DISCUSSION PAPER SERIES

No. 3109

TAKING THE BITE OUT OF FISCAL COMPETITION

Moshe Justman, Jacques-François Thisse
and Tanguy van Ypersele

PUBLIC POLICY

Centre for Economic Policy Research

www.cepr.org

Available online at: **www.cepr.org/pubs/dps/DP3109.asp**

ISSN 0265-8003

TAKING THE BITE OUT OF FISCAL COMPETITION

Moshe Justman, Ben Gurion University of the Negev
Jacques-François Thisse, CERAS, Paris and CORE, Université Catholique de Louvain and CEPR
Tanguy van Ypersele, Université de Namur and CORE

Discussion Paper No. 3109
December 2001

Centre for Economic Policy Research
90–98 Goswell Rd, London EC1V 7RR, UK
Tel: (44 20) 7878 2900, Fax: (44 20) 7878 2999
Email: cepr@cepr.org, Website: www.cepr.org

CEPR Discussion Paper No. 3109

December 2001

ABSTRACT

Taking the Bite Out of Fiscal Competition*

Regions can benefit by offering infrastructure services that are differentiated by quality, thus segmenting the market for industrial location. Regions that compete on infrastructure quality have an incentive to increase the degree of differentiation between them. This places an upper bound on the number of regions successfully able to participate in the location market, and limits the dissipation of regional surplus through Tiebout competition. It indicates a process of fiscal agglomeration, through which regional concentrations arise, which does not depend on the circular causation underlying much of the recent literature on economic geography.

JEL Classification: H73, O38, R12 and R58
Keywords: fiscal competition, regional development, technological infrastructure and vertical differentiation

Moshe Justman
Department of Economics
Ben-Gurion University
Beer Sheva 84105
ISRAEL
Tel: (972) 864 72292
Fax: (972) 864 72941
Email: justman@bgumail.bgu.ac.il

Jacques-François Thisse
CORE
Université Catholique de Louvain
34 Voie du Roman Pays
B-1348 Louvain-la-Neuve
BELGIUM
Tel: (32 10) 474312
Fax: (32 10) 474301
Email: thisse@core.ucl.ac.be

Tanguy van Ypersele
FUNDP Namur
Université de Namur
Rempart de la Vierge, 8
B-5000 Namur
BELGIUM
Tel: (32 81) 72 4846
Fax: (32 81) 72 4840
Email: tanguy@fundp.ac.be

For further Discussion Papers by this author see:
www.cepr.org/pubs/new~dps/dplist.asp?authorid=133931

* We are grateful to J Brueckner and two anonymous referees for helpful comments. The second author acknowledges the financial support of the Ministere de l'education, de la recherche et de la formation (Communautte francaise de Belgique), Convention 00/05 262. This Paper is produced as part of a CEPR research network on 'Specialization Versus Diversification: The Microeconomics of Regional Development and the Spatial Propagation of Macroeconomic Shocks in Europe', funded by the European Commission under the Research Training Network Programme (Contract No: HPRN-CT-2000-00072).

Submitted 21 November 2001

1 Introduction

Globalization of trade and investment and a general trend towards decentralization have intensified fiscal competition between regions in their efforts to attract private investment.[1] Offering subsidies is a common policy in this regard but raises the risk of a "race to the bottom" [4]. Examples abound of local development authorities luring investors with large subsidies that are difficult to justify in terms of surplus creation. Alternatively, regions can compete for investments by providing infrastructure. In the European Union the budget for regional policies is principally targeted toward the building of transportation infrastructure, on the grounds that infrastructure disparities in the EU are greater than income disparities; such spending has increased nearly tenfold since 1985 [14]. However, conventional infrastructure services tend to have very similar features [23], and their decentralized supply often leads to over-provision [19]. The strategic nature of such competition limits the benefits it can be expected to yield (see Wildasin [22] for a survey).

The rapid rate of technological change in recent years - in information technologies, life sciences, new materials - offers regions new opportunities to avoid the excesses of fiscal competition by exploiting new dimensions of differentiation inherent in technological infrastructure [9]. *Basic* forms of technological infrastructure provide specialized services to small and medium enterprises in low and mid-tech industries, which might include screening and testing new production technologies, supporting product design functions, standardizing quality control, addressing common ecological concerns, and so on.[2] More *advanced* forms of such infrastructure support the development of scientific and engineering capabilities serving the needs of firms operating at the leading edge of technological innovation.[3]

[1]We use the term region in a generic sense, to refer to "local" jurisdictions that compete for a common pool of firms through industrial development policies, including both competition between nations for foreign direct investment, and between regional authorities within a country vying to attract domestic investors.

[2]For a detailed taxonomy and survey of services aimed at improving the performance of small businesses, see Vickrey [20].

[3]The prototype of such policies is the MITI-orchestrated VLSI project in Japan, in the late 1970s, which promoted design and production capabilities for 1 megabit DRAMs [8] [18]. Similarly conceived programs subsequently implemented in other countries include the Alvey program in the UK [17], the European Union's ESPRIT program Mytelka, [16], SEMATECH in the US [6], ITRI in Taiwan [7], Israel's Magnet program [12], and Korea's Industrial Technology Infrastructure Program [15]).

Technological infrastructure thus involves a dimension of quality, which some firms are better able to exploit than others. This offers regions an opportunity to avoid head-to-head competition through quality differentiation, much as firms differentiate the quality of their products to relax price competition [1]. By providing different levels of infrastructure quality, regions can vertically segment the market, separating firms better able to take advantage of high quality infrastructure and willing to pay for it, from those for which quality is less valuable. In this paper we demonstrate the advantages of such vertical segmentation.

Our approach has much in common with the literature on fiscal competition between local authorities à la Tiebout. However, it departs from previous work in two main respects. First, it focuses on *quality* differentiation, which leads to a very different pattern of inter-regional competition. Second, by assuming that technological infrastructure is a pure public good at the regional level, it posits a setting in which there are many firms in each region. Consequently, as in Wildasin [21], competition among regions is strategic while firms do not have scope for strategic behavior.

When regions compete on a commonly ranked dimension of infrastructure quality they have an incentive to increase the degree of differentiation between them, limiting the dissipation of regional surplus through excessive Tiebout competition. Moreover, as we show, this places an upper bound on the number of regions successfully able to participate in the location market, a bound that depends only on the dispersion of firms' capabilities to exploit infrastructure services. This *fiscal agglomeration property* is an added impetus for regional agglomeration, working to foster regional concentrations of industrial activity alongside other centripetal forces such as network externalities, which are at the core of the new economic geography.[4]

We examine these issues in the context of a three-stage model in which regions and firms act individually to maximize their respective objective functions. In the first stage, each region chooses a quality level for its infrastructure, and in the second stage it selects a fee (subsidy) to be paid (received) by firms that choose to locate within its jurisdiction and utilize its infrastructure. Then, in the third stage, each firm decides in which region to locate and how much output to produce, thereby generating external benefits for the local economy. We require that in equilibrium each region is individually maximizing its net surplus given its correct anticipation of the actions of

[4]See Fujita and Thisse [5] for a survey.

other regions and of firms, and firms are maximizing their profits given the regions' choice of infrastructure quality and fee levels.

The structure of the paper is as follows. Section 2 presents the model. Section 3 then examines the second-stage equilibrium for the case of n regions, and shows that the fiscal agglomeration property holds. Section 4 derives existence and uniqueness conditions for the second-stage equilibrium in the case of two regions. Section 5 analyzes the first-stage equilibrium in which infrastructure quality levels are determined, and Section 6 concludes.

2 The Model

Consider an economy comprising $n \geq 2$ regions, indexed by i, in which the productivity of *some* firms is directly affected by the quality of technological infrastructure in the region in which they locate; thus we explicitly adopt a partial equilibrium framework for our analysis. A continuum of measure N of these firms produce a numéraire output y for which they require infrastructure services as well as labor, and which they sell on a competitive market. Each region i offers infrastructure services of quality q_i to firms locating within its jurisdiction and charges them a fee (pays them a subsidy) of $m_i > 0$ (< 0), and each firm locates in a single region. Regions choose the quality of their infrastructure services q_i from an exogenously given interval $[\underline{q}, \overline{q}]$, for which they incur only a fixed cost $c(q_i)$, where c is increasing and continuously twice differentiable, with $c(\underline{q}) > 0$. Thus we assume there is no variable cost associated with the provision of infrastructure services, treating it as a pure local public good.

Firms are *technologically differentiated*, and each is characterized by a type $\theta \in [\underline{\theta}, \overline{\theta}]$, $0 < \underline{\theta} < \overline{\theta}$, which describes its productivity in utilizing the quality of infrastructure. Let Φ be the cumulative distribution function and ϕ the density function of firm types. We assume that ϕ is differentiable and that its elasticity is strictly larger than -1 in the interval $[\underline{\theta}, \overline{\theta}]$

$$\frac{\partial \phi}{\partial \theta} \frac{\theta}{\phi} > -1 \tag{1}$$

so that $\theta\phi(\theta)$ is increasing in $[\underline{\theta}, \overline{\theta}]$. This simplifies the exposition but is not strictly necessary for the formal analysis. The production function of a firm of type θ located in region i is

$$y_i(l; \theta) = f(l, q_i; \theta)$$

where l is the amount of labor used by the firm. In what follows, we restrict our attention to separable production functions of the form

$$f(l, q_i; \theta) = \theta g(q_i) l^\alpha \tag{2}$$

in which $\alpha < 1$. Without loss of generality, we choose units of infrastructure quality such that $g(q_i) = q_i$.

We assume that labor is homogeneous and mobile. Hence, the wage rate w equalizes demand and supply of labor in the economy as a whole, and is the same in all regions. Our assumption that the firms directly affected by the process of fiscal competition in infrastructure do not represent a large share of the economy allows us to sidestep important labor market issues. It implies that the policy chosen by any region has a negligible impact on the global demand for labor, and hence on the level of wages in the economy. Accordingly, firms and regions treat the wage level w as exogenous.[5] The profit function of a firm of type θ locating in region i is then given by

$$\pi_i(l; \theta) = y_i(l; \theta) - wl - m_i$$

The sequence of decisions is as follows. First, each region chooses a quality level for its infrastructure, and the corresponding investments are sunk. Second, each region selects the fee (subsidy) to be paid (received) by firms that choose to locate in its jurisdiction. Sequencing regions' decisions in this way reflects our understanding that the choice of infrastructure quality is less easily changed than the choice of a fee or subsidy.[6] Lastly, each firm upon observing the infrastructure quality and fee levels chosen by the various regions, selects the region in which it locates and decides how much output to produce.

[5] In an economy characterized by low interregional labor mobility, a regional inflow (or exodus) of firms would likely have a significant impact on prevailing wage rates. In the first instance, the change in wages would counteract the flow of firms, dampening the change in local employment. Thus lesser mobility of labor implies that regions retain a greater share of the surplus, which should encourage regions to compete more aggressively to attract new investment. These considerations introduce new factors that add considerably to the complexity of the analysis, but we would not expect them to alter the direction of the net effects derived in our simpler model.

[6] Note also that using a simultaneous approach raises issues regarding the existence of an equilibrium in pure strategies.

3 The Fiscal Agglomeration Property

We solve the model recursively beginning with firms' production and location decisions. Assume that quality levels and fees have been set. Without loss of generality, we label the regions in such a way that $q_n > q_{n-1} > ... > q_1$,[7] and this must also be the order of fees among active regions, i.e., if regions i and j are active in equilibrium, and $q_i > q_j$, then we must also have $m_i > m_j$, for if region j were to charge a higher fee (or offer a smaller subsidy) than region i while providing an infrastructure of lesser quality it would not attract any firms.

Assume that a firm of type θ has located in region i. Then its profits are given by

$$\widehat{\pi}_i(\theta) = \max_l \{y_i(l;\theta) - wl - m_i\} \tag{3}$$

Applying the first-order condition to (3) yields

$$l_i(\theta) = \alpha y_i(l;\theta)/w$$

so that its profit-maximizing output is

$$\widehat{y}_i(\theta) = \left(\frac{\alpha}{w}\right)^{\frac{\alpha}{1-\alpha}} \theta^{\frac{1}{1-\alpha}} q_i^{\frac{1}{1-\alpha}} \tag{4}$$

As the firm's wage bill is equal to α times its output, its profit equals

$$\widehat{\pi}_i(\theta) = (1-\alpha)\widehat{y}_i(\theta) - m_i \tag{5}$$

Clearly, the profit earned by a firm locating in a region increases with the quality of the infrastructure available there.

Next, consider the location of firms. Since $\widehat{\pi}_i(\theta)$ is increasing in θ, it is readily verified that all firms locating in region i have a type that falls between $\widehat{\theta}_{i-1}$, the type of the firm indifferent between locating in regions i and $i-1$, and $\widehat{\theta}_i$, the type of the firm indifferent between locating in i and $i+1$. We set $\widehat{\theta}_n = \overline{\theta}$ and $\widehat{\theta}_0 = \underline{\theta}$. For $i = 1, ..., n-1$, the value of $\widehat{\theta}_i$ is obtained as the solution of the indifference condition

$$\widehat{\pi}_i(\theta) = \widehat{\pi}_{i+1}(\theta)$$

Using (5), this becomes

$$(1-\alpha)\widehat{y}_i(\theta) - m_i = (1-\alpha)\widehat{y}_{i+1}(\theta) - m_{i+1} \tag{6}$$

[7] We show in Section 5 that the inequalities are strict in equilibrium.

Given (4), this confirms our initial claim that if $q_{i+1} > q_i$ then $m_{i+1} > m_i$: the region supplying a better quality infrastructure is able to claim a higher fee or offer a lower subsidy. Substitution of (4) in (6) yields

$$\widehat{\theta}_i = \frac{w^\alpha}{\alpha^\alpha(1-\alpha)^{1-\alpha}} \left(\frac{m_{i+1} - m_i}{q_{i+1}^{1/(1-\alpha)} - q_i^{1/(1-\alpha)}} \right)^{1-\alpha}$$

We now proceed to the second stage in which regions decide on the level of fees (subsidies), after quality levels have been set. We focus on a Nash equilibrium in which region i's choice of fee maximizes an objective function comprising three parts: (i) gains from local employment, which we assume to be proportional to the wage bill; (ii) fee income, m_i per firm, which can be positive or negative; and (iii) the cost $c(q_i)$ of the infrastructure supplied by the region:

$$S_i = \int_{\widehat{\theta}_{i-1}}^{\widehat{\theta}_i} [\gamma y_i(\theta) + m_i]\phi(\theta)d\theta - c(q_i) \tag{7}$$

in which γ/α ($\gamma \leq \alpha$) is the fraction of the local wage bill which accrues to the region as a net gain.[8] We shall refer to S_i as the (regional) net surplus and to the integral as the gross surplus. The net surplus takes into account both the cost of the infrastructure and the fiscal impact of the fee or subsidy. However, it does not deal explicitly with the financing of any net costs (or the distribution of a net fiscal surplus); we assume that such costs are financed by a tax levied on other activities not modeled in the paper.

Differentiating (7) with respect to m_i yields

$$\begin{aligned} \frac{\partial S_i}{\partial m_i} &= \gamma y_i(\widehat{\theta}_i)\phi(\widehat{\theta}_i)\frac{\partial \widehat{\theta}_i}{\partial m_i} - \gamma y_i(\widehat{\theta}_{i-1})\phi(\widehat{\theta}_{i-1})\frac{\partial \widehat{\theta}_{i-1}}{\partial m_i} \\ &\quad + m_i\phi(\widehat{\theta}_i)\frac{\partial \widehat{\theta}_i}{\partial m_i} - m_i\phi(\widehat{\theta}_{i-1})\frac{\partial \widehat{\theta}_{i-1}}{\partial m_i} + \Phi(\widehat{\theta}_i) - \Phi(\widehat{\theta}_{i-1}) \end{aligned} \tag{8}$$

where

$$\frac{\partial \widehat{\theta}_i}{\partial m_i} = -\frac{(1-\alpha)\widehat{\theta}_i}{m_{i+1} - m_i} < 0 \tag{9}$$

[8] This gain might correspond to the local mutiplier effect of these firms, or to additional revenues which the local government can raise as a result of the increase in the level of economic activity in the region. We assume that this gain does not exceed the local wage bill, but this is not necessary for the formal analysis.

for $i = 1, ..., n-1$ and

$$\frac{\partial \widehat{\theta}_{i-1}}{\partial m_i} = \frac{(1-\alpha)\widehat{\theta}_{i-1}}{m_i - m_{i-1}} > 0 \tag{10}$$

for $i = 1, ..., n-1$. In other words, if region i raises its fee, it loses firms from both sides. If all regions are active, so that region i attracts a positive mass of firms $N_i^* \equiv \Phi(\widehat{\theta}_i) - \Phi(\widehat{\theta}_{i-1})$, then in equilibrium (8) is equal to zero for each $i = 1, ..., n$. Hence, it must be that

$$\begin{aligned} N_i^* &= -\frac{\partial \widehat{\theta}_i}{\partial m_i}[\gamma y_i(\widehat{\theta}_i) + m_i^*]\phi(\widehat{\theta}_i) + \frac{\partial \widehat{\theta}_{i-1}}{\partial m_i}[\gamma y_i(\widehat{\theta}_{i-1}) + m_i^*]\phi(\widehat{\theta}_{i-1}) \\ &\geq \frac{(1-\alpha)}{m_i^* - m_{i-1}^*}[\gamma y_i(\widehat{\theta}_{i-1}) + m_i^*]\widehat{\theta}_{i-1}\phi(\widehat{\theta}_{i-1}) \end{aligned}$$

where we have used (9) and (10). Consequently, we have

$$N_i^* \geq \frac{(1-\alpha)}{m_i^* - m_{i-1}^*}\{\gamma y_i(\widehat{\theta}_{i-1}) + m_i^* - [\gamma y_{i-1}(\widehat{\theta}_{i-1}) + m_{i-1}^*]\}\widehat{\theta}_{i-1}\phi(\widehat{\theta}_{i-1})$$

since we subtract a nonnegative term. Hence,

$$\begin{aligned} N_i^* &\geq \frac{(1-\alpha)}{m_i^* - m_{i-1}^*}\{\gamma[y_i(\widehat{\theta}_{i-1}) - y_{i-1}(\widehat{\theta}_{i-1})] + (m_i^* - m_{i-1}^*)\}\widehat{\theta}_{i-1}\phi(\widehat{\theta}_{i-1}) \\ &= \frac{(1-\alpha)}{m_i^* - m_{i-1}^*}\left[\frac{\gamma}{1-\alpha}(m_i^* - m_{i-1}^*) + (m_i^* - m_{i-1}^*)\right]\widehat{\theta}_{i-1}\phi(\widehat{\theta}_{i-1}) \end{aligned}$$

where we have used (6) so that, by (1),

$$\begin{aligned} N_i^* &\geq (1-\alpha+\gamma)\widehat{\theta}_{i-1}\phi(\widehat{\theta}_{i-1}) \\ &\geq (1-\alpha+\gamma)\underline{\theta}\phi(\underline{\theta}) \end{aligned}$$

which is a strictly positive constant independent of regions' behavior.[9] Summing across regions from 1 to n, we obtain

$$N = \sum_{i=1}^{n} N_i^* \geq (1-\alpha+\gamma)n\underline{\theta}\phi(\underline{\theta}) \tag{11}$$

[9] In the case of a general distribution, the lower bound on N_i^* is $(1-\alpha+\gamma) \min_{\theta \in [\underline{\theta}, \overline{\theta}]} \theta\phi(\theta)$.

This places an upper bound on the number n of active regions in equilibrium (if any, since our distribution of types is general), which is independent of the infrastructure qualities. Of course, the actual number of active regions may be smaller than this upper bound.[10]

For example, in the case of a uniform density we have $\phi(\theta) = N/(\overline{\theta} - \underline{\theta})$ so that the upper bound on the number of active regions given by (11) becomes

$$n < 1 + \frac{1}{1-\alpha+\gamma}\left(\frac{\overline{\theta}-\underline{\theta}}{\underline{\theta}}\right) \leq \frac{\overline{\theta}/\underline{\theta}}{1-(\alpha-\gamma)} \tag{12}$$

The upper bound on the number of active regions is directly related to $(\overline{\theta} - \underline{\theta})/\underline{\theta}$, the relative variation in productivity between the 'best practice' and 'worst practice' firms. Thus it varies directly with the degree of heterogeneity of firms, because this relaxes fiscal competition. It varies inversely with the benefit that regions derive from the location of firms, i.e., it is lower the closer γ is to α. When regions benefit from a larger fraction of the wage bill they compete more aggressively, which reduces the maximal number of active regions in equilibrium.

The discussion above can be summarized as follows.

Proposition 1 *Assume that a fee/subsidy equilibrium exists and the production function is given by (2). When regions are differentiated by the quality of their technological infrastructure, the number of active regions is bounded from above by a constant which is independent of regions' policy decisions.*

This result, which we call the *fiscal agglomeration property*, has several implications for the process of fiscal competition. It means that regardless of cost considerations and the number of competing regions, *the number of regions that will succeed in generating a positive gross surplus is limited by the dispersion of firms' capabilities in using infrastructure.* This implies that the process of fiscal competition is inherently strategic: when the upper bound is reached, the entry of new regions can only be achieved through the exit of incumbent regions, placing regional development policies in direct competition with each other. Furthermore, our analysis indicates that *the agglomeration of firms in a limited number of locations may result from fiscal competition*

[10] We discuss the second-order condition in Section 4. When it does not hold for a region in equilibrium, then the region is either inactive or the only active region. In both cases, the fiscal agglomeration property is still valid.

in developing infrastructure of different quality levels. This is a process of agglomeration that does not depend on the cumulative effect of network externalities underlying much of the recent literature on economic geography, but follows directly from the heterogeneity of firms and the strategic behavior of regions.

4 Existence of a Fee/Subsidy Equilibrium with Two Regions

In the foregoing analysis we implicitly assumed the existence of an equilibrium for any fiscal competition (sub)game. Uniqueness of such an equilibrium greatly simplifies the analysis of the infrastructure game considered in the next section. We derive here conditions for both existence and uniqueness of the second-stage equilibrium for the case of (at most) two active regions. To simplify the notation assume that $\gamma = \alpha$, i.e., the entire wage bill is included in the region's surplus. The argument is subdivided into four steps.

Step 1. We begin by considering the case in which both regions are active. Assume without loss of generality that $q_2 > q_1$ (the case $q_2 = q_1$ is discussed below). Then there is one marginal firm type, which must satisfy

$$(1-\alpha)\widehat{y}_1(\theta) - m_1 = (1-\alpha)\widehat{y}_2(\theta) - m_2 \tag{13}$$

After substitution this gives

$$\widehat{\theta} = \frac{w^\alpha}{\alpha^\alpha(1-\alpha)^{1-\alpha}} \left(\frac{m_2 - m_1}{q_2^{1/(1-\alpha)} - q_1^{1/(1-\alpha)}} \right)^{1-\alpha} \tag{14}$$

The first-order conditions for the two regions are then

$$\frac{\partial S_1}{\partial m_1} = \frac{\partial \widehat{\theta}}{\partial m_1} [\alpha y_1(\widehat{\theta}) + m_1^*] \phi(\widehat{\theta}) + \Phi(\widehat{\theta}) = 0 \tag{15}$$

$$\frac{\partial S_2}{\partial m_2} = -\frac{\partial \widehat{\theta}}{\partial m_2} [\alpha y_2(\widehat{\theta}) + m_2^*] \phi(\widehat{\theta}) + N - \Phi(\widehat{\theta}) = 0 \tag{16}$$

As shown in Appendix A, the second-order condition holds for region 2 provided that the distribution of θ satisfies certain conditions, which we shall assume to be the case. However, the second-order condition for region 1 holds only if there is sufficient differentiation of infrastructure quality, specifically if $q_2/q_1 \geq \delta$ where $\delta > 1$ is a constant that is implicitly derived in Appendix A. Assume for the moment that this condition is satisfied so that (16) and (15) determine the fee equilibrium. Subtracting (16) from (15), and using (9) to substitute for $\partial\widehat{\theta}/\partial m_1 = -\partial\widehat{\theta}/\partial m_2$, we obtain

$$-\frac{(1-\alpha)\widehat{\theta}}{m_2^* - m_1^*}\{\alpha[y_2(\widehat{\theta}) - y_1(\widehat{\theta})] + m_2^* - m_1^*\}\phi(\widehat{\theta}) + N - 2\Phi(\widehat{\theta}) = 0$$

After further substitution, using (5) this yields

$$-\frac{(1-\alpha)\widehat{\theta}}{m_2^* - m_1^*}\left[\frac{\alpha}{1-\alpha}(m_2^* - m_1^*) + (m_2^* - m_1^*)\right]\phi(\widehat{\theta}) + N - 2\Phi(\widehat{\theta}) = 0$$

which simplifies to

$$-\widehat{\theta}\phi(\widehat{\theta}) + N - 2\Phi(\widehat{\theta}) = 0 \tag{17}$$

Using (1), it is immediate that (17) has at most one solution, which is independent of the value of q_1 and q_2.[11] Furthermore, the LHS of (17) is decreasing in θ by (1) and negative at $\theta = \overline{\theta}$ since $\Phi(\overline{\theta}) = N$. Therefore, a necessary condition for (17) to have a solution interior to the interval $[\underline{\theta}, \overline{\theta}]$, i.e., for both regions to be active, is that the LHS of (17) is positive at $\underline{\theta}$. This holds if and only if

$$N > \underline{\theta}\phi(\underline{\theta}) \tag{18}$$

In words, this condition implies that the density of firms with minimal infrastructure requirements is small relative to the total mass of firms, i.e., that the left-hand tail of the distribution of firms is not too"fat".[12]

Deriving a fee/subsidy equilibrium in pure strategies then follows immediately from equations (15) and (16), which imply that it must satisfy:

$$\frac{\alpha y_2(\widehat{\theta}) + m_2^*}{\alpha y_1(\widehat{\theta}) + m_1^*} = \frac{N - \Phi(\widehat{\theta})}{\Phi(\widehat{\theta})}$$

[11]Note that (17) implies that the bound identified in condition (11) is tight for $n = 2$.

[12]In the special case of a uniform distribution of types, the solution of (17) is given by $\widehat{\theta} = (\overline{\theta} + \underline{\theta})/3$, which is larger than $\underline{\theta}$ if and only if $\overline{\theta} > 2\underline{\theta}$.

Combining this with (6), we find that, if there exists a fee/subsidy equilibrium in which both regions are active, it is unique and given by the pure fee strategies

$$m_1^* = \frac{\Phi(\widehat{\theta})}{N - 2\Phi(\widehat{\theta})}[y_2(\widehat{\theta}) - y_1(\widehat{\theta})] - \alpha y_1(\widehat{\theta}) \tag{19}$$

$$m_2^* = \frac{N - \Phi(\widehat{\theta})}{N - 2\Phi(\widehat{\theta})}[y_2(\widehat{\theta}) - y_1(\widehat{\theta})] - \alpha y_2(\widehat{\theta}) \tag{20}$$

Clearly, when there are two active regions, the region supplying a better quality of infrastructure (i.e. region 2) is able to charge a higher fee or offer a lower subsidy. Moreover, as (17) implies that $N - 2\Phi(\widehat{\theta}) > 0$, and hence that $\Phi(\widehat{\theta}) < N/2$, when there are two active regions *the region with the superior infrastructure attracts the majority of firms.*

Note that both of the m_i^* may be either positive or negative in equilibrium. From (19), both regions will charge a positive fee if and only if

$$y_2(\widehat{\theta})/y_1(\widehat{\theta}) > 1 + \alpha \frac{N - 2\Phi(\widehat{\theta})}{\Phi(\widehat{\theta})}$$

which, from (4), holds if and only if

$$q_2/q_1 > \left[1 + \alpha \frac{N - 2\Phi(\widehat{\theta})}{\Phi(\widehat{\theta})}\right]^{1-\alpha} \tag{21}$$

Thus, *only if the quality of the infrastructure in the two regions is sufficiently differentiated will each be able to charge a positive fee for locating in its region.* Conversely, when quality differentiation falls below a certain threshold, viz., when

$$\delta < q_2/q_1 < \left[1 + \alpha \frac{N - 2\Phi(\widehat{\theta})}{N - \Phi(\widehat{\theta})}\right]^{1-\alpha} \tag{22}$$

then both regions compete by offering subsidies to firms. At interim levels of differentiation, between the two bounds (21) and (22), region 2 competes on quality, charging a fee for locating in its region, while region 1 competes on price, offering a subsidy to firms locating in its region.

Following a similar line of reasoning, the comparative statics of m_i^*reveal that:

$$\begin{aligned} \partial m_1^*/\partial q_1 &< 0 \qquad \partial m_2^*/\partial q_1 < 0 \\ \partial m_1^*/\partial q_2 &> 0 \qquad \partial m_2^*/\partial q_2 > 0 \end{aligned}$$

When the region with the lower quality improves its quality it narrows the gap between the two regions, intensifying fiscal competition between them, and both regions lower their fees or increase their subsidies. Conversely, when the higher quality infrastructure is yet further improved the two regions are more strongly differentiated and both raise the fees they charge or lower their subsidies.[13] These inequalities will be central in the analysis of the game in infrastructure quality levels.

Step 2. Assume that the value of $\widehat{\theta}$ that solves (17) is no greater than $\underline{\theta}$ so that only region 2 is active: it attracts the entire population of firms while region 1 attracts none.[14] The fiscal agglomeration property yields a sufficient condition for this to be the only possible equilibrium, viz., $N \leq \underline{\theta}\phi(\underline{\theta})$.[15] Here we derive necessary conditions that such an equilibrium must satisfy.

If only region 2 is active, an equilibrium pair of fees (m_1^*, m_2^*) must satisfy three conditions: (i) firms of type $\underline{\theta}$ must prefer region 2 (or be indifferent between the two regions, if we ignore sets of measure zero), (ii) region 1 cannot benefit by lowering m_1 and (iii) region 2 cannot benefit by raising m_2.

(i) If a firm of type $\underline{\theta}$ is either indifferent between the two regions or

[13]Another implicit assumption in the analysis above is that firms always find it profitable to locate in one of the two regions, but when regions are sufficiently differentiated, the tax m_i^* could be so high that some firms would run a deficit. In order to focus on our main argument, we choose to set boundaries on the space of regional infrastructure types to ensure that all firms make positive profits at the fiscal competition equilibrium described by (19) and (20). Relaxing this assumption would not change the substance of the argument but would add to its complexity. In the fiscal competition stage, regions would have to take into account the fact that a marginal increase of the tax rate could induce some firms to exit entirely and not just leave one region for another. This would lead to equilibrium taxes that are lower than those described in (19) and (20).

[14]An equilibrium in which only region 1, the region with the inferior infrastructure, is active is clearly not feasible, as region 2 can attract all firms by offering the same fee/subsidy as region 1 and earn a larger gross surplus.

[15]Cf. (11) and (18) above.

prefers region 2 then m_1^* and m_2^* must satisfy

$$(1-\alpha)y_2(\underline{\theta}) - m_2^* \geq (1-\alpha)y_1(\underline{\theta}) - m_1^*$$

Equality must hold if region 2 maximizes its objective function.[16] Rearranging terms, this yields

$$m_2^* - m_1^* = (1-\alpha)[y_2(\underline{\theta}) - y_1(\underline{\theta})] \tag{23}$$

Thus the difference in fees between the two regions is bounded by the quality gap between them.

(ii) If region 1 cannot benefit by lowering m_1 when $\widehat{\theta} = \underline{\theta}$ then we must have

$$\frac{\partial S_1}{\partial m_1} = -\frac{(1-\alpha)\underline{\theta}}{m_2^* - m_1^*}[\alpha y_1(\underline{\theta}) + m_1^*]\phi(\underline{\theta}) + \Phi(\underline{\theta}) \geq 0$$

which amounts to

$$m_1^* \leq -\alpha y_1(\underline{\theta}) \tag{24}$$

(iii) Finally, if region 2 cannot benefit by raising m_2 when $\widehat{\theta} = \underline{\theta}$ then we must have

$$\frac{\partial S_2}{\partial m_2} = -\frac{(1-\alpha)\underline{\theta}}{m_2^* - m_1^*}[\alpha y_2(\underline{\theta}) + m_2^*]\phi(\underline{\theta}) + N - \Phi(\underline{\theta}) \leq 0$$

Using (23) to substitute for $m_2^* - m_1^*$ this gives

$$m_2^* \geq N[y_2(\underline{\theta}) - y_1(\underline{\theta})]/[\underline{\theta}\phi(\underline{\theta})] - \alpha y_2(\underline{\theta}) \tag{25}$$

Combining (23), (24) and (25), a necessary condition for m_1^* and m_2^* to support an equilibrium in which only region 2 is active is

$$N[y_2(\underline{\theta}) - y_1(\underline{\theta})]/[\underline{\theta}\phi(\underline{\theta})] - \alpha y_2(\underline{\theta}) + \alpha y_1(\underline{\theta}) \leq (1-\alpha)[y_2(\underline{\theta}) - y_1(\underline{\theta})] \tag{26}$$

Since we have assumed $q_2 > q_1$, this implies

$$N \leq \underline{\theta}\phi(\underline{\theta}) \tag{27}$$

[16]Otherwise region 2 can increase its surplus by slightly raising its fee without losing firms.

which is the opposite of (18). If the second-order condition holds, (27) is both necessary and sufficient for only one region to be active in equilibrium. In this case, equilibrium values of m_1 and m_2 are given by (24) and (25) with equality. If we constrain region 1 not to offer a subsidy in excess of the gross surplus generated by the most productive firm it is able to attract, $\widehat{\theta}$, i.e., if we require that $m_1^* \geq -\alpha y_i(\widehat{\theta})$, then this equilibrium is unique.[17]

Step 3. Consider the case $q_2/q_1 < \delta$ so that the second-order conditions for region 1 is not met, as its objective function is convex in the relevant range. If $N \leq \underline{\theta}\phi(\underline{\theta})$ then this is of no consequence as region 1 is not active. However, if $N > \underline{\theta}\phi(\underline{\theta})$ then there can be no pure strategy equilibrium, with either one or two active regions. When this is the case there is a mixed strategy equilibrium in which region 1 randomizes between setting a fee/subsidy that relinquishes the entire market to region 2 and one which captures the entire market, while region 2 adopts a pure strategy that maximizes its expected gross surplus.[18] In this case, region 1's gross surplus is zero and region 2's gross surplus converges to zero as the two regions become less and less differentiated, i.e., as q_2 converges to q_1.

Step 4. Finally, consider the case in which both regions select the same infrastructure quality, q. Both must then charge the same fee or offer the same subsidy, as otherwise the region with the higher fee or lower subsidy would not attract any firms; denote this common fee or subsidy m. Assuming that firms of each type are equally split between the two regions, each region has a gross surplus (before deducting the cost of providing the infrastructure) equal to

$$\frac{1}{2}\left[\alpha \int_{\underline{\theta}}^{\overline{\theta}} y(\theta) d\theta + mN\right]$$

where a negative value of m denotes a subsidy. Competition between the two regions is entirely price-based in this case, with small differences in fees or subsidies generating large swings in firm location. Consequently, both regions offer larger and larger subsidies until their gross surplus equals zero, at which point neither region can gain by further decreasing its fee. Thus if

[17] Without assuming this condition, there could be an inessential multiplicity of equilibria corresponding to a continuum of fees which leave region 1 empty while it offers a subsidy larger than $\alpha y_1(\underline{\theta})$. In all of these equilibria, region 1 does not attract any firms and does not distribute any subsidies, thus earning zero gross surplus.

[18] See Appendix B.

$q_1 = q_2$, in second-stage equilibrium both regions offer the same subsidy,

$$m^* = -\frac{\alpha}{N} \int_{\underline{\theta}}^{\overline{\theta}} y(\theta) d\theta \tag{28}$$

Given that both regions must also bear the cost $c(q)$ of providing the infrastructure, *when regions do not differentiate the quality of their infrastructures, head-to-head fiscal competition generates a negative net surplus in each region*, draining resources for local development.

Collecting results, we obtain

Proposition 2 *Consider a two-region economy and assume that region* 1 *is constrained not to offer subsidies in excess of the gross surplus it can generate from the most productive firm in its region, i.e.,* $m_1^* \geq -\alpha y_1(\widehat{\theta})$*, while the distribution of firms' types is such that the second-order condition holds for region* 2*.*

(i) If $q_2/q_1 \geq \delta > 1$ *and* $N > \underline{\theta}\phi(\underline{\theta})$*, then there exists a unique equilibrium in which both regions are active, and the fee/subsidy levels are given by (19) and (20).*

(ii) If $q_2 > q_1$ *and* $N \leq \underline{\theta}\phi(\underline{\theta})$*, then there exists a unique equilibrium in which region* 2 *attracts all firms, and the fees that support this equilibrium are given by (24) and (25) with equality.*

(iii) If $\delta > q_2/q_1 > 1$ *and* $N > \underline{\theta}\phi(\underline{\theta})$*, then there exists an equilibrium in which region* 1 *employs a mixed strategy and earns zero expected gross surplus, while region* 2 *responds with a pure strategy and earns a gross surplus that converges to zero as the two regions become less and less differentiated, i.e., as* q_2 *converges to* q_1*.*

(iv) If $q_2 = q_1$*, then there exists a unique equilibrium in which both regions offer the same subsidy, share the population of firms equally between them, and have zero gross surplus.*

5 Choosing Infrastructure Quality Levels

We now turn to the first stage in which the two regions choose their infrastructure quality levels, anticipating the fee structures in second-stage equilibrium derived in the previous section. We assume that the measure of firms is sufficiently large to allow for an equilibrium in which both firms are active ($N > \underline{\theta}\phi(\underline{\theta})$), which is described in the preceding proposition. The strategies of the first-stage game are the infrastructure quality levels $q_1, q_2 \in [\underline{q}, \overline{q}]$. For simplicity, we also assume that $c(\underline{q})$ is small enough for the two regions to have a positive net surplus in the equilibrium of the first stage game.

Consider region 1 first. When $q_2/q_1 < \delta$ so that second-order conditions do not hold, region 1's gross surplus is identically zero, and so

$$\frac{\partial S_1}{\partial q_1} = -c'(q_1) < 0$$

and region 1 seeks to set the lowest possible infrastructure quality level. When $q_2/q_1 \geq \delta$ so that second-order conditions hold for both regions and region 1 employs a pure fee strategy, its net surplus is given by

$$S_1 = \int_{\underline{\theta}}^{\hat{\theta}} [\alpha y_1(\theta) + m_1^*]\phi(\theta)d\theta - c(q_1)$$

where $\widehat{\theta}$ is independent of the quality levels, and given by (17); and m_1^* is determined by (19). Taking the derivative we obtain

$$\frac{\partial S_1}{\partial q_1} = \int_{\underline{\theta}}^{\hat{\theta}} \frac{\partial[\alpha y_1(\theta; q_1) + m_1^*(q_1, q_2)]}{\partial q_1}\phi(\theta)d\theta - c'(q_1) \tag{29}$$

The sign of the integrand is not immediately apparent, as $y_1(\theta; q_1)$ is increasing in q_1 while m_1^* is decreasing, but closer inspection reveals that the second effect is dominant. The integrand in (29) is negative when evaluated at $\hat{\theta}$. Indeed, (14) implies that

$$\frac{\partial[\alpha y_1(\widehat{\theta}; q_1) + m_1^*(q_1, q_2)]}{\partial q_1} = \frac{\partial}{\partial q_1}\left\{\frac{\Phi(\hat{\theta})}{N - 2\Phi(\hat{\theta})}[y_2(\hat{\theta}; q_2) - y_1(\hat{\theta}; q_1)]\right\} < 0$$

since $\partial y_2(\hat{\theta})/\partial q_1 = 0$ and $\partial y_1(\hat{\theta})/\partial q_1 > 0$. Moreover, the same integrand is increasing in θ as

$$\frac{\partial[\alpha y_1(\theta; q_1) + m_1^*(q_1, q_2)]}{\partial q_1 \partial\theta} = \frac{\alpha}{(1-\alpha)^2}\frac{y_1}{q_1\theta} > 0$$

Hence it must be negative for all values of $\theta < \widehat{\theta}$, and the first term on the right-hand side of (29) is negative. As c is increasing, $\partial S_1/\partial q_1 < 0$. Therefore in this range, too, region 1's dominant strategy is to chose the lowest possible infrastructure quality, $\underline{q}$, irrespective of region 2's choice of quality level.

Consider region 2 next, and we need only consider its optimal response to $q_1 = \underline{q}$. For $q_2 \geq \delta\underline{q}$ so that second-order conditions hold for both regions, and there is a fee/subsidy equilibrium in pure strategies, region 2's net surplus is given by

$$S_2 = \int_{\widehat{\theta}}^{\overline{\theta}} [\alpha y_2(\theta) + m_2^*]\phi(\theta)d\theta - c(q_2)$$

where $\widehat{\theta}$ is given by (17) and independent of the quality levels; and m_2^* is given by (20). Differentiating region 2's objective function then yields

$$\frac{\partial S_2}{\partial q_2} = \int_{\widehat{\theta}}^{\overline{\theta}} \frac{\partial[\alpha y_2(\theta; q_2) + m_2^*(q_1, q_2)]}{\partial q_2}\phi(\theta)d\theta - c'(q_2)$$

As both y_2 and m_2^* are increasing in q_2, the optimal choice of q_2 in the range $[\delta\underline{q}, \overline{q}]$ will depend on the relative steepness of c. If c is not too steep in relation to the slope of the benefit term then it is optimal for region 2 to provide the highest quality of infrastructure, i.e. to set $q_2 = \overline{q}$; if c is moderately steep then q_2 should be set at a level that equates the marginal benefit of improved infrastructure to its the marginal cost; and if c is very steep the optimal choice of q_2 in the range $[\delta\underline{q}, \overline{q}]$ is $\delta\underline{q}$. Similarly, S_2 is increasing in q_2 in the interval $[1, \delta\underline{q}]$, and the optimal choice will similarly vary with the steepness of c (a detailed analysis is provided in appendix B).

Thus, provided that c is not too steep, there exist strong incentives for *both regions to differentiate themselves by offering different qualities of infrastructure.* Such a policy allows them to alleviate the burden of fiscal competition and to collect larger surpluses where head to head competition leads to zero gross surplus.

We summarize our results in the following proposition:

Proposition 3 *In a two-region economy it is always optimal for region* 1 *to choose the lowest infrastructure quality,* $q_1^* = \underline{q}$*, while region* 2*'s choice of infrastructure depends on the steepness of the infrastructure quality cost function* $c(q)$*. If* $c(q)$ *does not increase too steeply with* q*, then region* 2 *chooses* $q_2^* = \bar{q}$*; if* $c(q)$ *increases more steeply, then region* 2 *chooses an infrastructure quality lower than* $\bar{q}$*.*

Each of the equilibrium quality levels and fees we have described represents, in effect, two equilibria, in which the roles of the two regions are permuted, and in which generally one region is better off than the other. Nevertheless, whichever region gains more, both are better off if they *differentiate themselves by offering different qualities of infrastructure.* This allows them to make positive gains whereas head-to-head competition in subsidies, absent differentiation, would result in a negative net surplus.

Further bounds on the quality range of available infrastructure can be derived by examining the relationship between the costs and benefits of infrastructure quality. Note that the fee a region charges cannot exceed what the best-practice firm is willing to pay

$$m_i \leq (1-\alpha)\widehat{y}_i(\overline{\theta}; q_i)$$

Similarly, as regions can ensure nonnegative surplus by setting $q_i = \underline{q}$, in equilibrium we must have

$$\frac{c(q_i)}{N_i} - \alpha\widehat{y}_i(\overline{\theta}; q_i) \leq m_i$$

Combining the two inequalities, we have

$$c(q_i) \leq N_i\widehat{y}_i(\overline{\theta}; q_i) = N\overline{\theta}^{\frac{1}{1-\alpha}} q_i^{\frac{1}{1-\alpha}} \left(\frac{\alpha}{w}\right)^{\frac{\alpha}{1-\alpha}}$$

which may be rewritten as follows:

$$q_i \geq K[c(q_i)]^{1-\alpha}$$

where K is a positive constant independent of q_i. Several cases may then arise: (i) if $[c(q)]^{1-\alpha}$ is a convex function of q, then the available range of infrastructure quality is bounded above by the solution of $q = K[c(q)]^{1-\alpha}$; (ii) if $[c(q)]^{1-\alpha}$ is a concave function of q, then the available range of infrastructure quality is bounded below by the solution of $q = K[c(q)]^{1-\alpha}$; and (iii) if $[c(q)]^{1-\alpha}$ is first concave in q (indicating an initial threshold quality that must be crossed) and then convex in q (reflecting an ultimate increase in the marginal cost of quality), the available levels of infrastructure quality are contained in an interval of intermediate values of q.

6 Concluding Remarks

We have seen that regions competing to attract investment by industrial firms can gain by differentiating the *quality* of infrastructure they offer rather than offering standard infrastructure and competing head-to-head on subsidies. When regions compete on infrastructure quality they have an inherent incentive to increase the degree of differentiation between them, which reduces the dissipation of regional surplus through Tiebout competition. However, the viability of this approach depends on two primary conditions: there must be a sufficiently wide effective range of infrastructure quality in which the cost of quality improvements is not prohibitively steep; and there must be sufficient heterogeneity in firms' willingness to pay for infrastructure quality. We show how this latter condition sets an upper bound on the number of regions successfully able to participate in the location market. This fiscal agglomeration property suggests that geographic concentrations of firms may derive from fiscal competition among regions in the quality of the local infrastructure they offer, an explanation which is consistent with, but distinct from, other explanations of agglomeration that figure prominently in the recent literature on economic geography.

There are numerous avenues for further extending this approach. We have concentrated here on vertical differentiation, ignoring its horizontal dimension, thus effectively treating different industry segments as unconnected to each other. This ignores inter-industry effects which may have a significant impact on costs, through economies of scope, and on the intensity of inter-regional competition. A multi-dimensional description of infrastructure quality could address these issues.[19] We have also assumed an exogenous wage rate, adopting a partial equilibrium approach in which labor is completely mobile. A general equilibrium approach would allow issues arising from the interdependence between investments in infrastructure and global labor demand to be considered; and if labor is less than perfectly mobile, the interaction between the location of firms and local labor markets could also be addressed. Another absent dimension is the existence of larger firms that interact strategically with regions (larger multinationals are often economically more powerful than the regions in which they locate), and bargain with them, generally under conditions of asymmetric information. One possible line of research in this vein might recognize that regional governments may be poorly informed about the specific contribution of individual firms to regional welfare [2]; and firms' information about the quality of regional

[19] In Justman *et al.* (2001) we consider horizontal differentiation in infrastructure but without a dimension of quality. A multi-dimensional approach would incorporate both types of differentiation.

infrastructure could also be less than perfect [13]. Another possible extension might address the political economy of regional development policy, in the spirit of Justman and Thisse [10]: identifying the varying effect of infrastructure policy on different groups in the region, and considering how the regional political balance of forces might affect regional investments in infrastructure and the consequent rate and direction of regional development.

Finally, we focused in this paper on a positive analysis of fiscal competition. There are important normative issues regarding the efficiency of infrastructure development and the distribution of wealth induced by different patterns of development, which we have not addressed. Abstracting from distributional issues, the public good nature of infrastructure suggests that it might be technically optimal to gather all firms in one region and supply the quality of infrastructure that equalizes marginal cost and marginal benefit. Hence, fiscal competition through technological infrastructure would lead to wasteful diversity, whereas the quality supplied under competition would be too low. However, this must be tempered in the first instance by congestion effects, and more fundamentally by the immobility of regional assets and of regional populations, which we have excluded from our analysis. Such considerations militate for a more balanced distribution of investments in infrastructure.

References

[1] S.P. Anderson, A. de Palma and J.-F. Thisse, *Discrete Choice Theory of Product Differentiation*. Cambridge MA, MIT Press (1992).

[2] D. Black and W. Hoyt, Bidding for Firms. *American Economic Review*, **79**, 1249-1256 (1989).

[3] G. Braunling, The Innovation Infrastructure: A Systems Approach and Role of the European Community. In Justman, M., ed., *Modernization and Growth in the Small Business Sector*, Jerusalem Institute of Israel Studies, 131-147 (1994) .

[4] J. Brueckner, Welfare Reform and the Race to the Bottom: Theory and Evidence. *Southern Economic Journal*, **66**, 505-525 (2000).

[5] M. Fujita and J.-F. Thisse, Economics of Agglomeration. *Journal of the Japanese and International Economies,* **10**, 339-378 (1996).

[6] P. Grindley, D. Mowery and B. Silverman, The Design of High-Technology Consortia: Lessons from SEMATECH. In Teubal, M., D. Foray, M. Justman, and E. Zuscovitch, eds., *Technological Infrastructure Policy: An International Perspective.* Dordrecht, Kluwer, 173-216 (1996).

[7] C.-M. Hou and S. Gee, National Systems supporting Technical Advance in Industry: The Case of Taiwan. In Nelson, R., ed., *National Innovation Systems: A Comparative Analysis.* New York, Oxford University Press (1993).

[8] S. Johnson, *MITI and the Japanese Miracle.* Stanford, CA, Stanford University Press (1982).

[9] M. Justman and M. Teubal, Technological Infrastructure Policy (TIP): Creating Capabilities and Building Markets. *Research Policy,* **24**, 259-281(1995).

[10] M. Justman and J.-F. Thisse, Local Public Funding of Higher Education when Skilled Labor is Mobile. *International Tax and Public Finance,* **7**, 247-258 (2000).

[11] M. Justman, J.-F. Thisse and T. van Ypersele, Fiscal Competition and Regional Differentiation. CORE Discussion Paper (2001).

[12] D. Kaufmann and T. Yinnon, Generic R&D Collaboration Between Firms: The Israeli Experience. In Teubal, M., D. Foray, M. Justman, and E. Zuscovitch, eds., *Technological Infrastructure Policy: An International Perspective.* Dordrecht, Kluwer pp. 247-268 (1996).

[13] I. King, R.P. McAfee and L. Welling, Industrial Blackmail: Dynamic Tax Competition and Public Investment. *Canadian Journal of Economics*, **26**, 590-608.

[14] P. Martin, Public Policies, Regional Inequalities and Growth. *Journal of Public Economics,* **73**, 85-105 (1999).

[15] Ministry of Trade, Industry and Energy, *Guidelines on Industrial Technology Infrastructure Expansion Plan, 1996-2000.* Seoul (1996).

[16] L. Mytelka, States, Strategic Alliances and International Oligopolies: The European Esprit Program. In Mytelka, L., ed., *Strategic Partnerships in the World Economy*. London, Pinter (1991).

[17] P. Quintas and K. Guy, Collaborative, Pre-Competitive R&D and the Firm. *Research Policy,* **24**, 325-348 (1995).

[18] J. Sigurdson, Industry and State Partnerships in Japan: The VLSI Circuits Program. Research Policy Institute DP 168. Lund (1986).

[19] L. Taylor, Infrastructural Competition among Jurisdictions. *Journal of Public Economics,* **49**, 241-259 (1992).

[20] G. Vickrey, Modernizing Manufacturing: Consultancy, Advisory and Extension Services to Improve Small Business Performance. In Teubal, M., D. Foray, M. Justman, and E. Zuscovitch, eds., *Technological Infrastructure Policy: An International Perspective*. Dordrecht, Kluwer, 335-373 (1996).

[21] D. Wildasin, *Urban Public Finance*. Chur, Harwood Academic Publishers (1986).

[22] D. Wildasin, Nash Equilibria in Models of Fiscal Competition. *Journal of Public Economics,* **35**, 229-240 (1988) .

[23] S. Young, N. Hood and A. Wilson, Targeting Policy as a Competitive Strategy for European Inward Investment Agencies, *European Urban and Regional Studies,* **1**, 143-159 (1994).

APPENDIX

A. Second-order conditions

Lemma A.1. There exists δ such that $1 < q_2/q_1 < \delta$ (resp. $q_2/q_1 \geq \delta > 1$) implies

$$\partial^2 S_1/\partial m_1^2\big|_{m_1=m_1^*, m_2=m_2^*} \geq 0 \text{ (resp. } < 0)$$

Proof. Differentiating (14) with respect to m_1 yields

$$\left.\frac{\partial\widehat{\theta}}{\partial m_1}\right|_{m_1=m_1^*,m_2=m_2^*} = -\frac{(1-\alpha)\hat{\theta}}{m_2^*-m_1^*} \tag{A.1}$$

so that $\partial S_1/\partial m_1$ may be rewritten as follows:

$$\frac{\partial S_1}{\partial m_1} = -\frac{(1-\alpha)\hat{\theta}}{m_2^*-m_1^*}\left[\alpha y_1(\widehat{\theta})+m_1^*\right]\phi(\widehat{\theta})+\Phi(\widehat{\theta})$$

Differentiating $\partial S_1/\partial m_1$ with respect to m_1, we get

$$\frac{\partial^2 S_1}{\partial m_1^2} = -\frac{(1-\alpha)\hat{\theta}}{(m_2^*-m_1^*)^2}[\alpha y_1(\widehat{\theta})+m_1^*]\phi(\widehat{\theta})-\frac{(1-\alpha)\hat{\theta}}{m_2^*-m_1^*}\phi(\widehat{\theta})+\frac{\partial^2 S_1}{\partial m_1\partial\hat{\theta}}\frac{\partial\widehat{\theta}(m_1^*,m_2^*)}{\partial m_1}$$

Differentiating $\partial S_1/\partial m_1$ with respect to $\hat{\theta}$ and using (A.1) leads to

$$\frac{\partial^2 S_1}{\partial m_1\partial\hat{\theta}} = -\left[\frac{2-\alpha}{1-\alpha}\frac{\Phi(\widehat{\theta})}{\hat{\theta}}-\phi(\widehat{\theta})\frac{m_2^*}{m_2^*-m_1^*}+\phi'(\widehat{\theta})\frac{\Phi(\widehat{\theta})}{\phi(\widehat{\theta})}\right]$$

Hence,

$$\frac{\partial^2 S_1}{\partial m_1^2} = \frac{1-\alpha}{m_2^*-m_1^*}\left\{\Phi(\widehat{\theta})\left[1+\frac{\phi'(\widehat{\theta})}{\phi(\widehat{\theta})\widehat{\theta}}\right]-\left(1+\frac{m_2^*}{m_2^*-m_1^*}\right)\widehat{\theta}\phi(\widehat{\theta})\right\}$$

Since $m_2^* > m_1^*$ we have

$$\frac{\partial^2 S_1}{\partial m_1^2} \lesseqgtr 0 \Leftrightarrow \Phi(\widehat{\theta})\left[1+\frac{\phi'(\widehat{\theta})}{\phi(\widehat{\theta})\widehat{\theta}}\right]/[\widehat{\theta}\phi(\widehat{\theta})]-1 \lesseqgtr \frac{m_2^*}{m_2^*-m_1^*}$$

where, from (13) and (20)

$$\begin{aligned}
\frac{m_2^*}{m_2^*-m_1^*} &= \frac{N-\Phi(\widehat{\theta})}{(1-\alpha)\left[N-2\Phi(\widehat{\theta})\right]}-\frac{\alpha y_2(\widehat{\theta})}{(1-\alpha)\left[y_2(\widehat{\theta})-y_1(\widehat{\theta})\right]}\\
&= \frac{N-\Phi(\widehat{\theta})}{(1-\alpha)\left[N-2\Phi(\widehat{\theta})\right]}-\frac{\alpha q_2^{\frac{1}{1-\alpha}}}{(1-\alpha)\left(q_2^{\frac{1}{1-\alpha}}-q_1^{\frac{1}{1-\alpha}}\right)}\\
&= \frac{N-\Phi(\widehat{\theta})}{(1-\alpha)\left[N-2\Phi(\widehat{\theta})\right]}-\frac{\alpha}{(1-\alpha)\left[1-(q_2/q_1)^{-\frac{1}{1-\alpha}}\right]}
\end{aligned}$$

Therefore

$$\begin{aligned}\frac{\partial^2 S_1}{\partial m_1^2} &\lesseqgtr 0 \Leftrightarrow \frac{\alpha}{(1-\alpha)\left(1-(q_2/q_1)^{-\frac{1}{1-\alpha}}\right)} \\ &\lesseqgtr 1+\frac{N-\Phi(\widehat{\theta})}{(1-\alpha)\left[N-2\Phi(\widehat{\theta})\right]}-\Phi(\widehat{\theta})\left[1+\frac{\phi'(\widehat{\theta})}{\phi(\widehat{\theta})\widehat{\theta}}\right]/[\widehat{\theta}\phi(\widehat{\theta})]\end{aligned}$$

Since the LHS of the second inequality has a vertical asymptote at $q_1 = q_2$ and is an decreasing function of q_2/q_1 when $q_2 > q_1$, while the LHS is independent of q_1/q_2, there exists $\delta > 1$ for which $\partial^2 S_1/\partial m_1^2 < 0$ (resp. ≥ 0) when $\delta < q_2/q_1$ (resp. $1 < q_2/q_1 \leq \delta$). ■

Lemma A.2. A sufficient condition for the second-order condition to hold for region 2 is given by

$$\frac{3\Phi(\hat{\theta})-N}{N-2\Phi(\hat{\theta})}+\alpha<0$$

Proof. Differentiating (14) with respect to m_2 yields

$$\left.\frac{\partial\widehat{\theta}}{\partial m_2}\right|_{m_1=m_1^*,m_2=m_2^*}=\frac{(1-\alpha)\hat{\theta}}{m_2^*-m_1^*} \tag{A.2}$$

so that $\partial S_2/\partial m_2$ may be rewritten as follows:

$$\frac{\partial S_2}{\partial m_2}=-\frac{(1-\alpha)\hat{\theta}}{m_2^*-m_1^*}[\alpha y_2(\widehat{\theta})+m_2^*]\phi(\widehat{\theta})+N-\Phi(\widehat{\theta})$$

Since

$$\frac{\partial y_2(\widehat{\theta})}{\partial\hat{\theta}}=\frac{y_2(\widehat{\theta})}{(1-\alpha)\widehat{\theta}}$$

we obtain

$$\frac{\partial^2 S_2}{\partial m_2^2}=\frac{(1-\alpha)\hat{\theta}}{(m_2^*-m_1^*)^2}[\alpha y_2(\widehat{\theta})+m_2]\phi(\widehat{\theta})-\frac{(1-\alpha)\hat{\theta}}{m_2^*-m_1^*}\phi(\widehat{\theta})+\frac{\partial^2 S_2}{\partial m_2\partial\hat{\theta}}\frac{\partial\widehat{\theta}}{\partial m_2}$$

Differentiating $\partial S_2/\partial m_2$ with respect to $\hat{\theta}$ and using (A.2) leads to

$$\frac{\partial^2 S_2}{\partial m_2\partial\hat{\theta}}==-\left[\frac{2-\alpha}{1-\alpha}\frac{N-\Phi(\widehat{\theta})}{\hat{\theta}}-\phi(\widehat{\theta})\frac{m_1}{m_2^*-m_1^*}\right]-\phi'(\widehat{\theta})\frac{N-\Phi(\widehat{\theta})}{\phi(\widehat{\theta})}$$

Therefore, we get

$$\frac{\partial^2 S_2}{\partial m_2^2} = \frac{1-\alpha}{m_2^* - m_1^*} \left\{ \frac{2m_1^* - m_2^*}{m_2^* - m_1^*} \widehat{\theta}\phi(\widehat{\theta}) - [N - \Phi(\widehat{\theta})] \left[1 + \frac{\phi'(\widehat{\theta})}{\phi(\widehat{\theta})\widehat{\theta}} \right] \right\}$$

Since

$$\frac{\phi'(\widehat{\theta})}{\phi(\widehat{\theta})\widehat{\theta}} > -1$$

holds by assumption, a sufficient condition for $\partial^2 S_2 / \partial m_2^2$ to be negative is that

$$2m_1^* - m_2^* = [y_2(\widehat{\theta}) - y_1(\widehat{\theta})] \left[\frac{3\Phi(\hat{\theta}) - N}{N - 2\Phi(\hat{\theta})} + \alpha \right] - \alpha y_1(\widehat{\theta}) < 0$$

In turn, this condition is always satisfied when

$$\frac{3\Phi(\hat{\theta}) - N}{N - 2\Phi(\hat{\theta})} + \alpha < 0$$

since $y_2(\widehat{\theta}) > y_1(\widehat{\theta})$. ■

B. The fee/subsidy policy when $q_2/q_1 \leq \delta$ and $N > \underline{\theta}\phi(\underline{\theta})$

We consider here the special case in which $N > \underline{\theta}\phi(\underline{\theta})$ rules out the possibility of a pure-strategy equilibrium in which only one region is active, while insufficient differentiation of infrastructure quality implies that the second-order condition does not hold for region 1, and so a pure strategy equilibrium in which both regions are active is also ruled out. We show that in this case there is a mixed-strategy equilibrium in which region 1 earns zero gross surplus while region 2's surplus goes to zero when the degree of differentiation becomes arbitrarily small.

Denote region i's reaction function in pure strategies to region j's choice of fee by $m_i^*(m_j)$, i.e., it is the choice of m_i that maximizes S_i given m_j. As in the text, we assume that the second-order condition holds for region 2, so that $m_2^*(m_1)$ is a continuous, increasing function of m_1 uniquely determined by its first-order condition. However, $S_1(m_1; m_2)$ is convex in m_1, so that for given m_2 region 1's maximal surplus is achieved at one of two extremal values, $\underline{m}_1(m_2)$ and $\overline{m}_1(m_2)$, where $\underline{m}_1(m_2)$ is the maximal fee that allows region 1 to capture the entire range of firm types, while $\overline{m}_1(m_2)$ is the minimal fee such that region 1 attracts no firms:

$$\begin{aligned}\underline{m}_1(m_2) &\equiv m_2-(1-\alpha)\left[y_2(\overline{\theta})-y_1(\overline{\theta})\right]\\ \overline{m}_1(m_2) &\equiv m_2-(1-\alpha)\left[y_2(\underline{\theta})-y_1(\underline{\theta})\right]\end{aligned}$$

Clearly, it can never be in region 1's interest to set a fee lower than the highest fee that attracts all firms, and in order to avoid inessential ambiguities, we also posit that it never sets a fee in excess of $\overline{m}_1(m_2)$ as such a fee is never collected. Thus

$$\underline{m}_1(m_2)\leq m_1^*(m_2)\leq \overline{m}_1(m_2)$$

Denoting the corresponding extremal values for region 2

$$\begin{aligned}\underline{m}_2(m_1) &\equiv m_1+(1-\alpha)\left[y_2(\underline{\theta})-y_1(\underline{\theta})\right]\\ \overline{m}_2(m_1) &\equiv m_1+(1-\alpha)\left[y_2(\overline{\theta})-y_1(\overline{\theta})\right]\end{aligned}$$

a similar line of reasoning implies that

$$\underline{m}_2(m_1)\leq m_2^*(m_1)\leq \overline{m}_2(m_1)$$

Given a choice of fee m_2 by region 2, region 1's extremal response can be determined by comparing $S_1(\overline{m}_1(m_2);m_2)$ and $S_1(\underline{m}_1(m_2);m_2)$. The definition of $\overline{m}_1$ implies that $S_1(\overline{m}_1(m_2);m_2)=0$, while straightforward calculation yields

$$\begin{aligned}S_1(\underline{m}_1(m_2);m_2) &= \int_{\underline{\theta}}^{\overline{\theta}}[\alpha y_1(\theta)+\underline{m}_1(m_2)]\phi(\theta)d\theta-c(q_1) \qquad \text{(A.3)}\\ &= \alpha\int_{\underline{\theta}}^{\overline{\theta}} y_1(\theta)\phi(\theta)d\theta+\underline{m}_1(m_2)N-c(q_1)\\ &= \alpha\int_{\underline{\theta}}^{\overline{\theta}} y_1(\theta)\phi(\theta)d\theta-(1-\alpha)\left[y_2(\underline{\theta})-y_1(\underline{\theta})\right]N+m_2N-c(q_1)\end{aligned}$$

which is an increasing linear function of m_2. Hence, there is a unique value $\widetilde{m}_2$ at which region 1's gross surplus equals zero (so that $S_1(\underline{m}_1(\widetilde{m}_2);\widetilde{m}_2)=-c(q_1)$), with $S_1(\underline{m}_1(m_2);m_2)>S_1(\overline{m}_1(m_2);m_2)$ when $m_2>\widetilde{m}_2$ and $S_1(\underline{m}_1(m_2);m_2)<$

$S_1(\overline{m}_1(m_2); m_2)$ when $m_2 < \widetilde{m}_2$. Consequently, region 1's reaction function, $m_1^*(m_2)$, is given by

$$m_1^*(m_2) = \begin{cases} \underline{m}_1(m_2) & \text{when } m_2 > \widetilde{m} \\ \overline{m}_1(m_2) & \text{when } m_2 < \widetilde{m} \end{cases}$$

with region 1 indifferent between $\underline{m}_1(\widetilde{m}_2)$ and $\overline{m}_1(\widetilde{m}_2)$ since its gross surplus is zero in both cases.

Lemma A.3. For any value of m_2, we have

$$m_2^*(\overline{m}_1(m_2)) \geq m_2 \geq m_2^*(\underline{m}_1(m_2))$$

Proof. To prove the first inequality note that

$$m_2^*[\overline{m}_1(m_2)] \geq \underline{m}_2[\overline{m}_1(m_2)]$$

where by definition

$$\underline{m}_2(\overline{m}_1(m_2)) = m_2 - [y_2(\underline{\theta}) - y_1(\underline{\theta})] + [y_2(\underline{\theta}) - y_1(\underline{\theta})] = m_2$$

Similarly

$$m_2^*(\overline{m}_1(m_2)) \leq \overline{m}_2(\overline{m}_1(m_2))$$

where

$$\overline{m}_2(\underline{m}_1(m_2)) = m_2 + \left[y_2(\overline{\theta}) - y_1(\overline{\theta})\right] - \left[y_2(\overline{\theta}) - y_1(\overline{\theta})\right] = m_2$$

proving the second inequality. ■

Proposition A.4. If $q_2/q_1 \leq \delta$ and $N > \underline{\theta}\phi(\underline{\theta})$, then it is an equilibrium in mixed strategies for region 2 to set its fee equal to $\widetilde{m}_2$ and for region 1 to set its fee equal to $\underline{m}_1(\widetilde{m}_2)$ with probability p and $\overline{m}_1(\widetilde{m}_2)$ with probability $1 - p$ where $0 \leq p \leq 1$ is given by

$$p = \frac{\partial S_2(\widetilde{m}_2, \overline{m}_1(\widetilde{m}_2))/\partial m_2}{\partial S_2(\widetilde{m}_2, \overline{m}_1(\widetilde{m}_2))/\partial m_2 - \partial S_2(\widetilde{m}_2, \underline{m}_1(\widetilde{m}_2))/\partial m_2}$$

Region 1 obtains zero expected gross surplus and region 2 obtains an expected gross surplus proportional to

$$q_2^{\frac{1}{1-\alpha}} - q_1^{\frac{1}{1-\alpha}}$$

which goes to zero as q_2 approaches q_1.

Proof. By definition of $\widetilde{m}_2$ region 1 can do no better than earn zero gross surplus in response, and as

$$S_1(\underline{m}_1(\widetilde{m}_2); \widetilde{m}_2) = S_1(\overline{m}_1(\widetilde{m}_2); \widetilde{m}_2) = -c(q_1)$$

region 1's posited mixed strategy is an optimal response. To see that $\widetilde{m}_2$ is an optimal response for region 2 to region 1's mixed strategy, note that if it sets its fee/subsidy equal to m_2 its expected gross surplus is

$$ES(m_2) \equiv pS_2(m_2, \underline{m}_1(\widetilde{m}_2)) + (1-p)S_2(m_2, \overline{m}_1(\widetilde{m}_2)) - c(q_2)$$

the derivative of which is

$$ES'(m_2) = p\partial S_2(m_2, \underline{m}_1(\widetilde{m}_2))/\partial m_2 + (1-p)\partial S_2(m_2, \overline{m}_1(\widetilde{m}_2))/\partial m_2$$

It follows immediately from the definition of p and straightforward substitution that $ES'(\widetilde{m}_2) = 0$ so that region 2's gross surplus is maximized at $\widetilde{m}_2$ (the second-order condition follows immediately from our assumption that it is generally satisfied for region 2).

Next, we show that our choice of p satisfies $0 \leq p \leq 1$. Note first that $S_2(m_2, \underline{m}_1(\widetilde{m}_2))$ is maximized at $m_2^*(\underline{m}_1(\widetilde{m}_2))$, and $\widetilde{m}_2 \geq m_2^*(\underline{m}_1(\widetilde{m}_2))$ from Lemma A.3. Consequently, as the second-order condition holds for region 2, we must have $\partial S_2(\widetilde{m}_2, \underline{m}_1(\widetilde{m}_2))/\partial m_2 \leq 0$ at $\widetilde{m}_2$. Similarly, $S_2(m_2, \overline{m}_1(\widetilde{m}_2))$ is maximized at $m_2^*(\overline{m}_1(\widetilde{m}_2))$, and $\widetilde{m}_2 \leq m_2^*(\overline{m}_1(\widetilde{m}_2))$ from Lemma A.3. Consequently, as the second-order condition holds for region 2, we must have $\partial S_2(\widetilde{m}_2, \overline{m}_1(\widetilde{m}_2))/\partial m_2 \geq 0$ at $\widetilde{m}_2$. Hence, it must be that

$$0 \leq p = \frac{\partial S_2(\widetilde{m}_2, \overline{m}_1(\widetilde{m}_2))/\partial m_2}{\partial S_2(\widetilde{m}_2, \overline{m}_1(\widetilde{m}_2))/\partial m_2 - \partial S_2(\widetilde{m}_2, \underline{m}_1(\widetilde{m}_2))/\partial m_2} \leq 1$$

Finally, region 2's expected gross surplus in equilibrium is given by

$$\begin{aligned} ES(\widetilde{m}_2) &= (1-p)\int_{\underline{\theta}}^{\overline{\theta}} [\alpha y_2(\theta) + \widetilde{m}_2]\phi(\theta)d\theta - c(q_2) \\ &= (1-p)\left[\alpha \int_{\underline{\theta}}^{\overline{\theta}} y_2(\theta)\phi(\theta)d\theta + \widetilde{m}_2 N\right] - c(q_2) \end{aligned}$$

since $m_1 = \underline{m}_1(\widetilde{m}_2)$ implies $\widehat{\theta} = \overline{\theta}$ and $m_1 = \overline{m}_1(\widetilde{m}_2)$ implies $\widehat{\theta} = \underline{\theta}$. By definition of $\widetilde{m}_2$, it follows from (A.3) that

$$\alpha \int_{\underline{\theta}}^{\overline{\theta}} y_1(\theta)\phi(\theta)d\theta + \widetilde{m}_2 N - (1-\alpha)\left[y_2(\underline{\theta}) - y_1(\underline{\theta})\right] N = 0$$

and so

$$\begin{aligned}
ES(\widetilde{m}_2) &= (1-p)\left\{\alpha \int_{\underline{\theta}}^{\overline{\theta}} y_2(\theta)\phi(\theta)d\theta + \widetilde{m}_2 N\right\} - c(q_2) \\
&= (1-p)\left\{\alpha \int_{\underline{\theta}}^{\overline{\theta}} [y_2(\theta) - y_1(\theta)]\phi(\theta)d\theta + (1-\alpha)[y_2(\underline{\theta}) - y_1(\underline{\theta})]N\right\} - c(q_2) \\
&= (1-p)(\frac{\alpha}{w})^{\frac{\alpha}{1-\alpha}}\left(q_2^{\frac{1}{1-\alpha}} - q_1^{\frac{1}{1-\alpha}}\right) \times \\
&\quad \left[\alpha \int_{\underline{\theta}}^{\overline{\theta}} \theta^{\frac{1}{1-\alpha}}\phi(\theta)d\theta + (1-\alpha)\underline{\theta}^{\frac{1}{1-\alpha}} N\right] - c(q_2)
\end{aligned}$$

Thus region 2's expected gross surplus is proportional to $q_2^{\frac{1}{1-\alpha}} - q_1^{\frac{1}{1-\alpha}}$, which goes to zero as q_2 approaches q_1. ■