)^2}$. $W_2(t^N, g^N) - W_2(t^A, g^A) = \frac{7}{128} - \frac{\delta\epsilon}{16}\frac{(-9+48\delta-76\delta^2+32\delta^3-18\delta^2\epsilon+40\delta^3\epsilon)}{(-3+8\delta)^2(-1+2\delta)^2}$.
When $\epsilon \in \left[0, \frac{\delta-1}{\delta}\right)$, $W_2(t^N, g^N) - W_2(t^A, g^A) \geq \max\left\{\frac{7}{128}, \frac{-1488\delta^3+1216\delta^4+444\delta^2+12\delta-9}{128(-3+8\delta)^2(-1+2\delta)^2}\right\} > 0$ for $\delta > 1$.

(ii) $W_1(t^S, g^S) = \frac{(-3+10\delta+5\delta\epsilon)^2(-1+5\delta)}{2(-8+25\delta)^2}$. $W_1(t^S, g^S) - W_1(t^N, g^N) = \frac{\delta}{128(-8+25\delta)^2(-3+8\delta)^2}((2000\delta^2-775\delta+48)(-3+8\delta)^2+8\epsilon(-3+8\delta)(2000\delta^3-3175\delta^2+1248\delta-144)+16\delta\epsilon^2(2000\delta^3-324+2628\delta-5575\delta^2)) \equiv A(\delta)+\epsilon B(\delta)+\epsilon^2 C(\delta)$. For $\delta < 1.065112416$, $B(\delta) < 0$ and $C(\delta) < 0$. For $\delta \in [1.065112416, 2.231096464)$, $B(\delta) \geq 0$ and $C(\delta) < 0$. For $\delta \geq 2.231096464$, $B(\delta) > 0$ and $C(\delta) \geq 0$. In all cases, $W_1(t^S, g^S) - W_1(t^N, g^N) \geq \min\{A(\delta), A(\delta)+B(\delta)+C(\delta)\}$. $A(\delta) = \frac{\delta(2000\delta^2-775\delta+48)}{128(-8+25\delta)^2} > 0$ for $\delta > 1$, and $A(\delta)+B(\delta)+C(\delta) = \frac{\delta(3888-53631\delta+256392\delta^2+288000\delta^4-486000\delta^3)}{128(-8+25\delta)^2(-3+8\delta)} > 0$ for $\delta > 1$.

$W_2(t^S, g^S) = \frac{3(1-3\delta+\delta\epsilon)^2(-3+25\delta)}{2(-8+25\delta)^2}$. The same analysis as in the case of region 1 shows that $W_2(t^S, g^S) - W_2(t^N, g^N) = \frac{3\delta}{128(-8+25\delta)^2(-3+8\delta)^2}((4400\delta^2-3053\delta+528)(-3+8\delta)^2+8\epsilon(-3+8\delta)(400\delta^3-323\delta^2+208\delta-48)-16\delta\epsilon^2(3600\delta^3-84+748\delta-2707\delta^2)) > 0$ for all $\epsilon \in [0,1]$. *Q.E.D.*

Proof of Proposition 5.1: The simultaneous investment outcome is

(g_1^S, g_2^S) . We have shown that (10) always holds. If region 1 leads and region 2 follows in the investment game, $r_2(g_1) = \dfrac{3(3\delta - \delta\epsilon - g_1)}{25\delta - 3}$. The investment leader solves $\max_{g_1} V_1^S(g_1, r_2(g_1))$, yielding the equilibrium investments $(g_1, g_2) = \left(\dfrac{25\delta(-3 + 10\delta + 5\delta\epsilon)}{-275\delta + 9 + 625\delta^2}, \dfrac{3\delta(-34 + 75\delta + 3\epsilon - 25\delta\epsilon)}{-275\delta + 9 + 625\delta^2}\right)$. For this outcome, $g_1 - g_2 = \dfrac{\delta(27 + 25\delta + 200\delta\epsilon - 9\epsilon)}{-275\delta + 9 + 625\delta^2} > 0$, so condition (10) always holds. If region 2 leads and region 1 follows in the investment game, the equilibrium investments are derived as $(g_1, g_2) = \left(\dfrac{\delta(10\delta + 5\delta\epsilon - \epsilon - 5)}{-13\delta + 1 + 25\delta^2}, \dfrac{3\delta(-1 - \delta\epsilon + 3\delta)}{-13\delta + 1 + 25\delta^2}\right)$. For this outcome, condition (10) holds if and only if $\epsilon > \min\left\{0, \dfrac{1}{5}\dfrac{2-\delta}{\delta(-1+5\delta)}\right\} \equiv \underline{\epsilon}$. If region 2 chooses *Late*, since $V_1^{LS} - V_1^{NS} = \dfrac{9}{2}\dfrac{(-3 + 10\delta)^2 - 30\delta\epsilon + 100\epsilon\delta^2 + 25\delta^2\epsilon^2}{(-8 + 25\delta)^2(-275\delta + 9 + 625\delta^2)} > 0$, region 1 chooses *Early*. If region 2 chooses *Early*, $V_1^{NS} - V_1^{FS} = \dfrac{3}{2}\dfrac{(-1 + 5\delta)(3\delta - 1 - \delta\epsilon)}{(-8 + 25\delta)^2(-13\delta + 1 + 25\delta^2)}(500\delta^3 - 3 - 410\delta^2 + 89\delta + 250\epsilon\delta^3 - 130\epsilon\delta^2 + 13\delta\epsilon) > 0$, so region 1 chooses *Early*. In the same way, $V_2^{LS} - V_2^{NS} > 0$ and $V_2^{NS} - V_2^{FS} > 0$, so the choice of *Early* is the dominant strategy for region 2. Therefore, the pair of (*Early*, *Early*) constitutes the dominant strategy equilibrium. *Q.E.D.*

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