CIRJE-F-456

Competing for capital when labor is heterogeneous

Yasuhiro Sato
Graduate School of Environmental Studies, Nagoya University

Jacques-François Thisse
Université catholique de Louvain

December 2006

Competing for capital when labor is heterogeneous*

Yasuhiro Sato† and Jacques-François Thisse‡

December 21, 2006

Abstract

This paper investigates the impacts of capital mobility and tax competition in a setting with imperfect matching between firms and workers. The small country attracts less firms than the large one but accommodates a share of the industry that exceeds its capital share - a reverse home market effect. This allows the small country to be more aggressive and to set a higher tax rate than the large one, thus implying that tax competition reduces international inequalities. However, the large country always attains a higher utility than does the small country. Our model thus encapsulates both the "importance of being small" and the "importance of being large". Last, tax harmonization benefits to the small country but is detrimental to the large one.

Keywords: local labor markets, capital mobility, reverse home market effect, fiscal competition

JEL Classification: F21, H32, J31

*We thank two referees, K. Behrens, G. Duranton, J. Hamilton, Y. Kanemoto, K. Miyazawa, T. Mori, S. Mun, Y. Murata, H. Ogawa, R. Okamoto, G. Ottaviano, S. Peralta, F. Robert-Nicoud, D. Sasaki, T. Tabuchi, T. Takahashi, H. Vandenbussche, T. van Ypersele, and the participants of various seminars and conferences for very useful comments and discussions. This paper was written while the first author was visiting CORE. The first author acknowledges the financial support from the Japan Society for the Promotion of Science through a Grant-in-Aid for Scientific Research ((B)14330004 and (S)18103002), and a Grant-in-Aid for Young Scientists ((B)18730162).

†Graduate School of Environmental Studies, Nagoya University (Japan).

‡CORE, Université catholique de Louvain (Belgium), Institute of Economic Research, Kyoto University (Japan), PSE (France), and CEPR.

1 Introduction

During the last two decades, OECD countries have experienced very high increases in foreign direct investments (OECD, 2003). As economic integration gets deeper, these investments are likely to become more responsive to differentials in corporate tax rates. The empirical evidence collected by Mooij and Ederveen (2003) confirms the idea that governments vastly use such an instrument to influence firms' locational choices. Building on that observation, the literature on fiscal competition studies how governments choose their tax rates in order to attract firms (Wilson, 1999). Because the outcome of fiscal competition crucially hinges on the international mobility of capital, it seems promising and reasonable to build on the microeconomic underpinnings of firms' locational choices. New economic geography (NEG) aims precisely at explaining how firms do interact to form clusters within a few regions (Fujita *et al.*, 1999; Baldwin *et al.*, 2003). It is, therefore, natural to tackle the process of fiscal competition by using the main ingredients of NEG, namely increasing returns, market size, and imperfect competition.

This is the road taken recently in various papers (Baldwin and Krugman, 2004; Ottaviano and van Ypersele, 2005; Borck and Pflüger, 2006). However, very much like in NEG, they all have chosen to focus on the product market. Yet, recent empirical contributions suggest that labor market pooling is one of the main explanations for the existence of firms' clusters (Dumais *et al.*, 2002; Rosenthal and Strange, 2004). The specificity of human capital being itself the main reason for imperfect matching between firms and workers, we find it natural to study how skill mismatch affects the spatial distribution of firms through both firms' locational choices and the working of local labor markets. When the labor force is heterogeneous in the skill space, firms are able to set wages below the marginal productivity of labor by differentiating technologies. Hence, they operate on imperfectly competitive labor markets. As firms also exhibit scale economies at the plant level, it appears that our setting blends the main ingredients of NEG. However, we obtain results that are very different from existing ones.

First, we show that the large country's residents enjoy a higher utility level than do those of the small country. Yet, though the large country has more firms than does the small one, competition on local labor markets hinders the large country to have a more than proportionate share of firms. We thus get a reverse home market effect: *the share of firms in the larger region is less than the share of consumers in that region.* Put together, the last two results mean that our model encapsulates both the "importance of being small" and the "importance of being large", two aspects that have been emphasized in distinct papers.

Second, the few existing studies focussing on tax competition between asymmetric countries predict that the large country sets a higher corporate tax rate than does the small one (Bucovetsky, 1991; Wilson, 1991; Haufler and Wooton, 1999; Ottaviano and van Ypersele, 2005). This prediction does not necessarily fit well the real world, however. In their analysis of the effective corporate tax rates set in several OECD countries, Devereux *et al.* (2002) report much more mixed results. For example, their Figure 7 reveals that, if the effective average tax rates in Germany, Japan, and the United States are higher than those set in Austria, Finland and Sweden, those prevailing in Belgium and Greece are higher than those in France and the United Kingdom. There is, therefore, a need for a different approach.

This is what we accomplish in this paper where we show that *the small country levies higher corporate tax rate than does the large country*, the reason being that the small country enjoys a reverse home market effect that allows it to follow a more aggressive tax policy. Hence, by focussing on the microeconomic underpinnings of local labor markets, we are able to establish that the main implication of the above-mentioned studies is reversed. Such a prediction seems to fit well what we observe in the European Union. To see it, consider the six founding EU-members (Belgium, France, Germany, Italy, Luxembourg, and the Netherlands), the economies of which are fairly well integrated. Figures 1 and 2 show the relationship between the share of corporate taxes in total tax receipts and, respectively, these countries' GDP and population size. Clearly, both relationships are downward sloping and correlations between variables are very high.[1]

Insert Figures 1 and 2 about here

[1] Considering the EU-15 also leads to decreasing relationships. However, the correlation values are lower.

Third, our analysis has three major redistributional implications. The first one is that tax competition leads to redistribution from the large to the small country. This is due to the fact that, because of the reverse home market effect, the small country is able to tax both domestic and foreign capital. However, the large country always reaches a higher utility level than does the small country. This sharply differs from the result obtained in the existing studies where the small country typically attains higher utility under tax competition (Bucovetsky, 1991; Wilson, 1991). The next implication is that tax competition reduces international inequalities in the sense that the large country's residents prefer the no-tax outcome, whereas those of the small country are better off under tax competition. The final implication is that tax harmonization leads to redistribution from the large to the small country. In other words, *countries are bound to disagree on the need to allow for tax competition as well as on the choice of a common tax rate.*

Our last contribution is methodological in nature. Even in the case of simple games such as those by Wilson (1986) and Zodrow and Mieszkowski (1986), showing the existence of a (pure-strategy) Nash equilibrium in tax games is known to be a very problematic issue.[2] Here, we propose a new approach to show that our tax game has a unique Nash equilibrium. It is worth stressing that this is done without imposing ad hoc restrictions. This in turn allows us to compare the fiscal competition outcome to both the autarky and no-tax cases on solid grounds, unlike many existing contributions.

The remaining of the paper is organized as follows. The model is presented in section 2. In section 3, we study the international distribution of capital in the no-tax case, whereas the process of fiscal competition is discussed in section 4. Section 5 concludes by discussing extensions and policy implications.

[2] So far, the existence of a Nash equilibrium has been proven only in special cases. For example, Laussel and Le Breton (1998) simplify the tax game by ignoring consumers' capital income, whereas Bucovetsky (2003) shows the existence of a Nash equilibrium in a tax game with a continuum of countries. Peralta and van Ypersele (2006) show that a tax competition model with a quadratic production function and a perfectly competitive markets has a Nash equilibrium.

2 The model and preliminary results

Consider an economy formed by two countries, labeled 1 and 2, and a total mass L of consumers. There are two production factors, labor and capital. National capital endowments are evenly owned by local workers, who inelastically supply one unit of labor each. The unit of capital is chosen for each worker to own a single unit of capital. Our modeling strategy thus abstracts from redistributional issues between capital-owners and workers. Because most FDI takes place in countries with similar technologies and factor endowments (think of the OECD countries), we abstract from comparative advantage of both the Ricardian and Heckscher-Ohlin types. However, although many models of fiscal competition assume that competing jurisdictions have the same size, countries involved in FDI often differ in terms of market sizes. Let $\theta \in (0, 1)$ denote the share of consumers in country 1, which implies that θ also measures that country's shares of labor and capital. Let $l_1 = \theta L$ and $l_2 = (1-\theta)L$ denote the mass of consumers in countries 1 and 2, respectively. Without loss of generality, we assume that $l_1 \geq l_2$. Throughout this paper, we refer to θ and to $(1 - \theta)$ as being the *size* of countries 1 and 2. Unless explicitly mentioned, we consider asymmetric countries with $\theta > 1/2$, thus implying that country 1 (2) is the large (small) country. Consumers are immobile and can supply labor only in the country in which they reside, so that labor markets are *local*. By contrast, consumers are free to supply capital wherever they want.

2.1 Firm technology and labor market friction

The industry is formed by heterogeneous firms that supply a homogeneous good sold in each country on a competitive market. This good can be shipped at zero cost between the two countries so that the law of one price holds; we take it as the numéraire. In other words, product market conditions do not influence firms' locational choices. This somewhat extreme assumption is made to capture the idea that economic integration weakens the relative influence of product market competition on firms' location, whereas it exacerbates the effect of costs differences of immobile factors. It is worth stressing, however, that introducing positive transport costs for the final good does not change our main results provided that these costs are sufficiently low.[3]

Each firm has a single plant that uses both capital and labor as inputs; its cost function is given by $C(q) = fr + cwq$, where f is the fixed requirement of capital and c the marginal requirement of labor; r and w are the rate of return of capital and the wage rate, which are both endogenous. To ease the burden of notation, we normalize both f and c to one. At this stage, one may wonder if our assumption of a perfectly competitive product market is compatible with that of increasing returns at the firm level. As we will see later, we consider imperfect competition on the labor market in which firms pay wages lower than the marginal productivity of labor. Thus, firms make positive operating profits that allow them to cover their payment for their fixed requirement of capital.

Each firm uses a specific technology in the sense that workers can produce only when they perfectly match the firm's skill needs. Workers have a priori heterogeneous skills, so that they have different matches with a firm's job offer. Thus, if firm k hires a worker whose skill differs from x_k, the worker must get trained and her cost of training to meet the firm's skill requirement is a function of the difference between the worker's skill x and the firm k's skill requirement x_k.

In describing the heterogeneity of workers, we follow Kim (1989) and others by assuming that the skill space is described by the circumference C of a circle. As our main focus is about the impact of country size on the international distribution of capital under different scenarios, we also assume that the two countries have the same skill space; we normalize the length of C to one. Individuals' skills are continuously and uniformly distributed along this circumference; the density is constant in country i and denoted by l_i. Hence, the value of l_i measures the size of the local labor market.

There are n_i firms in country i, with $n_1 + n_2 = L$. Firms' job requirements x_k are equally spaced along the circumference C so that $1/n_i$ is the distance between two adjacent firms in the skill space. The training cost function is $\beta |x - x_k|$, where β expresses the ability of a worker to learn how to adjust to a technology different from her skill. After training, all workers are identical from the firm's viewpoint since their ex post productivity is observable and equal to 1 by normalization (thus, there is no moral hazard problem within firms).

[3] This is because the inequalities shown below remain true. We will examine this issue later on.

We assume that firms are not able to observe each worker's skill type, perhaps because both labor markets are thick.[4] Firms know only the distribution of x. However, workers know their own types and observe the firms' skill needs. In order to induce the appropriate set of workers to take jobs with the most suitable firm, workers must therefore pay at least some part of the training cost. In addition, since the supply of a worker is inelastic, firms cannot offer a wage menu so that the worker must pay for all the costs of training, which are not observable to the firm (hence resolving the adverse selection problem). Consequently, workers must pay their entire training costs, whereas each firm i offers the same wage to all its workers, conditional on the worker having been trained to the skill x_i. Each worker then compares the wage offers of firms and the required training costs; she simply chooses to work for the firm offering the highest wage net of training costs (Hamilton *et al.*, 2000).

Suppose that firm k is located in country i. When firms on each side of k offer wages $w_{i,k-1}$ and $w_{i,k+1}$, firm k's labor pool consists of two subsegments whose outer boundaries are $\overline{x}_{i,k}$ and $\overline{x}_{i,k+1}$. The worker at $\overline{x}_{i,k}$ receives the same net wage from firm k and firm $k-1$, whereas the worker at $\overline{x}_{i,k+1}$ receives the same net wage from firm k and firm $k+1$. Because firm k knows the training cost function and all firms' skill requirements, it can determine $\overline{x}_{i,k}$ and $\overline{x}_{i,k+1}$ as the solutions to the two equations $w_{i,k}-\beta\left|x_{i,k}-\overline{x}_{i,k}\right| = w_{i,k-1}-\beta\left|\overline{x}_{i,k}-x_{i,k-1}\right|$ and $w_{i,k}-\beta\left|\overline{x}_{i,k+1}-x_{i,k}\right| = w_{i,k+1}-\beta\left|x_{i,k+1}-\overline{x}_{i,k+1}\right|$. Hence, we have

$$\begin{aligned} \overline{x}_{i,k} &= \frac{w_{i,k-1} - w_{i,k} + \beta(x_{i,k} + x_{i,k-1})}{2\beta} \\ \overline{x}_{i,k+1} &= \frac{w_{i,k} - w_{i,k+1} + \beta(x_{i,k} + x_{i,k+1})}{2\beta}. \end{aligned} \qquad (1)$$

We choose the unit of the homogeneous good for each worker to produce one unit of good. Firm

[4] When firms are able to observe worker's skill type, our main results, especially those regarding the reverse home market effect, are likely to be the same. Indeed, firms have to bear the training costs, thus implying that it is less profitable for firms to enter the economy (Hamilton et al., 2000). Because the incentives to enter are the same in the two countries, their relative attractiveness should be unaffected.

k's profits are then given by

$$\pi_{i,k} = \int_{\overline{x}_{i,k}}^{\overline{x}_{i,k+1}} l_i(1 - w_{i,k})dx - r_i$$
$$= l_i(1 - w_{i,k})(\overline{x}_{i,k+1} - \overline{x}_{i,k}) - r_i \quad (2)$$

where r_i is the price of capital and $w_{i,k}$ the wage firm k pays when it is located in country i.

In the rest of this section, we focus on our benchmark case in which capital is immobile. The output being sold at the same price, the trade balance implies that each country consumes only its own production. Accordingly, our benchmark case may be referred to as the *autarky* case. The amount of capital available in country i being l_i, capital market clearing implies that the number of firms in country i is fixed and given by

$$n_i^a = l_i \quad (3)$$

where the superscript a stands for the autarky case. This in turn implies that the large country has a larger number of firms than does the small ($n_1^a > n_2^a$).

2.2 Equilibrium factor prices

We first determine the equilibrium values of $w_{i,k}$. The trade-off that allows us to determine the equilibrium wage is straightforward (see (4)). Everything else being equal, higher wages lead to lower profits because the wage bill rises. However, higher wages also foster higher profits by attracting more workers, hence yielding a larger output. These two effects are balanced at the equilibrium wage rate, which may be found by taking the first-order condition for $\pi_{i,k}$ with respect to $w_{i,k}$:

$$\frac{\partial \pi_{i,k}}{\partial w_{i,k}} = -l_i(\overline{x}_{i,k+1} - \overline{x}_{i,k}) + l_i(1 - w_{i,k}) \left(\frac{\partial \overline{x}_{i,k+1}}{\partial w_{i,k}} - \frac{\partial \overline{x}_{i,k}}{\partial w_{i,k}} \right) = 0. \quad (4)$$

This wage game has a unique Nash equilibrium, which is symmetric (Hamilton *et al.*, 2000). It then follows from (1), (4), and $\overline{x}_{i,k+1} - \overline{x}_{i,k} = 1/n_i$ that

$$w_{i,k}^* = 1 - \frac{\beta}{l_i} \equiv w_i^* \quad (5)$$

which is positive as long as $\beta < (1 - \theta)L$, a condition we assume to hold throughout the rest of the paper. Thus, the equilibrium wage is equal to the marginal productivity of labor after training, minus a premium that local firms are able to levy because workers cannot move costlessly from one firm to another. Note that this premium is required for each firm to be able to cover its (endogenous) fixed capital cost. As expected, it decreases as the number of firms located in country i rises because firms have less monopsony power on the labor market.

Substituting $w^*_{i,k}$ into (2), we get

$$\pi^*_{i,k} = \frac{\beta l_i}{n_i^2} - r_i = \frac{\beta}{l_i} - r_i. \tag{6}$$

All else the same, individual profits decrease with the country size.

It remains to describe how the price of capital is determined. As usual, we assume that there is free entry and exit in the industry. Consequently, competition for capital among entrepreneurs implies that rental rates exactly absorb firms' operating profits, so that r_i must be such that $\pi^*_{i,k} = 0$. This yields the equilibrium price of capital in country i:

$$r_i^* = \frac{\beta l_i}{n_i^2}. \tag{7}$$

Thus, the price of capital in autarky is

$$r_i^a = \frac{\beta}{n_i^a} = \frac{\beta}{l_i}. \tag{8}$$

As a larger country allows firms to earn lower operating profits under autarky, the price of capital is lower in the large country than in the small one.

We are now equipped to describe the two main effects at work in our setting. On the one hand, when the size l_i of a country increases, it becomes more profitable to firms because a larger labor pool allows them to hire more workers, whence to produce and sell more. We refer to that as the *market size effect*. On the other hand, a larger labor market also leads to more firms and, therefore, to lower average training costs. This reduces the monopsony power of firms, thus implying that they have to pay higher wages. We call this force the *labor-market crowding effect*. Expressions (6) and (8) show that the latter effect always dominates the former when there is autarky.

The indirect utility of an individual of skill type x working for firm k in country i is given by

$$V_{i,k}(x) = w_i^* - \beta |x - x_{i,k}| + r_i^* \tag{9}$$

which is equal to

$$V_{i,k}(x) = 1 - \frac{\beta}{n_i} - \beta\,|x - x_{i,k}| + \frac{\beta l_i}{n_i^2}.$$

Individual utilities being quasi-linear, we may add them up to define the social surplus. Then, the average utility of firm k's employees is

$$\begin{aligned} V_{i,k} &= \left\{ \int_{\overline{x}_{i,k}}^{x_{i,k}} l_i \left[1 - \frac{\beta}{n_i} - \beta(x_{i,k} - x) + r_i^* \right] dx \right. \\ &\quad \left. + \int_{x_{i,k}}^{\overline{x}_{i,k+1}} l_i \left[1 - \frac{\beta}{n_i} - \beta(x - x_{i,k}) + r_i^* \right] dx \right\} \times \left(\int_{\overline{x}_{i,k}}^{\overline{x}_{i,k+1}} l_i dx \right)^{-1}. \end{aligned}$$

Because $\overline{x}_{i,k+1} = x_{i,k} + 1/2n_i$ and $\overline{x}_{i,k} = x_{i,k} - 1/2n_i$ at the symmetric equilibrium, we have

$$V_{i,k} = 1 - \frac{5\beta}{4n_i} + r_i^* \equiv V_i. \tag{10}$$

In this expression, the second term represents the effect of improving the quality match. When the number of local firms rises, the average mismatch decreases, implying that the equilibrium wage increases. However, as shown by (7), an increase in the number of firms also leads to a lower capital price. Thus, the total impact of the number of firms on welfare is a priori ambiguous.

Under autarky, it follows from (3), (8) and (10) that

$$\begin{aligned} V_1^a - V_2^a &= \frac{5\beta}{4}\left(\frac{1}{n_2^a} - \frac{1}{n_1^a}\right) + \beta\left[\frac{l_1}{(n_1^a)^2} - \frac{l_2}{(n_2^a)^2}\right] \\ &= \frac{\beta}{4}\left(\frac{1}{n_2^a} - \frac{1}{n_1^a}\right) = \frac{\beta(2\theta - 1)}{4L\theta(1-\theta)} > 0 \end{aligned}$$

which implies

$$\frac{d(V_1^a - V_2^a)}{d\theta} > 0.$$

Hence, the large country's residents are better off than those of the small country. Note that this welfare gap is a reflection of the presence of aggregate increasing returns. Furthermore, the welfare gap rises as the share of the large country in the global economy increases since

$$\frac{d^2(V_1^a - V_2^a)}{d\theta^2} > 0.$$

Summarizing the foregoing discussion, we have:

Proposition 1 *When capital is immobile, consumers reach a higher utility level in the large country. Furthermore, the larger the difference in size, the larger the gap in individual welfare levels between the two countries.*

3 Capital mobility

In this section, we allow for capital mobility so that the number of firms located in a country is no longer tied to the amount of local capital. A spatial equilibrium is such that no agent has an incentive to change her international allocation of capital and such that no firm has an incentive to enter or exit the market. These two conditions will hold when no agent can get a higher rental rate by relocating her capital and when rental rates exactly absorb firms' operating profits. A spatial equilibrium is the outcome of the following two opposite forces: the market size effect has the nature of an *attraction* force, whereas the labor-market crowding effect acts as a *repulsion* force. In what follows, we restrict our analysis to the meaningful case of interior spatial equilibria only.

Throughout the rest of the paper, we assume that the number of firms is sufficiently large to avoid the integer problem; we thus treat n_i as a positive real number.

3.1 The free market outcome

When capital is mobile, it flows to the country with higher capital price and arbitrage induces the capital prices in both countries to be the same:[5]

$$r_1^* = r_2^*.$$

Using (7), this equilibrium condition can be rewritten as follows:

$$\frac{l_1}{n_1^2} = \frac{l_2}{n_2^2} \tag{11}$$

so that $n_1^* > n_2^*$ if and only if $l_1 > l_2$, whereas $l_1 = l_2$ implies that $n_1^* = n_2^*$. Because $n_1 + n_2 = L$, (11) allows us to determine the equilibrium number of firms in country i:

$$n_i^m = \frac{\sqrt{l_i}}{\sqrt{l_1} + \sqrt{l_2}} L \tag{12}$$

[5] Note that national wages may differ because labor is spatially immobile.

where the superscript m stands for the case of mobile capital.

Using $l_1 = \theta L$ and $l_2 = (1-\theta)L$, the corresponding value of the price of capital is then obtained by substituting (12) into (7):

$$r^m = \frac{\beta}{L}\left(\sqrt{\theta} + \sqrt{1-\theta}\right)^2$$

which is a decreasing and concave function of θ over the interval $(1/2, 1)$. In other words, increasing the relative size of the large country decreases the interest rate at a decreasing rate.

As expected, once the two countries have different sizes, the mobility of capital generates a distribution of firms that differs from the one arising under autarky. A key-question is whether the mobility of capital strengthens or reduces international inequality. Comparing (3) and (12), it is readily verified that

$$n_1^m < n_1^a \qquad n_2^m > n_2^a. \tag{13}$$

Thus, capital is exported from the large country to the small country. This implies that capital mobility between asymmetric countries leads to a more dispersed international allocation of capital. This should not come as a surprise since, under autarky, the price of capital is higher in the small country than in the large one.

Yet, the large country retains a larger number of firms than the small one, $n_1^m > n_2^m$. This is because the equalization of profits between countries implies that the market size effect generated by the large country has to be exactly offset by a stronger labor-market crowding effect. For that, it must be that the large country hosts more firms than the small country. Putting all these results together, we obtain the following ranking:

$$n_1^a > n_1^m > n_2^m > n_2^a.$$

We now want to determine whether the equilibrium outcome exhibits a "home market effect". According to Helpman and Krugman (1985), when the industry is characterized by scale economies at the firm level and imperfect competition, the large country would attract a more than proportionate share of firms. Define the share of firms in country 1 as $\lambda = n_1^m/L$. It then follows immediately from

(12) that

$$\lambda = \frac{\sqrt{\theta}}{\sqrt{\theta} + \sqrt{1-\theta}}.$$

Accordingly, we have

$$\lambda = \frac{\sqrt{\theta}}{\sqrt{\theta} + \sqrt{1-\theta}} < \frac{\theta}{\theta + \sqrt{1-\theta}\sqrt{1-\theta}} = \theta$$

because $\theta > 1-\theta$, where the equality holds if and only if $\theta = 1/2$. Thus, unless the two countries have the same size, *the large country hosts a less than proportionate share of the industry*, thus running against what has been called the "pervasiveness" of the home market effect (Head *et al.*, 2002).

To understand the main forces at work, consider the following thought experiment. Under autarky, (2) implies that firms located in the large country enjoy higher profits gross of fixed cost than firms set up in the small one. Assume now that capital becomes mobile but that wages remain fixed in both countries. The gross profit differential thus triggers a flow of capital from the small country to the large one. As a result, the share of firms installed in the large country exceeds its share of capital. In other words, other things the same, the large market would attract a more than proportionate share of the industry. However, when more (less) firms set up in the large (small) country, wages are not constant. They increase in the large country due to the labor-market crowding effect and decrease in the small one. Our result shows that this effect is sufficiently strong to overcome the market size effect, thus giving rise to what we may call a "reverse home market effect" (in short RHME).[6]

Several comments are in order. First, our result cannot be dismissed on the grounds that we have assumed zero transport cost for firms' output. Indeed, everything hold true when such costs are positive but not too high. This is because the foregoing inequalities are strict and will remain valid in the presence of a small price wedge on the homogenous good market. Stated differently, combining scale economies, imperfect competition and transport costs may well yield a RHME.

[6] Formally, as shown by (11), the market size effect is proportional to the number of firms, whereas the labor-market crowding effect is proportional to the square of the number of firms. This makes the large country relatively less attractive to firms. Clearly, this argument depends on the fact that our model is linear. For the same reason, we may conjecture that the results derived here are robust against alternative specifications that are not too nonlinear.

Second, we want to stress the fact that the home market effect is typically derived in settings in which wages are fixed and determined in another sector operating under constant returns and perfect competition (Head *et al.*, 2002). In such a context, the market size effect is the only one at work, thus entailing a more than proportionate share of firms in the large country. However, frictions on the labor market may overcome this effect. They are, therefore, likely to play an important role in the determination of the industry structure and the effects of the liberalization of capital movements. In particular, we may expect imperfect matching on the labor market could slow down the possible agglomeration of firms in a few regions, at least when workers are spatially immobile.[7]

Third, it is hard to believe that such a difference in results is due to the sole existence of strategic interactions in our setting. Indeed, as shown by Head *et al.* (2002), strategic competition on the product market does not invalidate the home market effect. Instead, this suggests that, under imperfect competition, product-market and input-market analyses need not lead to similar conclusions.

Last, the foregoing result sheds light on the fact that the evidence regarding the presence of the home market effect in real-world data is described as being "highly mixed" by Head and Mayer (2004, p.2642) in their survey of the empirical literature. In this perspective, our result is potentially important because there is ample evidence that labor market frictions are pervasive, whether home market effects are or not (Davis and Weinstein, 1999, 2003).

Our main results may be summarized as follows.

Proposition 2 *When capital is mobile, the large country accommodates more firms than the small country, but its industry share is less than its capital share.*

Furthermore, it is readily verified that $d\lambda/d\theta < 1$ over a large interval of θ-values, which implies that the gap $\theta - \lambda$ expands. In this case, increasing the relative size of the large country exacerbates

[7] Amiti and Pissarides [1] consider labor heterogeneity in a monopolistic competition model of trade. However, their setting is different from ours along the following lines: (i) firms can observe workers' skill characteristics and, whence, discriminate workers with respect to wage payment; (ii) there is inter-sectoral mobility of workers. Amiti and Pissarides then show that these two assumptions lead firms to pay a constant average wage to skilled workers. This prevents the emergence of a labor-market crowding effect.

the RHME. However, when θ becomes very large ($\gtrsim 0.893$), the gap $\theta - \lambda$ shrinks, thus showing that the RHME is not necessarily magnified by the market size effect.

Finally, as the small country imports capital, both countries face different incentives to tax firms. We will see in section 4 how this is reflected in the tax outcome.

3.2 The welfare implications of capital mobility

The equilibrium distribution of firms minimizes total training costs in the global economy. Indeed, total training costs are given by

$$\begin{aligned} T(n_1, n_2) &= 2n_1 \int_0^{1/(2n_1)} l_1 \beta \sigma d\sigma + 2n_2 \int_0^{1/(2n_2)} l_2 \beta \sigma d\sigma \\ &= \frac{\beta l_1}{4n_1} + \frac{\beta l_2}{4n_2}. \end{aligned}$$

The first order condition for the minimization of T with respect to n_1 and n_2, taking $n_1 + n_2 = L$ into account, yields (11). Note that the net output of the global economy is $L - T(n_1, n_2)$. Hence, the equilibrium distribution of firms maximizes the net output of the global economy. Thus, despite imperfect competition on local labor markets, the international allocation of capital is globally efficient under free mobility, as in standard neoclassical models. However, it generates redistributive effects between the two countries.

To see how, we compare the welfare levels reached in each country at the market outcome with and without capital mobility. From $r_1 = r_2$ and (12), the utility difference across countries in the mobile capital case is given by

$$V_1^m - V_2^m = \frac{5\beta}{4} \left(\frac{1}{n_2^m} - \frac{1}{n_1^m} \right) = \frac{5\beta (2\theta - 1)}{4L\sqrt{\theta}\sqrt{1-\theta}} > 0$$

as long as $\theta > 1/2$. Such a welfare gap finds its origin in the fact that the large country has a larger number of firms, which implies higher wages and lower training costs (see (5) and (10)). Furthermore, it also rises as the size discrepancy increases.

Turning to comparisons of welfare under mobility and autarky, standard calculations show that

$$\begin{aligned} V_i^m - V_i^a &= \left(\frac{1}{n_i^a} - \frac{1}{n_i^m}\right)\left[\frac{5\beta}{4} - \beta l_i \left(\frac{1}{n_i^m} + \frac{1}{n_i^a}\right)\right] \\ &= \frac{\beta\left(l_j - \sqrt{l_i}\sqrt{l_j}\right)\left(l_j - 3l_i - 4\sqrt{l_i}\sqrt{l_j}\right)}{4(l_1 + l_2)^2 l_i}. \end{aligned}$$

As $\theta > 1/2$ and, hence, $l_1 > l_2$, this implies that

$$V_1^m - V_1^a > 0.$$

Hence, *the large country always gains from capital mobility.* Though intuitive, this result is not totally immediate. Indeed, country 1's residents get higher capital incomes because its price rises when it can be invested abroad, but they earn lower wages because the number of local firms is lower.

The implications of capital mobility for the small country are even less straightforward. Because $l_1 - \sqrt{l_1}\sqrt{l_2} > 0$, it turns out that $V_2^m - V_2^a > 0$ holds if and only if

$$l_1 - 3l_2 - 4\sqrt{l_1}\sqrt{l_2} = (4\theta - 3 - 4\sqrt{\theta}\sqrt{1-\theta})L > 0.$$

This is a second degree inequality that is satisfied on the unit interval if and only if $\theta > \theta_c \equiv (5+\sqrt{7})/8 > 1/2$. Thus, we have:

Proposition 3 *Compared to the autarky case, capital mobility always raises the utility level in the large country. However, the utility level in the small country increases if and only if countries have very different sizes.*

This may be understood as follows. When capital is mobile, the global output net of training costs increases and reaches its maximum at the equilibrium distribution of firms. However, these gains need not benefit each country as some firms move to the small country. In the large country, capital income rises but its labor income falls, whereas these two effects go in the opposite direction in the small country. In the large country, the gains resulting from the higher price of capital for country 1's residents always more than compensate their wage decrease. This is because the large country hosts more firms than the small one, thus making the marginal impact of the labor-market crowding effect weak enough because labor markets are local, whereas the marginal impact of the capital price remains strong enough because the capital market is fully integrated. In the small country, consumers earn higher wages under capital mobility than under autarky (see Figure 3). Whether these gains are large enough to compensate for the lower price of capital now depends on the relative size of the two countries. As the large country gets bigger and bigger, the wage level in the small country goes down, but its decrease is sharper under autarky than under capital mobility. Consequently, when θ is sufficiently large, the gains in wage income may compensate the loss in capital income. By contrast, when country sizes are similar, such a compensation is no longer possible. This shows that *country size matters in the sense that capital mobility may exacerbate international inequalities.*

Insert Figure 3 about here

4 Capital taxation

In this section, we study the effects of tax competition on the location of firms. Because our main focus is on the impact of fiscal competition on the location of firms, we disregard the possible inefficiency of public goods provision and assume that national governments tax capital to make their residents better off. More precisely, we consider two national governments that maximize the welfare of their residents. Following a well-established tradition in fiscal competition (Cremer and Pestieau, 2004), we assume a per-unit capital tax. It is the only instrument available to each government, which redistributes the proceeds to their residents. In addition, each government is subject to a budget-balance constraint.

We consider a two-stage game in which national governments, first, choose simultaneously their tax level and, then, firms enter the market, decide where to locate and pay the corresponding wage. From now on, we will refer to the first stage game as the *tax game*. The equilibrium concept we adopt is a subgame perfect Nash equilibrium. As usual, the model is solved by backward induction.

4.1 The tax game

Let t_i denote the per-unit capital tax rate in country i and s_i the transfer to the residents of this country.[8] In such a context, the profit of a firm (6) and the utility level of a worker (10) become:

$$\pi^*_{i,k} = \frac{\beta l_i}{n_i^2} - r_i - t_i \tag{14}$$

$$V_i = 1 - \frac{5\beta}{4n_i} + r_i + s_i. \tag{15}$$

Consider the second stage subgame induced by s_i and t_i $(i = 1, 2)$. The capital price in each country is then given by

$$r_i = \frac{\beta l_i}{n_i^2} - t_i. \tag{16}$$

Free entry and the equalization of capital prices then lead to the equilibrium condition for the second stage:

$$\frac{\beta l_1}{n_1^2} - t_1 = \frac{\beta l_2}{n_2^2} - t_2. \tag{17}$$

Given $n_1+n_2 = L$, it is readily verified that this equation has a single solution $n_1^*(t_1, t_2)$ and $n_2^*(t_1, t_2)$. The implicit function theorem implies that these two functions are continuous with respect to t_1 and t_2. To ease the burden of notation, we denote these functions n_1 and n_2.

Let us now focus on the tax game. Country i's government, which fully anticipates the influence of its decision on the resulting distribution of firms determined by (17), maximizes (15) with respect to s_i and t_i under the budget constraint

$$s_i l_i = t_i n_i.$$

Substituting (16) and $s_i l_i = t_i n_i$ into (15), we obtain

$$V_i = 1 - \frac{5\beta}{4n_i} + \frac{\beta l_i}{n_i^2} - t_i + \frac{n_i t_i}{l_i} \tag{18}$$

which is a continuous function of t_i and t_j. Substituting $n_j = L - n_i$ into (17), we get

[8] Note that the tax and transfer may be negative ($t_i < 0$ and $s_i < 0$), thus meaning that government i may decide to subsidize firms and, therefore, to tax its residents instead of taxing capital.

$$g(t_i, n_i; t_j) \equiv \frac{\beta l_i}{n_i^2} - t_i - \frac{\beta l_j}{(L - n_i)^2} + t_j = 0 \tag{19}$$

which is a continuous function of t_i and t_j. Thus, the welfare problem of government i is modeled as a game in which this government maximizes (18) with respect to t_i, subject to the constraint (19).

Totally differentiating $g(t_i, n_i; t_j)$ for a given t_j yields

$$\frac{dn_i}{dt_i} = -\frac{1}{2\beta}\left(\frac{l_i}{n_i^3} + \frac{l_j}{n_j^3}\right)^{-1}. \tag{20}$$

Applying the first-order condition to V_i and using dn_i/dt_i yields the following expression:

$$t_i^* = \frac{3\beta l_i}{4n_i^2} + \frac{2\beta l_i l_j}{n_j^3}\left(\frac{n_i}{l_i} - 1\right). \tag{21}$$

A similar argument holds for country $j \neq i$. From $n_1 + n_2 = L = l_1 + l_2$, it follows that

$$l_i - n_i = n_j - l_j. \tag{22}$$

Substituting (21) for $i = 1, 2$ into (19), rearranging terms, and using (22), (19) may be rewritten as follows:

$$\frac{1}{l_1}\left(\frac{l_1}{n_1}\right)^2\left(\frac{7}{8} - \frac{l_1}{n_1}\right) = \frac{1}{l_2}\left(\frac{l_2}{n_2}\right)^2\left(\frac{7}{8} - \frac{l_2}{n_2}\right). \tag{23}$$

Because (23) encapsulates both the equilibrium conditions of each government and the constraint (19), a Nash equilibrium (t_1^*, t_2^*) of the tax game (if any) must satisfy (23) where $n_1 + n_2 = L$.

The following result is shown in Appendix A.

Proposition 4 *The tax game has a unique Nash equilibrium.*

Having done that, we first characterize the equilibrium distribution of firms at the tax equilibrium (the proof is given in Appendix B).

Proposition 5 *The large country has more firms at the tax-game outcome than at the no-tax outcome, but the reverse home market effect is still present.*

Thus, *tax competition weakens the RHME generated by the market forces.* In other words, if tax competition affects the international distribution of capital, it does not change its structural properties. In particular, this proposition implies that

$$n_2^g < n_2^m < n_1^m < n_1^g \tag{24}$$

and

$$\frac{n_1^g}{l_1} < \frac{n_2^g}{l_2} \tag{25}$$

where the superscript g represents the capital mobile case with active national governments.

Let us now come to the equilibrium tax rates. Since $n_1 + n_2 = N$ can be rewritten as

$$l_1 \left(\frac{n_1}{l_1} - 1 \right) = l_2 \left(1 - \frac{n_2}{l_2} \right)$$

expression (25) implies that

$$\frac{n_1^g}{l_1} < 1 < \frac{n_2^g}{l_2}. \tag{26}$$

Combining (26) with (21), we then obtain our first result about tax rates:

$$t_2^* > 0.$$

Moreover, it follows from (25) that $7/8 - l_1/n_1^g > 7/8 - l_2/n_2^g$. This and (23) thus yields

$$\frac{l_2}{(n_2^g)^2} > \frac{l_1}{(n_1^g)^2}. \tag{27}$$

Thus, (17) implies that

$$t_1^* - t_2^* = \beta \left[\frac{l_1}{(n_1^g)^2} - \frac{l_2}{(n_2^g)^2} \right] < 0.$$

So far, we do not know whether or not t_1^* is positive. The following numerical example, in which $L = 1$ and $\beta = 0.1$, suffices to show that country 1 may choose to tax or to subsidy capital according to its relative size. Indeed, we see from Figure 4 that the tax rate decreases and that taxation is replaced by subvention once θ exceeds $0.84 < 0.893 < 0.9$.[9] The RHME being exacerbated over the interval $[0.5, 0.893]$, country 1 reacts by subsidizing capital.

[9] Thus, the condition $\beta < (1 - \theta)L$ is satisfied.

Insert Figure 4 about here

We may summarize our results as follows.

Proposition 6 *At the tax-game outcome, the government of the small country always taxes firms. However, the government of the large country either subsidies or taxes firms. When it taxes firms, its tax level is always lower than the one chosen by the government of the small country.*

One can think of this result as follows. At the no-tax outcome, the large country exports capital and is, therefore, less induced to tax it because the subsidy each of its workers gets is $s_1 = t_1 n_1 / l_1 < t_1$. The reverse holds in the small country where $s_2 = t_2 n_2 / l_2 > t_2$, thus implying that the it has more incentives to tax capital. This effect is in turn reinforced by the fact that wages increase in the capital exporting country and decrease in the capital importing one. The same holds when the RHME is still present at the tax outcome, which is precisely what we have shown above. In game-theoretic terms, our result may be explained by means of best reply functions. Numerical simulations indicate that the best reply of the large country is upward slopping: when the small country raises its tax rate, the large one capitalizes on the market size effect to follow suit. By contrast, the best reply of the small country is downward slopping. Whenever the large country decreases its tax rate, the small country may afford to increase its own rate because of the RHME. In other words, the fact that the small country imports capital at the no-tax outcome allows it to build on this comparative advantage to design a more aggressive tax policy that balances the marginal gain of a tax rise and the marginal cost of losing firms.

The foregoing proposition is to be contrasted to those obtained in models with imperfect competition in the product market (Baldwin and Krugman, 2004; Ottaviano and van Ypersele, 2005; Borck and Pflüger, 2006). All these papers assume two countries competing for monopolistic competitive firms in which the large country is relatively more attractive than the small one. Accordingly, the small country must offer a lower tax rate than does the large country in order to counterbalance the comparative advantage of the large country. It is worth stressing that such a result hinges on the presence of a home market effect. In our model, the labor-market crowding effect dominates the market size effect, thus making the large country relatively less attractive than the small one. This in turn allows the small country to set a higher tax rate than the large country.

4.2 Tax competition versus tax coordination

It remains to compare the welfare level reached in each country at the tax-competition and no-tax (efficient) outcomes. Consider, first, the case of cooperation between governments. Using (18) and (19), it is straightforward that the average utility level in the global economy is given by

$$\overline{V} = \frac{1}{L}\left(l_1 V_1 + l_2 V_2\right) = L - T(n_1, n_2).$$

As seen in the previous section, T is minimized in the no-tax case. Consequently, cooperation leads to the same outcome as in the no-tax case.

Comparing utilities in two countries, we show in Appendix C that

$$V_1^g - V_2^g > 0$$

which means that , under tax competition, the large country's residents attains higher utility than do the small country's residents. Moreover, we also show in Appendix C that

$$V_2^g - V_2^m > 0.$$

As the allocation of capital ceases to be efficient under tax competition, it must be that

$$V_1^g - V_1^m < 0.$$

Our results may then be summarized as follows.

Proposition 7 *Under tax competition, the large country's residents are always better off than the small country's residents. Yet, the large country's residents are always better off at the no-tax outcome, whereas the small country's residents prefer the tax-game outcome.*

Despite the RHME, in the absence of tax competition, the inhabitants of the large country are always better off than those of the small one (Proposition 1). Tax competition reduces this welfare gap by allowing the small country to implement a more generous redistribution policy, which relies itself on the RHME generated by the labor-market crowding effect (Proposition 2). However, the small country still preserves part of its attractiveness by not overshooting.

Again, *country size matters in the sense that fiscal competition reduces international inequalities* once it is recognized that the location of firms is more driven by labor market than product market considerations. This confirms what we have seen in the foregoing, namely the existing contributions that point to the advantage of being large in tax competition rests on the home market effect. By contrast, our setting uncovers the advantage being small in a framework involving increasing returns and labor market friction, two pervasive features of modern economies.

It remains to consider the effect of tax harmonization, that is, the two countries set the same tax rate $\bar{t}$ on capital. Because (17) is reduced to (11), the distribution of firms is the same as in the free market outcome. Therefore, there is no distortion in the sense that the net global output is maximized. This is not the end of the story, however. Indeed, it follows from (18) that tax harmonization has redistributional effects. Specifically, a resident of country i gains (or loses) from tax harmonization by an amount equal to

$$\Delta_i = \bar{t}\left(\frac{n_i^m}{l_i} - 1\right).$$

Expressions (25) and (26) then imply that $\Delta_1 < 0$ and $\Delta_2 > 0$. Consequently, we have:

Proposition 8 *A move from tax competition to tax harmonization leads to income redistribution from the large to the small country.*

As expected, under tax harmonization, the large country loses firms and income. However, because the net global output is maximized, this implies that the small country gains from tax harmonization. Again, this points to the existence of conflicting interests between countries of different sizes when they have to agree about the possible harmonization of capital taxation.

5 Concluding remarks

We have obtained new results in tax competition in an otherwise standard model, which goes back at least to Salop (1979). Whereas the large country has more firms per capita than does the small country both under tax competition and tax cooperation in Ottaviano and van Ypersele (2005), we have seen that the large country always exports capital toward the small one. This is because we have a RHME, whereas the home market effect holds in Ottaviano and van Ypersele. This shows that the way firms choose their location is crucial in assessing the merits of tax competition. Stated differently, uncovering the various mechanisms that drive the mobility of firms across countries is needed to understand the possible implications of fiscal competition.

An interesting implication of our framework is to shed light on the fact that fiscal competition might well trigger unemployment in a country. To see it, consider an economic environment in which some workers might not take a job, the setting being otherwise similar to the one described above. Specifically, we assume that workers get the same level of unemployment benefit $b > 0$ when unemployed. This implies that a worker supplies labor provided that her wage net of training costs is greater than or equal to b. Thisse and Zenou (2000) then show that the labor market equilibrium involves unemployment in country i when $1 < b + \beta/n_i$ holds, namely when the number of firms located in this country is sufficiently small. In this case, the most distant workers on the skill circle refrain from working, thus implying that each firm acts as a monopsony in the labor market. Thus, capital mobility could foster unemployment in the large country that now has a smaller number of firms, thus qualifying Proposition 3. On the other hand, as fiscal competition leads to a reduction in the number of firms installed in the small country when compared to the no-tax case, it is now the small country that could experience unemployment at the taxation outcome, thus qualifying Proposition 7.

At least three possible extensions are worth mentioning. First, countries could use the tax proceeds to subsidize workers' training. In such a context, training costs would become lower and wages higher. However, lower training costs would make the corresponding country less attractive by reducing firms' market power on the labor market. The following question thus suggests itself:

to which extent does one country subsidy its labor force more than the other, and get a better trained labor force, according to its size? Second, introducing capital accumulation with the aim of studying the relationship between economic growth and skill mismatch appears to be a fairly natural topic to investigate. Last, some empirical evidence suggests that several countries tax discriminate between local and foreign firms instead of applying the same tax rate as in this paper (Huizinga and Nicodème, 2005). It would be interesting to revisit our model when national governments may use such additional instruments. These topics are left for future investigation.

References

[1] Amiti, M., Pissarides, C. A., 2005. Trade and industrial location with heterogeneous labor. Journal of International Economics 67, 392-412.

[2] Baldwin, R. E., Forslid, R., Martin, Ph., Ottaviano, G. I. P., Robert-Nicoud, F., 2003. Economic Geography and Public Policy. Princeton University Press, Princeton.

[3] Baldwin, R. E., Krugman, P., 2004. Agglomeration, integration and tax harmonization. European Economic Review 48, 1-23.

[4] Borck, R., Pflüger, M., 2006. Agglomeration and tax competition. European Economic Review 50, 647-668.

[5] Bucovetsky, S., 1991. Asymmetric tax competition. Journal of Urban Economics 30, 167-181.

[6] Bucovetsky, S., 2003. Existence of Nash equilibrium for tax competition among a large number of jurisdictions. Working paper, York University.

[7] Cremer, H., Pestieau, P., 2004. Factor mobility and redistribution. In: Henderson, J. V., Thisse, J.-F. (Eds.), Handbook of Regional and Urban Economics, vol. 4. North-Holland, Amsterdam, pp. 2529-2560.

[8] Davis, D., Weinstein, D., 1999. Economic geography and regional production structure: an empirical investigation. European Economic Review 43, 379-407.

[9] Davis, D., Weinstein, D., 2003. Market access, economic geography and comparative advantage: an empirical assessment. Journal of International Economics 59, 1-23.

[10] Devereux, M. P., Griffith, R., Klemm, A., 2002. Corporate income tax reforms and international tax competition. Economic Policy 35,451-495.

[11] Dumais, G., Ellison, G., Glaeser, E. L., 2002. Geographic concentration as a dynamic process. Review of Economics and Statistics 84, 193-204.

[12] Fujita, M., Krugman, P., Venables, A. J., 1999. The Spatial Economy. Cities, Regions and International Trade. MIT Press, Cambridge, MA.

[13] Hamilton, J., Thisse, J.-F., Zenou, Y., 2000. Wage competition with heterogeneous workers and firms. Journal of Labor Economics 18, 453-472.

[14] Haufler, A., Wooton, I., 1999. Country size and tax competition for foreign direct investment. Journal of Public Economics 71, 121-139.

[15] Head, K., Mayer, T., 2004. The empirics of agglomeration and trade. In: Henderson, J.V., Thisse, J.-F. (Eds.), Handbook of Regional and Urban Economics, vol. 4. North-Holland, Amsterdam, pp. 2609-2669.

[16] Head, K., Mayer, T., Ries, J., 2002. On the pervasiveness of the home market effect. Economica 69, 371-390.

[17] Helpman, E., Krugman, P. R., 1985. Market Structure and Foreign Trade. The MIT Press, Cambridge, MA.

[18] Huizinga, H., Nicodème, G., 2006. Foreign ownership and corporate income taxation: an empirical evaluation. European Economic Review 50, 1223-1244

[19] Kim, S., 1989. Labor specialization and the extent of the market. Journal of Political Economy 97, 692-705.

[20] Laussel, D., Le Breton, M., 1998. Existence of Nash equilibria in fiscal competition games. Regional Science and Urban Economics 28, 283-296.

[21] Mooij, R. A., Ederveen, S., 2003. Taxation and foreign direct investment. A synthesis of empirical research. International Tax and Public Finance 10, 673–693.

[22] OECD, 2003. OECD Economic Outlook 2003. Paris.

[23] Ottaviano, G. I. P., van Ypersele, T., 2005. Market size and tax competition. Journal of International Economics 67, 25-46.

[24] Peralta, S., van Ypersele, T., 2006. Coordination of capital taxation among asymmetric countries. Regional Science and Urban Economics 36, 708-726.

[25] Rosenthal, S., Strange, W. C., 2004. Evidence on the nature and sources of agglomeration economics. In: Henderson, J. V., Thisse, J.-F. (Eds.), Handbook of Regional and Urban Economics, vol. 4. North-Holland, Amsterdam, pp. 2119-2171.

[26] Salop, S.C., 1979. Monopolistic competition with an outside good. Bell Journal of Economics 10, 141-56.

[27] Wilson, J. D., 1986. A theory of interregional tax competition. Journal of Urban Economics 19, 296-315.

[28] Wilson, J. D., 1991. Tax competition with interregional differences in factor endowments. Regional Science and Urban Economics 21, 423-452.

[29] Wilson, J. D., 1999. Theories of tax competition. National Tax Journal 52, 268-304.

[30] Thisse, J.-F., Zenou, Y., 2000. Skill mismatch and unemployment. Economics Letters 69, 415-420.

[31] Zodrow, G. R., Mieszkowski, P., 1986. Pigou, Tiebout, property taxation, and the underprovision of local public goods. Journal of Urban Economics 19, 356-370.

Appendix A. Proof of Proposition 4

The proof involves four steps.

Step 1. The condition (23) has a unique solution

Substituting $n_2 = L - n_1$ into (23), we see that both the left hand side (LHS) and the right hand side (RHS) of (23) depend on n_1. The LHS is negative and increases in n_1 in the interval $(0, 8l_1/7)$, and is positive in $(8l_1/7, L]$. Moreover, it is readily verified that $\lim_{n_1 \to 0} LHS = -\infty$ and $LHS|_{n_1=8l_1/7} = 0$. The RHS is positive in $[0, L - 8l_2/7)$, and is negative and decreasing in n_1 in $(L - 8l_2/7, L)$. We also have $RHS|_{n_1=L-8l_2/7} = 0$ and $\lim_{n_1 \to L} RHS = -\infty$. Because $8l_1/7 - (L - 8l_2/7) = L/7 > 0$, it is readily verified that there exists a unique n_1 that satisfies (23). Combining this with (21) shows that there exists a unique point (n_1^*, t_1^*, t_2^*) for which both the first-order conditions $dV_1/dt_1 = 0$ and $dV_2/dt_2 = 0$ and the equalization of capital prices (19) hold. Note also that this equilibrium (if it exists) is such that $n_i^* > 0$ for $i = 1, 2$. Hence, the tax game has at most one interior Nash equilibrium.

Step 2. The function $V_i(t_i, t_j^*)$ is quasi-concave w.r.t. t_i

For that, we show that the second-order condition is always satisfied at any point for which both the first-order conditions of the two countries ($dV_1/dt_1 = 0$ and $dV_2/dt_2 = 0$) and the equalization of capital prices (19) hold. In doing so, we use the facts that conditions (24), (25), (26) and (27) must hold at any solution to (23), which will be shown in Appendix B.

It follows from (19) that n_i, hence V_i, is twice continuously differentiable with respect to t_i:

$$\begin{aligned} \frac{dn_i}{dt_i} &= -\frac{1}{2\beta}\left(\frac{l_i}{n_i^3} + \frac{l_j}{n_j^3}\right)^{-1} < 0 \\ \frac{d^2 n_i}{dt_i^2} &= 6\beta\left(\frac{dn_i}{dt_i}\right)^2\left(\frac{l_j}{n_j^4} - \frac{l_i}{n_i^4}\right). \end{aligned} \tag{A1}$$

The first-order condition for the maximization of V_i with respect to t_i is

$$\frac{dV_i}{dt_i} = \frac{n_i}{l_i} - 1 + \left(\frac{5\beta}{4n_i^2} - \frac{2\beta l_i}{n_i^3} + \frac{t_i}{l_i}\right)\frac{dn_i}{dt_i} = 0 \tag{A2}$$

whereas the second-order derivative of V_i with respect to t_i yields

$$\frac{d^2 V_i}{dt_i^2} = \frac{2}{l_i}\frac{dn_i}{dt_i} + \frac{\beta}{n_i^3}\left(\frac{6l_i}{n_i} - \frac{5}{2}\right)\left(\frac{dn_i}{dt_i}\right)^2 + \left(\frac{5\beta}{4n_i^2} - \frac{2\beta l_i}{n_i^3} + \frac{t_i}{l_i}\right)\frac{d^2 n_i}{dt_i^2}.$$

Using (A1) and (A2), d^2V_i/dt_i^2 may then be rewritten as follows:

$$\begin{aligned}\frac{d^2V_i}{dt_i^2} &= \left(-\frac{4\beta l_j}{l_i n_j^3} - \frac{13\beta}{2n_i^3} + \frac{6\beta l_i}{n_i^4}\right)\left(\frac{dn_i}{dt_i}\right)^2 + 6\beta\left(\frac{n_i}{l_i} - 1\right)\left(\frac{l_i}{n_i^4} - \frac{l_j}{n_j^4}\right)\frac{dn_i}{dt_i} \\ &= \Phi_i\left(\frac{dn_i}{dt_i}\right)^2 + 6\beta\Psi_i\frac{dn_i}{dt_i}\end{aligned}$$

where

$$\begin{aligned}\Phi_i &\equiv -\frac{4\beta l_j}{l_i n_j^3} - \frac{13\beta}{2n_i^3} + \frac{6\beta l_i}{n_i^4} \\ \Psi_i &\equiv \left(\frac{n_i}{l_i} - 1\right)\left(\frac{l_i}{n_i^4} - \frac{l_j}{n_j^4}\right).\end{aligned}$$

When $i = 1$, (24) implies that

$$\frac{n_1^g}{l_1} > \frac{n_1^m}{l_1} = \frac{1}{\left(\theta + \sqrt{\theta}\sqrt{1-\theta}\right)} > \frac{4}{5}$$

implying that

$$\frac{5}{4} > \frac{l_1}{n_1^g}$$

so that

$$\Phi_1 < -\frac{4\beta l_2}{l_1\left(n_2^g\right)^3} - \frac{13\beta}{2\left(n_1^g\right)^3} + \frac{30\beta}{4\left(n_1^g\right)^3}.$$

It then follows from (24) and (27) that

$$\frac{l_2}{\left(n_2^g\right)^3} > \frac{l_1}{\left(n_1^g\right)^3}$$

which in turn implies that

$$\Phi_1 < -\frac{4\beta l_1}{l_1\left(n_1^g\right)^3} - \frac{13\beta}{2\left(n_1^g\right)^3} + \frac{30\beta}{4\left(n_1^g\right)^3} = -\frac{3\beta}{\left(n_1^g\right)^3} < 0. \tag{A3}$$

Similarly, (24) and (27) yields

$$\frac{l_2}{\left(n_2^g\right)^4} > \frac{l_1}{\left(n_1^g\right)^4} \tag{A4}$$

which, combined with (26), implies that

$$\Psi_1 > 0. \tag{A5}$$

For $i = 2$, (26) implies that

$$1 > \frac{l_1}{n_2^g}.$$

Hence, we obtain

$$\Phi_2 < -\frac{4\beta l_1}{l_2 \left(n_1^g\right)^3} - \frac{13\beta}{2\left(n_2^g\right)^3} + \frac{6\beta}{\left(n_2^g\right)^3} = -\frac{4\beta l_1}{l_2 \left(n_1^g\right)^3} - \frac{\beta}{2\left(n_2^g\right)^3} < 0. \tag{A6}$$

Similarly, (A4) and (26) lead to

$$\Psi_2 > 0. \tag{A7}$$

From (A1), (A3) and (A5) to (A7), it then follows that

$$\frac{d^2 V_i}{dt_i^2} < 0$$

so that the second-order condition is satisfied for each $i = 1, 2$. Because Step 1 has shown that there exists a unique t_i^* that satisfies $dV_i/dt_i = 0$ for given t_j^*, $V_i(t_i, t_j^*)$ is quasi-concave w.r.t. t_i.

Step 3. The behavior of dV_i/dt_i when $t_i \to \pm\infty$

For t_j^* given, it follows from

$$\frac{\beta l_i}{n_i^2} = \frac{\beta l_j}{\left(L - n_i\right)^2} + t_i - t_j^*$$

that n_i is a continuously differentiable function of $t_i \in (-\infty, \infty)$. Furthermore, it follows immediately from this equation that (i) $\lim_{t_i \to \infty} n_i = 0$, (ii) $\lim_{t_i \to \infty} t_i n_i^3 = 0$, (iii) $\lim_{t_i \to -\infty} n_i = L$, and (iv) $\lim_{t_i \to -\infty} t_i (L - n_i)^3 = 0$.

Using (20), we get

$$\begin{aligned} \frac{dV_i}{dt_i} &= \frac{n_i}{l_i} - 1 + \left(\frac{5\beta}{4n_i^2} - \frac{2\beta l_i}{n_i^3} + \frac{t_i}{l_i}\right)\left[-\frac{1}{2\beta}\left(\frac{l_i}{n_i^3} + \frac{l_j}{n_j^3}\right)^{-1}\right] \\ &= \frac{n_i}{l_i} - 1 - \frac{1}{2\beta}\left(\frac{5\beta}{4n_i^2} - \frac{2\beta l_i}{n_i^3}\right)\left[\frac{l_i}{n_i^3} + \frac{l_j}{(L - n_i)^3}\right]^{-1} - \frac{1}{2\beta}\frac{t_i}{l_i}\left[\frac{l_i}{n_i^3} + \frac{l_j}{(L - n_i)^3}\right]^{-1} \end{aligned}$$

so that

$$\lim_{t_i \to -\infty} \frac{dV_i}{dt_i} = \frac{L}{l_i} - 1 > 0.$$

To study the behavior of dV_i/dt_i when $t_i \to \infty$, it is convenient to rewrite it as follows:

$$\frac{dV_i}{dt_i} = \frac{n_i}{l_i} - 1 + \left(\frac{5\beta n_i}{4} - 2\beta l_i + \frac{n_i^3 t_i}{l_i}\right)\left[-\frac{1}{2\beta}\left(l_i + \frac{n_i^3 l_j}{n_j^3}\right)^{-1}\right].$$

It is then readily verified that

$$\lim_{t_i \to \infty} \frac{dV_i}{dt_i} = -1 - 2\beta l_i \left(-\frac{1}{2\beta l_i}\right) = 0.$$

These two conditions together with Step 2 implies that $V_i(t_i, t_j^*)$ is maximized at t_i^*. In other words, (t_1^*, t_2^*) is a Nash equilibrium of the tax game.

Step 4. Corner solutions

It remains to consider the cases of corner solutions in which one country has no firms ($n_i = 0$). Two cases may arise. In the former, a country sets a tax rate sufficiently high for all the firms to be established in the other country. Clearly, such a strategy is never optimal from this country's point of view. In the latter, a country gives a sufficiently high subsidy to attract all firms. Again, this cannot happen in equilibrium because the other government would reduce its tax rate. Thus, (t_1^*, t_2^*) is the unique Nash equilibrium of the tax game. Q.E.D.

Appendix B. Proof of Proposition 5

From (23), we have

$$\left(\frac{n_2^g/l_2}{n_1^g/l_1}\right)^2 = \frac{(7/8 - l_2/n_2^g)\, l_1}{(7/8 - l_1/n_1^g)\, l_2}. \tag{B1}$$

From (12), we also have

$$\left(\frac{n_2^m/l_2}{n_1^m/l_1}\right)^2 = \frac{l_1}{l_2}. \tag{B2}$$

Let us define γ as follows:

$$\gamma = \frac{7/8 - l_2/n_2^g}{7/8 - l_1/n_1^g}.$$

Step 1 in Appendix A implies that $L - 8l_2/7 < n_1^g < L < 8l_1/7$. This and $n_2 = L - n_1$ imply that $7/8 - l_i/n_i^g < 0$ for $i = 1, 2$, and that $\gamma > 0$. (B1) and (B2) yield

$$\frac{n_2^g/l_2}{n_1^g/l_1} = \gamma^{1/2} \frac{n_2^m/l_2}{n_1^m/l_1} = \left(\frac{\gamma l_1}{l_2}\right)^{1/2}. \tag{B3}$$

Now assume that $\gamma \geq 1$. This implies that $7/8 - l_1/n_1^g \geq 7/8 - l_2/n_2^g$, which is reduced to $n_1^g/l_1 \geq n_2^g/l_2$. However, since $\gamma \geq 1$ and $l_1 > l_2$, (B3) yields $n_2^g/l_2 > n_1^g/l_1$, which is a contradiction. Therefore, it must be true that $\gamma < 1$. This means $7/8 - l_2/n_2^g > 7/8 - l_1/n_1^g$, which gives

$$\frac{n_2^g}{l_2} > \frac{n_1^g}{l_1}. \tag{B4}$$

Furthermore, from (B3), we obtain

$$\frac{n_2^m/l_2}{n_1^m/l_1} > \frac{n_2^g/l_2}{n_1^g/l_1}. \tag{B5}$$

Note that $n_1 + n_2 = l$ implies

$$\frac{n_2/l_2}{n_1/l_1} = \frac{Ll_1}{n_1 l_2} - \frac{l_1}{l_2}.$$

Substituting this into (B5) gives

$$n_1^g > n_1^m. \tag{B6}$$

Similarly, we have

$$\frac{n_2/l_2}{n_1/l_1} = \frac{1}{Ll_2/l_1 n_2 - l_2/l_1}$$

which and (B5) yield

$$n_2^m > n_2^g. \tag{B7}$$

Furthermore, $n_1^m > n_2^m$ and (25) imply that $n_2^g < n_2^m < n_1^m < n_1^g$. Note here that $\theta = l_1/L$, $1-\theta = l_2/L$, $\lambda = n_1/L$ and $1-\lambda = n_2/L$ by definition. Hence, (B4) leads to

$$\frac{1-\lambda}{1-\theta} > \frac{\lambda}{\theta} \qquad \Leftrightarrow \qquad \theta > \lambda. \tag{B8}$$

The proposition then follows from (B4), (B6), (B7) and (B8). Q.E.D.

Appendix C. Comparison of welfare levels

(i) Comparing utilities in two countries, we have

$$\begin{aligned} V_1^g - V_2^g &= \frac{\beta}{4}\left(\frac{1}{n_2^g} - \frac{1}{n_1^g}\right) + \frac{n_2^g}{l_2}\left[\frac{\beta l_2}{(n_2^g)^2} - t_2\right] - \frac{n_1^g}{l_1}\left[\frac{\beta l_1}{(n_1^g)^2} - t_1\right] \\ &= \frac{\beta}{4}\left(\frac{1}{n_2^g} - \frac{1}{n_1^g}\right) + \frac{n_2^g}{l_2}\left[\frac{\beta l_1}{(n_1^g)^2} - t_1\right] - \frac{n_1^g}{l_1}\left[\frac{\beta l_1}{(n_1^g)^2} - t_1\right] \\ &= \frac{\beta}{4}\left(\frac{1}{n_2^g} - \frac{1}{n_1^g}\right) + \left[\frac{\beta l_1}{(n_1^g)^2} - t_1\right]\left(\frac{n_2^g}{l_2} - \frac{n_1^g}{l_1}\right) \end{aligned}$$

where the second equality follows from (17). Because $n_1^m > n_2^m$, (25) implies that $n_2^g < n_2^m < n_1^m < n_1^g$ and, hence, $1/n_2^g - 1/n_1^g > 0$. Moreover, (21) and (26) imply that $\beta l_1/\left(n_1^g\right)^2 - t_1 > 0$. Therefore, we have

$$V_1^g - V_2^g > 0.$$

(ii) Substituting (21) into (18), we also have

$$V_2^g - V_2^m = \frac{5\beta}{4n_2^m} - \frac{\beta}{2n_2^g} - \frac{3\beta l_2}{4\left(n_2^g\right)^2} + \beta l_2 \left[\frac{1}{\left(n_2^g\right)^2} - \frac{1}{\left(n_2^m\right)^2}\right] + \frac{2\beta l_1 l_2}{\left(n_1^g\right)^3}\left(\frac{n_2^g}{l_2} - 1\right).$$

Since (26) gives $l_2/n_2^g < 1$, we have

$$\frac{5\beta}{4n_2^m} - \frac{\beta}{2n_2^g} - \frac{3\beta l_2}{4\left(n_2^g\right)^2} > \frac{5\beta}{4}\left(\frac{1}{n_2^m} - \frac{1}{n_2^g}\right).$$

As a result, we obtain

$$V_2^g - V_2^m > \left(\frac{1}{n_2^m} - \frac{1}{n_2^g}\right)\left[\frac{5\beta}{4} - \beta l_2\left(\frac{1}{n_2^g} + \frac{1}{n_2^m}\right)\right] + \frac{2\beta l_1 l_2}{\left(n_1^g\right)^3}\left(\frac{n_2^g}{l_2} - 1\right).$$

That $n_2^m > n_2^g$ and (26) imply that $V_2^g - V_2^m > 0$ if $5\beta/4 - \beta l_2\left(1/n_2^g + 1/n_2^m\right) < 0$. Since $n_2^m > n_2^g$ and (26) give that $1 < n_2^g/l_2 < n_2^m/l_2$, it is readily verified that

$$\frac{5\beta}{4} - \beta l_2\left(\frac{1}{n_2^g} + \frac{1}{n_2^m}\right) < \frac{5\beta}{4} - \beta l_2 \frac{2}{n_2^m} < -\frac{3\beta}{4} < 0.$$

Hence, we have

$$V_2^g - V_2^m > 0.$$

(iii) Finally, as total output is lower under tax competition than under free competition, it must be that

$$V_1^g - V_1^m < 0.$$

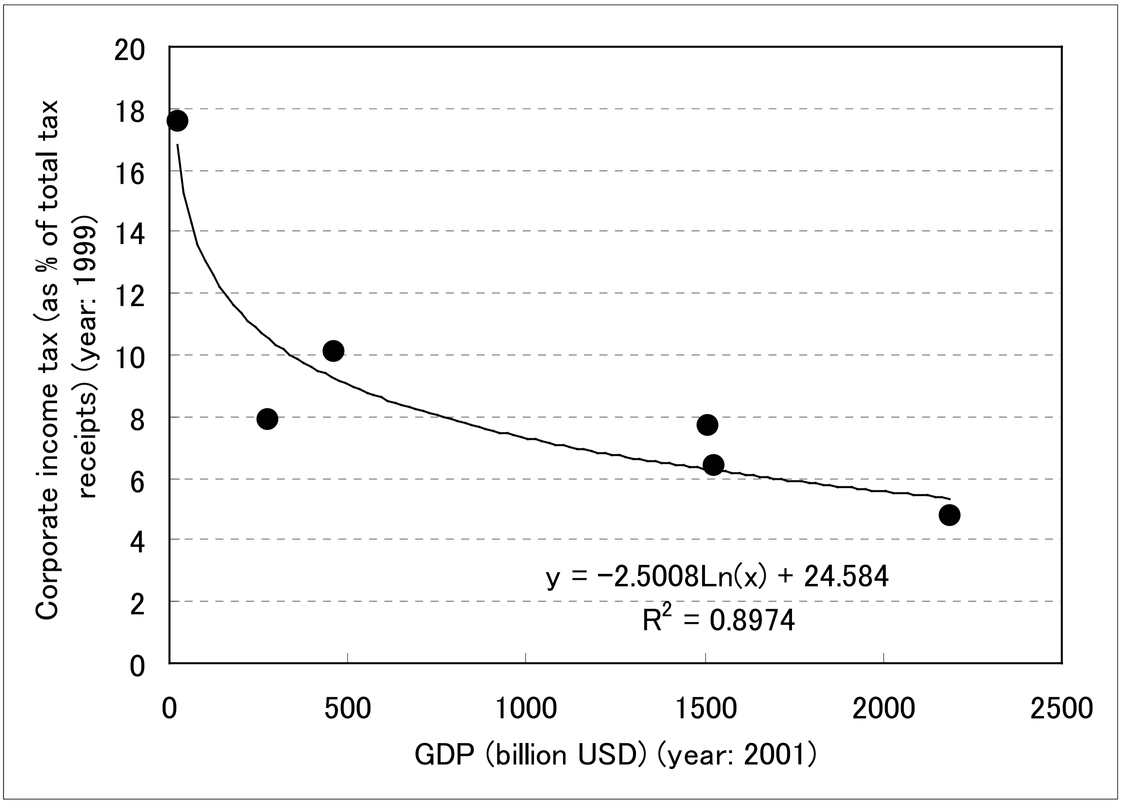

Figure 1: The relationship between the share of corporate taxes in total tax receipts and GDP in EU6 (source: OECD in Figures 2003)

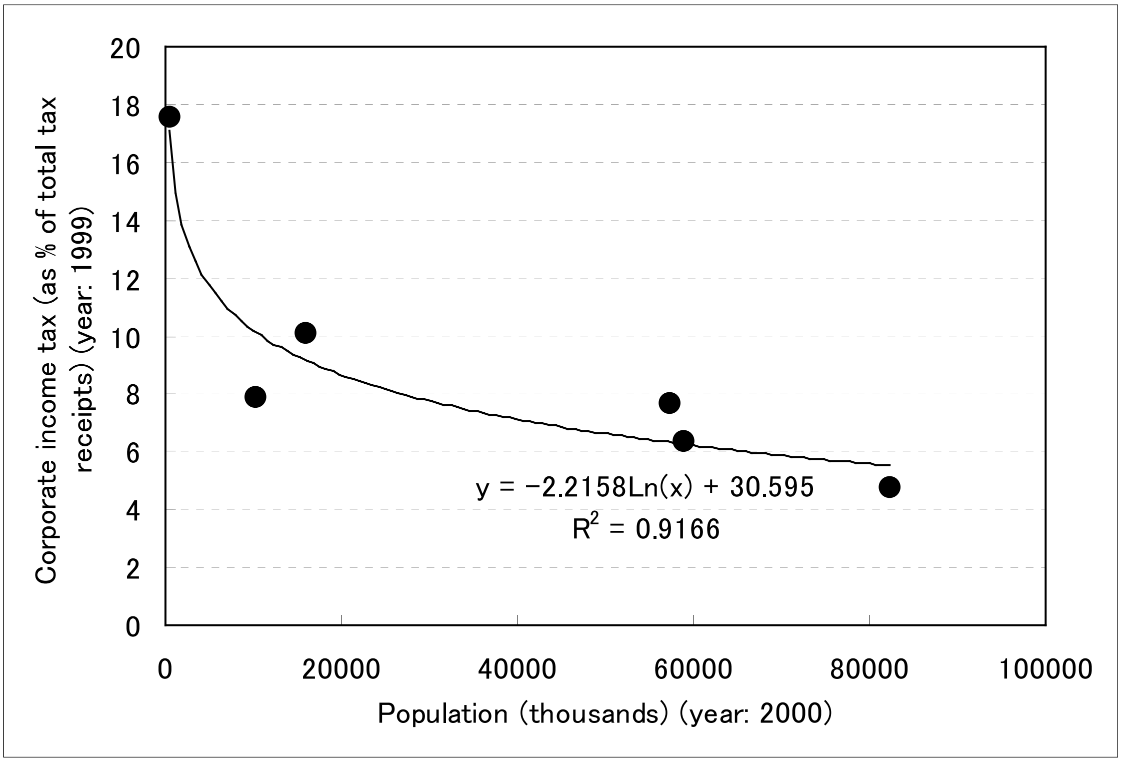

Figure 2: The relationship between the share of corporate taxes in total tax receipts and population size in EU6 (source: OECD in Figures 2003)

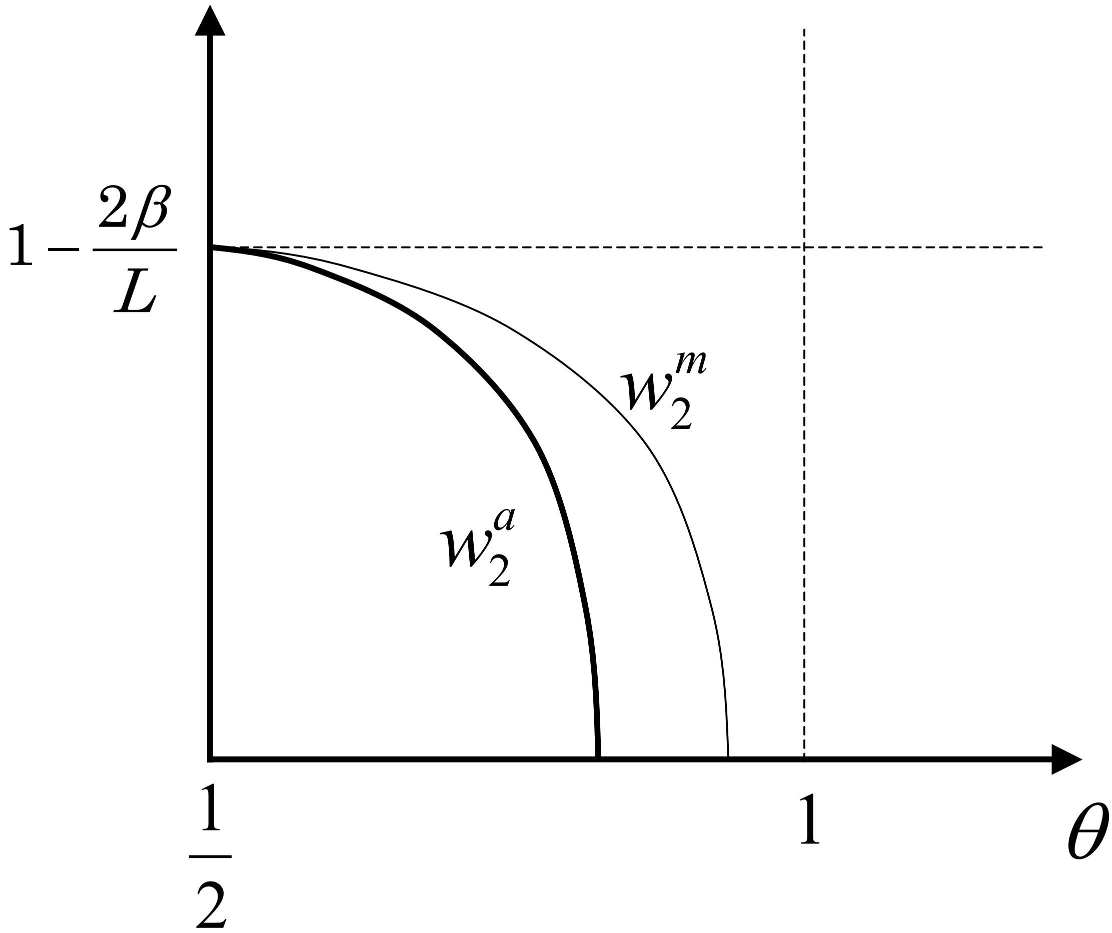

Figure 3: The effect of increases in θ on the wage rate in the small country

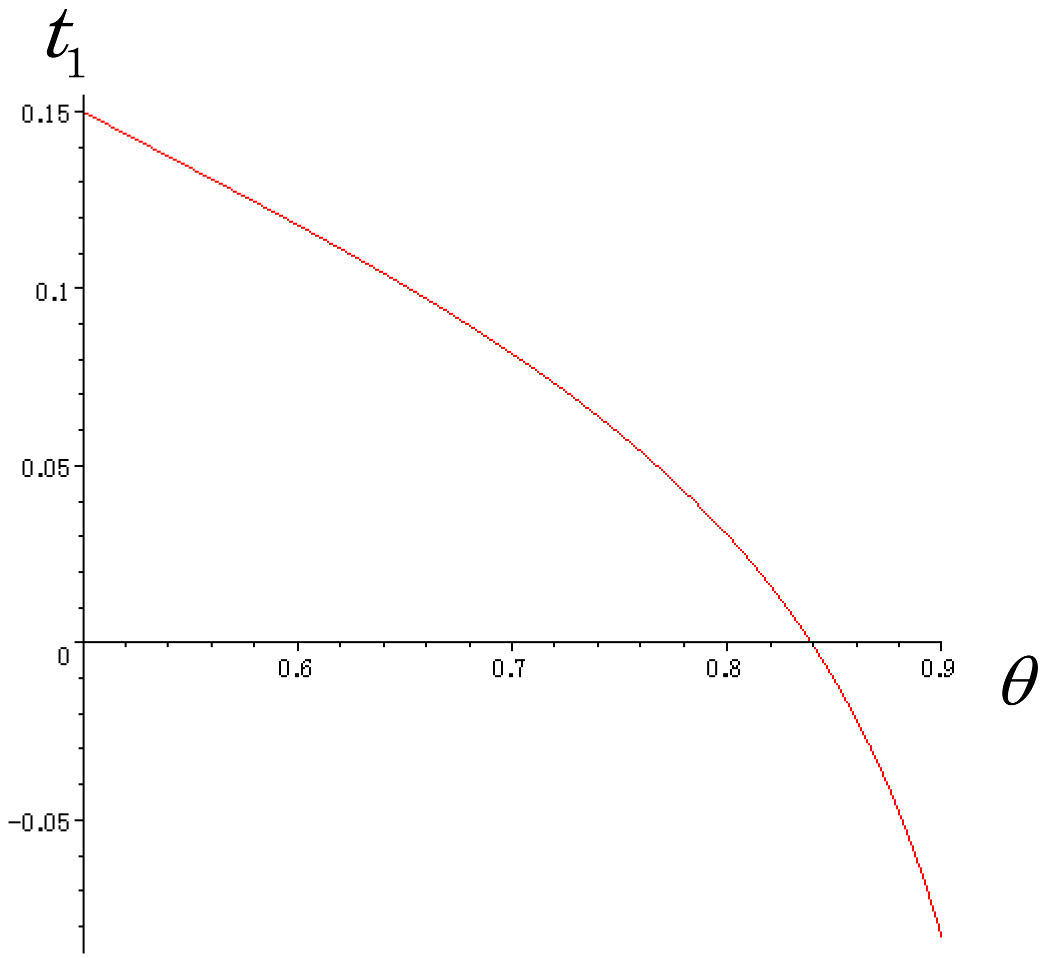

Figure 4: The tax rate of the large country

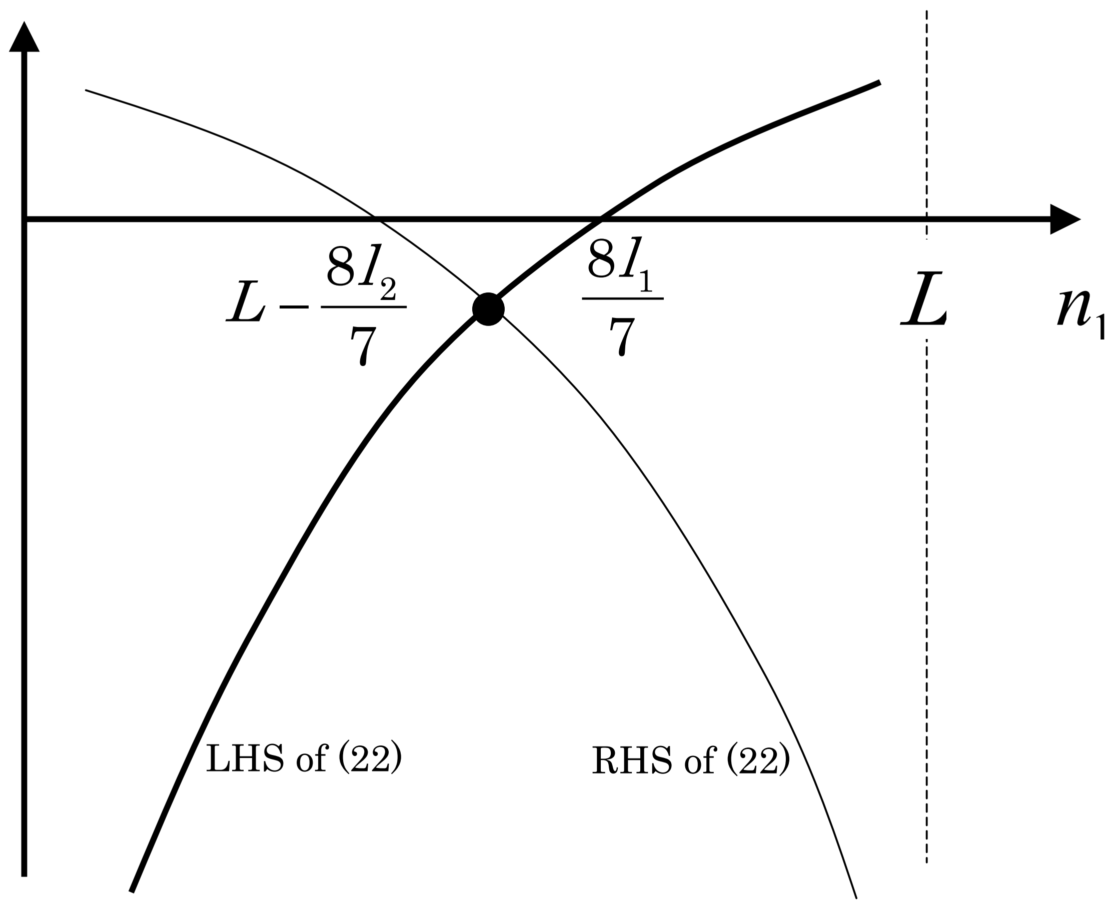

Figure 5: Nash equilibrium