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The Role of Public Infrastructure and Subsidies for Firm Location and International Outsourcing*

Hartmut Egger† and Josef Falkinger‡

June 30, 2005

Abstract

This paper presents a model in which final goods producers outsource intermediate input production. Intermediate inputs are differentiated and their production can be located at home or abroad. The model is used to examine competitive location policy in a (two-country) free trade area (FTA). It is shown that national public infrastructure investment has a positive effect on both the number of intermediate input producers and the return to the immobile factor in the home country. International outsourcing from home declines. Opposite effects are triggered in the partner country. In a welfare analysis we characterize national infrastructure policies that aim to maximize national income (net of tax costs) and compare the non-cooperative FTA-equilibrium with optimal policies from an integrated point of view. We show whether or not there is a need for policy coordination. Firm subsidies are discussed as an alternative to public infrastructure investment.

Key words: International outsourcing; Firm location; Public infrastructure; Welfare effects;

JEL classification:F12; F15; F42; H54;

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1 Introduction

Location has become a key issue in the political debate on the macroeconomic consequences of the recent wave of globalization. In the past, production of manufacturing goods was to a large extent integrated within a single firm so that changing location was an exceptional phenomenon. It meant that a wide range of different production stages had to be shifted from one place to another. Technical progress in recent years has dramatically changed the production process. Increased fragmentability and lower costs for service links make production and assembling of different parts of the value added chain at different locations feasible and profitable (see Jones, 2000; and Jones and Kierzkowski, 2001). Therefore, modern industrial production is characterized by a high and increasing degree of vertical fragmentation and international outsourcing.\(^1\) The optimal location is chosen for individual production stages, and specialized input producers make use of competitive location advantages all over the world. These changes in firm location are usually associated with international capital flows.

Indeed, it is a salient feature of empirical evidence that at the same time capital mobility, firm mobility and the volume of intermediate goods trade have increased substantially. However, an integrated approach for analyzing these phenomena is so far missing in the literature. To close this gap is the purpose of our paper. It provides a simultaneous explanation of the location of input producers, the volume of international outsourcing (in the form of intermediate input trade) and the returns to immobile production factors in a model with international capital mobility. Explanatory variables are the economic fundamentals and national public infrastructure provision which is used for the purpose

\(^1\)Hummels et al. (2001) find for a sample of 14 economies (10 OECD members and four emerging markets countries) that the share of exports due to vertical specialization (i.e., international outsourcing) in total exports grew by about 30% over the period of 1970-1990 and that growth in vertical specialization accounted for 30% of the growth in the overall export/GDP ratio. Egger and Egger (2003) provide evidence on the development of outsourcing to Eastern economies after the fall of the Iron Curtain. See also Feenstra (1998) and Feenstra and Hanson (2001) for a discussion on the relevance of vertical fragmentation and international outsourcing in modern industrial production.
of competitive location policy. Firm subsidies are another instrument of competitive location policy that is considered.

Our model emphasizes the importance of public infrastructure investment for a country’s attractiveness as a location for intermediate input production. There is broad consensus among economists and politicians that public infrastructure for firms is an important aspect of competitive location policy. EU members, for example, agreed upon a benchmark method to determine the competitiveness of the EU economies. Among 54 indicators that are used for the assessment, provision of infrastructure plays a prominent role (see Brakman et al., 2002). And the Portland Development Commission (2002) states that "an important role of government is to increase economic capacity by improving quality and efficiency of public infrastructure and utilities necessary to business operation" (p. 7). In the context of vertical fragmentation, governments can use public infrastructure provision as a policy instrument to attract a higher number of intermediate input producers and therefore to reduce the volume of a country’s component imports from abroad and to increase its attractiveness as a target for foreign outsourcing.3

International outsourcing involves three types of decisions: (i) integrated vs. fragmented production (technological separation), (ii) in-house production vs. outsourcing (organizational separation) and (iii) national vs. international outsourcing (locational separation). In this paper, we focus on the locational aspect, taking decisions (i) and (ii) as given. We set up a general equilibrium model with one final good and differentiated intermediate inputs. Production in the final goods sector employs internationally immobile labor for assembling the outsourced (differentiated) intermediate inputs, which are supplied under monopolistic competition. The intermediate inputs can be imported from foreign suppliers (international outsourcing) or be purchased at home (national outsourcing).

2“A competitive location policy is a comprehensive policy ... that includes all aspects that define the attractiveness of a location.” (Brakman et al., 2002, p. 2; in translation of Dutch Ministry of Economic Affairs, 1999, p. 114 f.)

3There is indeed strong empirical evidence that infrastructure matters for international outsourcing activities. For instance, Egger and Egger (2005) find that infrastructure quality in the target countries explains about 30–40 percent of EU outward processing trade.
ing). Intermediate input production makes use of internationally mobile capital. Final goods markets as well as factor markets are competitive.

We assume that two small industrialized economies characterized by identical production technologies form a free trade agreement (FTA). Endowments consist of immobile labor and mobile capital that is owned by residents of the respective country. Intermediate input suppliers can decide about their location within the FTA, thereby taking into account the attractiveness of the two FTA member countries for intermediate input production. The idea that firms are located at some place implies that there are fixed costs which are incurred at a certain location and not at another (making imperfect competition in the intermediate goods market a key aspect of our analysis). Hence, the attractiveness of a country depends on the fixed costs requirements for setting up a firm. Governments can influence the location choice of input suppliers through national infrastructure policy. A higher level of public infrastructure reduces the fixed cost of setting up a firm in this economy and therefore raises the attractiveness of a country. (See for a similar assumption Bougheas et al., 2000; and Justman et al., 2001.)

The paper is organized as follows. Section 2 discusses related literature and shows how our analysis contributes. After introducing the basic framework in Section 3 and solving the FTA-equilibrium in Section 4, Section 5 provides the comparative-static analysis of the effects of public infrastructure investment on firm location, international outsourcing and wages (i.e., the factor return to immobile labor). In Section 6 we analyze the role of public infrastructure investment as a competitive location policy instrument that is financed by lump-sum taxes. In addition, we investigate the role of policy coordination by comparing the non-cooperative policy equilibrium with optimal infrastructure provision from an integrated point of view. In Section 7 we discuss the effects of infrastructure

\footnote{Holtz-Eakin and Lovely (1996) allow public infrastructure investment to affect either variable or fixed costs of production. In their approach, the two types of infrastructure investment may have quite different implications in terms of output and the number of producers. The robustness of our results is discussed in Subsection 7.1. We find that the basic mechanisms remain valid if public infrastructure reduces variable production costs rather than fixed costs.}
investment that reduces variable production costs and analyze subsidies as an instrument of competitive location policy. The last section concludes.

2 Related Literature

Due to our focus on the international location of input suppliers, our analysis is closely related to the traditional trade literature dealing with international outsourcing as intermediate goods trade. (See for instance Arndt, 1997; Deardorff, 2001; Jones, 2000; Jones and Kierzkowski, 2001; and Kohler, 2003.) However, there are important differences. Models in the vein of the traditional trade literature make the assumption of perfect competition at final as well as intermediate goods markets and do not account for the role of firms and their location decisions. In our model we account for firm location by assuming that set-up costs have to be incurred in the country of production. This implies imperfect competition. A crucial mechanism in our analysis is the interaction between the location of intermediate goods producers and the attraction of internationally mobile capital. The relationship between capital mobility and international outsourcing has first been analyzed by Feenstra and Hanson (1996). They assume that capital movements are triggered by scarcity of this factor in a certain economy and analyze the impact of capital flows on the location of input production. However, they do not account for the role of public infrastructure investment as an instrument of competitive location policy. In our analysis, national capital supply plays no role since capital is traded at an exogenous world interest rate. Capital flows are triggered by differences in public infrastructure investment (or subsidies) which make a country attractive for firm entry.

Specifying firms explicitly is less important in a world without scale economies. But, if external economies of scale and agglomeration effects are important, the number of producers at a certain location is crucial for the performance of countries. In this respect, our model is closely related to the new economic geography literature that highlights the relationship between firm location and factor mobility to explain a core-periphery pattern in (international) goods production (see for instance Krugman, 1991). However,
the focus of those models lies on final goods production, whereas outsourcing of intermediate component production is typically not considered.\(^5\) In contrast, we assume that external scale economies arise at the intermediate goods level and that agglomeration rents are totally absorbed by immobile factors. The latter is motivated by our focus on small open economies and a competitive market for internationally mobile capital. As a consequence, agglomeration effects are weaker in our framework than in the above mentioned Krugman-type models and do not result in full divergence in the sense that all sophisticated (intermediate goods) production stays in the core and only labor-intensive final assembly survives in the periphery. Rather, we speak of a core (periphery) country if it hosts more (less) intermediate goods producers than its partner in the free trade agreement, resulting in higher (lower) marginal productivity of immobile labor.

More recently, agglomeration effects have also been addressed in the tax competition literature. See Baldwin and Krugman (2004), Kind et al. (2000) and Ludema and Wooton (2000). These papers emphasize that governments can tax mobile factors if they earn rents due to their location in the core. Bucovetsky (2004) analyzes locational competition through public input provision in a multi-region framework with external economies of scale. In that paper, national provision of public inputs is put forward as an explanation for core-periphery patterns in industrial production. Furthermore, it is shown that over- or underprovision of the public input may arise, depending on the particular objective function of governments. However, Bucovetsky’s model is not in the tradition of the new economic geography literature since it neglects the role of transport costs. Moreover, he considers perfect competition so that it is the amount of the mobile factor employed at a certain location and not the number of firms that determines total income.

Martin and Rogers (1995) investigate the role of public expenditures on national and international transport costs for firm location in a new economic geography framework.\(^6\)

\(^5\)For an exception see Krugman and Venables (1995) who allow for final as well as intermediate goods trade. See also Baldwin et al. (2003, chapter 8) for a discussion on vertical linkages (i.e. input and output relationships among firms) in models of the new economic geography.

\(^6\)The authors distinguish between national and international transport costs to give insights on how regional aid policy should be shaped, when fostering industrial convergence is at the agenda of policy-
In this respect, their analysis is closely related to the topic of our study. However, there are important differences. First, while Martin and Rogers study the location of final goods producers, we deal with the location of intermediate input producers and analyze the impact of infrastructure investment on the outsourcing pattern. Second, we focus on public attempts of reducing fixed set up costs of firms. This allows us to discuss besides the role of public infrastructure also the effects of subsidies as an instrument of competitive location policy. Third, we investigate non-cooperative policy decisions and provide insights into the gains of international coordination.7

For completeness, it is worth noting that our model includes some aspects which are also addressed in the literature on multinational firms, like location decisions for production plants (see for instance Markusen, 2002; Markusen and Venables, 2000). However, that literature focuses on intra-firm rather than arm’s length transactions. Moreover, in the theory of multinational firms both the decision on setting up a production plant abroad and the decision on intra-firm trade are simultaneously made by a multinational’s headquarters. This is different in our model of international outsourcing, where the input suppliers decide on whether to set up intermediate goods production at a certain location and the final goods producers decide on the volume of international outsourcing. Recently, several studies have analyzed a multinational’s decision to enter a foreign market through direct investment and subsidiary production or through international outsourcing and arm’s length transaction. (See e.g. Grossman and Helpman, 2003, 2004; and Markusen, 2002.) Such a decision problem is not considered in our paper. We focus on market transactions. Bilateral relations based on contractual arrangements are not considered.

They conclude that poor countries should prefer infrastructure projects that reduce national transport costs, to avoid relocation provoked by lower international transport costs.

7Bougheas et al. (2003) analyze the efficiency of uncoordinated investment in infrastructure which reduces variable transportation costs. Their results point to the possibility of overinvestment in the public provision of national and international transport facilities. Further contributions to public infrastructure spending in settings of the new economic geography include Bougheas et al. (1999, 2000) and Justman et al. (2002). However, as noted by Baldwin et al. (2003, p. 421): "Relatively few papers to date address issues of tax and tax competition in an economic geography framework".
The contribution of our paper can be summarized in the following way: First, our focus is on the location of input producers. This allows us to investigate the nexus between factor mobility, outsourcing and firm location, when governments can invest in infrastructure to improve the attractiveness of a country as a location for industrial production. Second, we rigorously investigate possible Nash equilibria of strategic infrastructure provision in a 2-country setting and compare the results with the outcome under coordination. Thereby, the existence of transport costs plays a key role for the basic incentive of strategic infrastructure provision. However, transport costs are exogenous in our analysis. We focus on infrastructure provision which reduces fixed costs for setting up firms. This procedure not only allows us to solve the model analytically (thereby avoiding reliance on numerical simulation exercises) but also makes a comparison between infrastructure provision (a pure public good) and subsidies (characterized by perfect rivalry) possible.

3 Theoretical Framework

We consider economies with a single final good $Y$ (the numéraire good) and two primary production factors: internationally immobile labor $L$ and internationally mobile $K$, which may be interpreted as capital or know-how. Production of final output makes use of differentiated intermediate inputs $x_i$ and primary input $L$. The production of differentiated intermediate inputs is outsourced by the final goods producers and purchased through arm’s length transactions from (anonymous) input suppliers at market prices. Labor requirements $L$ may be associated with business service activities that are essential in the assembling process. The production technology for final output $Y$ is of a Cobb-Douglas type and given by $^8$

$$Y = X^\alpha L^{1-\alpha}, \quad X = \left(\sum_i x_i^\rho\right)^{1/\rho}, \quad 0 < \alpha < \rho < 1.$$  \hspace{1cm} (1)

$^8$The assumption $\alpha < \rho$ guarantees that the marginal product of $x_i$ increases in the use of $x_j$, $j \neq i$. An immediate consequence of this assumption is that overall output $Y$ is positively related to labor endowment $L$. This can be seen by using $(8)$, (A.15) and the definition of $A^k$ (given below (9)) in (1).
Following Ethier (1982) we assume that the contribution of intermediate inputs \( x_i \) can be aggregated by a CES-index. For the production of differentiated inputs employment of \( K \) is essential. To keep the analysis tractable, we assume that the production of differentiated inputs does not require employment of factor \( L \). The production technology in the \( X \)-sector is identical for all firms and given by

\[
\textit{ Gate } K_i. 
\]  

(2)

In addition, setting up an input production facility has fixed costs. They are incurred by investing \( f \) units of final output. We follow the common approach that monopolistic competition characterizes the market for the differentiated intermediate inputs \( x_i \). Free entry of input producers leads to average cost pricing, so that revenues equal total costs in equilibrium.

4 Equilibrium under a Free Trade Agreement

Let \( H \) and \( F \) be two industrialized economies characterized by identical production technologies and endowments \( E^H \) and \( E^F \) of the immobile factor, respectively. The two economies form a free trade agreement (FTA) so that there are no tariff barriers on intermediate input and final goods trade between \( H \) and \( F \). In addition, we assume that commodity \( Y \) is freely traded between the FTA and the rest of the world (RoW), whereas there is no trade of intermediate goods outside the FTA.\(^9\) Finally, we assume that both countries \( H \) and \( F \) are small economies. Figure 1 summarizes the structure of our model.

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\(^9\)There are several reasons why intermediate inputs cannot be traded between the FTA and the RoW. First, trading costs between the FTA and the RoW may be prohibitive for sophisticated intermediate inputs. Second, there may be a complex set of rules of origin, which prohibits use of intermediate inputs from outside the world. For a discussion on the negative effects of rules of origins in the presence of a FTA see Baldwin (2001) and Lloyd (2001). Finally, the RoW may employ an integrated production technology for commodity \( Y \), so that there is neither supply of nor demand for sophisticated intermediate inputs in the RoW. In any case, the production structure in the RoW is not explicitly specified.
The small country assumption paired with perfect mobility of factor $K$ implies that its factor return, $r$, is determined in the world market outside the FTA. This renders country-specific endowments with capital irrelevant for the subsequent analysis. The price, $w^k$, for the immobile factor depends on its location $k = H, F$. It is determined by the condition that labor earns its marginal product and full-employment $L^k = \bar{L}$ prevails in equilibrium. Thus, according to (1)

$$\frac{(1 - \alpha) Y^k}{L} = w^k,$$

where $Y^k$ is the equilibrium level of final output in country $k = H, F$. Denote by $p_{H,i}^k$ ($p_{F,j}^k$) the (trade costs including) prices of the intermediate component $x_{H,i}^k$ ($x_{F,j}^k$) produced by input supplier $i$ ($j$) located in country $H$ ($F$, respectively) and used by a final goods producer located in country $k = H, F$. The free trade agreement allows the firms in the final goods sector to choose freely between intermediate inputs regardless of their origin. Demand of $x_{H,i}^k$ ($x_{F,j}^k$) is determined by the profit maximization problem of the representative firm

$$\max_{x_{H,i}^k, x_{F,j}^k} Y^k - \left[ \sum_i p_{H,i}^k x_{H,i}^k + \sum_j p_{F,j}^k x_{F,j}^k \right],$$

which gives:

$$\frac{\alpha Y^k}{X^k} \left( \frac{X^k}{x_{H,i}^k} \right)^{1 - \rho} = p_{H,i}^k, \quad i = 1, \ldots, n_H; \quad k = H, F;$$

$$\frac{\alpha Y^k}{X^k} \left( \frac{X^k}{x_{F,j}^k} \right)^{1 - \rho} = p_{F,j}^k, \quad j = 1, \ldots, n_F; \quad k = H, F;$$

where $X^k := \left[ \sum_{i=1}^{n_H} (x_{H,i}^k)^\rho + \sum_{j=1}^{n_F} (x_{F,j}^k)^\rho \right]^{1/\rho}$. The number of input producers, $n_H, n_F$, will be endogenously determined by the entry/exit decisions of firms.

Using (4a), (4b) and defining aggregate price index $P_X^k := \sum_{i=1}^{n_H} (p_{H,i}^k)^{-\sigma} + \sum_{j=1}^{n_F} (p_{F,j}^k)^{-\sigma}$, $\sigma = 1/(1 - \rho)$, we find that

$$p_{H,i}^k = \left( \frac{\alpha Y^k}{P_X^k} \right)^{1 - \rho} (x_{H,i}^k)^{-\rho (1 - \rho)} \quad \text{and} \quad p_{F,j}^k = \left( \frac{\alpha Y^k}{P_X^k} \right)^{1 - \rho} (x_{F,j}^k)^{-\rho (1 - \rho)};$$

$k = H, F$, are the demand functions relevant for an $x_i$-producer located in country $H$ and an $x_j$-producer located in country $F$, respectively. This gives us for the maximization.

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10 Use (4a), (4b) and the definition of $X^k$ to see that $\sum_{i=1}^{n_H} p_{H,i}^k x_{H,i}^k + \sum_{j=1}^{n_F} p_{F,j}^k x_{F,j}^k = \alpha Y^k$. Moreover, solve (4a) and (4b) for $x_{H,i}^k$ and $x_{F,j}^k$, respectively. Show then that $P_X^k = (\alpha Y^k / X^k)^{1 - \sigma}$. 

---
problem of an \( x_i \)-producer located in country \( H \):

\[
\max_{x_{H,i}, x_{F,i}} \left( x_{H,i}^H \right)^\rho D_H + \left( x_{F,i}^F \right)^\rho D_F - r \left( x_{H,i}^H + x_{F,i}^F \right) - t x_{H,i}^H - f_H,
\]

where \( D_k := \left( \frac{Y_k}{p_k} \right)^{1-\rho} \), \( k = H,F \), is exogenous to the single producer. Note that, according to (2), marginal production costs of intermediate goods are equal to factor price \( r \) of internationally mobile \( K \) which is determined in the world market. \( t > 0 \) are unit trade costs for international \( x \)-transactions, identical for both economies. Setting up an input production facility in country \( k \), requires investment of \( f_k \) units of final output. The country-specific fixed costs \( f_k \) depend on the country’s infrastructure and reflect the attractiveness of a location for intermediate goods production and thus employment of \( K \). The maximization problem of an \( x_j \)-producer located in country \( F \) is:

\[
\max_{x_{H,j}, x_{F,j}} \left( x_{H,j}^H \right)^\rho D_H + \left( x_{F,j}^F \right)^\rho D_F - r \left( x_{H,j}^H + x_{F,j}^F \right) - t x_{F,j}^H - f_F.
\]

Within each country intermediate input producers are symmetric. Solving (5) and (6) we obtain a system of four first-order conditions for intermediate goods producers. Together with (1), the two zero profit conditions of intermediate input producers and the six conditions in (3) and (4), describing the final goods sector in countries \( H \) and \( F \), we have fourteen equations. (Note that (1) applies to both \( Y^H \) and \( Y^F \).) They determine the endogenous variables \( x^H_k, x^F_k, p_k^H, p_k^F, n_k, w_k \) and \( Y^k, k = H,F \), as functions of the fundamentals of the two economies. In particular, the outcome depends on fixed costs \( f_k \) which are affected by public infrastructure policy. This will allow us to do comparative-static analysis of policy effects (see Section 5). Equilibrium prices, quantities and numbers of intermediate input producers implied by (1) and (4)-(6) are given by the following expressions:

\[
p_k^H = \frac{r}{\rho} \quad \text{and} \quad p_k^F = \frac{r + t}{\rho},
\]

\[
x_k^H = x_k \left( \frac{r}{r + t} \right) \quad \text{and} \quad x_k^F = \left[ f_k - f_k' \left( \frac{r}{r + t} \right)^{\sigma - 1} \right] \frac{\phi}{1 - \left( \frac{r}{r + t} \right)^{2(\sigma - 1)}},
\]
\[
n_k = \frac{A^k \left[ (1/x_k^k)^B - \left( \frac{r}{r+t} \right)^{\sigma-1} \left( L_k' / L_k \right)^B (1/x_k^k)^B \right]}{1 - \left( \frac{r}{r+t} \right)^{2(\sigma-1)}},
\]
with \( k \neq k' \in \{H, F\} \). Thereby, \( \phi := \frac{\rho}{(1-\rho)t} \), \( A^k := \left( \frac{\alpha \rho}{r} \right)^{\frac{B}{1-\alpha}} \left( L_k^k \right)^B \) and \( B := \frac{\rho(1-\alpha)}{\rho - \alpha} > 1 \) are constants depending on \( r, \bar{L}_k \) and technology parameters.

In an Ethier-type model with constant elasticity of substitution between varieties, firms set prices according to a constant markup rule. Since labor is not employed in the production of intermediate goods and the factor return to capital is determined in the world market outside the FTA, input prices are exogenous, according to (7). In addition, the same production technologies are used in the two economies. Hence, input prices are symmetric: \( p_{H}^H = p_{F}^F \) and \( p_{H}^F = p_{F}^H \). However, transport costs imply that export prices are higher than prices for domestic sales, i.e. \( p_{k}^{k'} > p_{k}^k \). This gives rise to a home bias with respect to the use of intermediate inputs in final goods production. The output level sold to the foreign market is proportional to the level of local sales of a foreign producer, according to (8). The ratio \( x_{k}^{k'} / x_{k}^k \) depends on the price differential \( p_{k}^{k'} / p_{k}^k \) and is constant (since both \( r \) and \( t \) are exogenous). The level of sales is determined by the zero profit condition. Firm size and output pattern \((x_k^k, x_k^{k'})\) must be consistent with the condition that revenues equal total costs. Hence, according to (8), equilibrium output per firm depends on the parameters characterizing the demand behavior of final goods producers and on the parameters representing the variable and fixed cost components in intermediate input production. The number of viable firms depends in addition on the market size parameters \( \bar{L}_k \) and \( \bar{L}_k' \). A higher \( \bar{L}_k \) renders country \( k \) a more attractive location for input production, since it increases local demand there. As a consequence, other things equal, \( n_k \) increases and \( n_{k'} \) declines if \( \bar{L}_k \) rises.

Finally, according to (1), a rise in the number of input producers has a positive effect on labor productivity in the final goods sector. Thus, any policy that promotes firm entry in the intermediate goods sector positively feeds back on final output and wages.
Combining equations (7)-(9) with (1) and (3), we get for the equilibrium wage

\[ w^k = \frac{C^k \left( \frac{1}{x^k} \right) \tilde{B}}{\tilde{L}}, \]  \hspace{1cm} (10)

with \( C^k := (1 - \alpha) \left( \frac{A^k}{\rho} \right)^{1-\alpha} \) and \( \tilde{B} := \alpha \left( \frac{B}{\rho} - 1 \right) \). Changes in the fixed costs by public infrastructure investment affect the number of input producers simultaneously with their size. Lower fixed costs allow smaller and more firms to enter profitably. This is good for labor productivity and wages. The following section discusses the role of infrastructure policy for firm location, international outsourcing and wages in detail. For a formal derivation of (7)-(10) see Appendix A.1.

The FTA-equilibrium was derived under the assumption of interior solutions (i.e., \( n_k > 0, x^k_H > 0, x^k_F > 0, k = H, F \)). According to (8) and (9), the following conditions are necessary and sufficient for an interior solution

\[ t > r \cdot \max \left[ \left( \frac{f_F}{f_H} \right)^{\frac{1}{\sigma - 1}} - 1, \left( \frac{f_H}{f_F} \right)^{\frac{1}{\sigma - 1}} - 1 \right] \]  \hspace{1cm} (11)

and

\[ 1 > \left( \frac{r}{r + t} \right)^{\sigma - 1} \cdot \max \left[ \left( \frac{\tilde{L}^F x^H_H}{\tilde{L}^H x^F_F} \right)^B, \left( \frac{\tilde{L}^H x^F_F}{\tilde{L}^F x^H_H} \right)^B \right]. \]  \hspace{1cm} (12)

Roughly spoken, the two conditions are fulfilled if fixed costs \( f_H, f_F \) and immobile factor endowments \( \tilde{L}^H, \tilde{L}^F \) are not too different. In the symmetric case, i.e. if \( f_H = f_F \) and \( \tilde{L}^H = \tilde{L}^F \), both conditions (11) and (12) are satisfied for any \( t > 0 \).

5 Public Infrastructure Expenditures, Firm Location, International Outsourcing and Wages

In this section we provide a positive analysis on how public infrastructure expenditures affect the location of input producers, the amount of international outsourcing and wages in the two economies. As mentioned in the introduction we follow Bougheas et al. (2000) and assume that public infrastructure only has an impact on fixed costs \( f_k \). An increase
of public infrastructure investment in country $H$ reduces fixed costs $f_H$ and therefore increases the attractiveness of country $H$ as a location of intermediate input production. Fixed costs in country $F$ are not affected.\(^{11}\) Of course, there is an indirect effect of infrastructure expenditures on the marginal productivity of immobile labor, due to a change in number, size and location of input suppliers. This results in wage adjustments in the two economies, as will be explained in detail below.

We assume that there are two types of fixed costs: (i) fixed costs $f_k^P$ that are reduced/replaced by public infrastructure investment and (ii) firm-specific fixed costs $f_k^0$ that are independent of public infrastructure investment.\(^ {12}\) Examples for the first type of fixed costs are connection facilities to outside world (e.g., internet). An example for the second type would be establishment of the intra-firm information and communication system. Formally, public infrastructure investment and fixed costs are related in the following way:

\[
 f_k(G_k) = \begin{cases} 
 f_k^0 + f_k^P(G_k) & \text{if } G_k \in [0, \overline{G}_k], \\
 f_k^0 & \text{if } G_k \geq \overline{G}_k 
\end{cases}, \quad k = H, F. \quad (13)
\]

$G_k$ represents the level of public infrastructure investment. $f_k^P(G_k)$ is a negatively sloped function in interval $G_k \in [0, \overline{G}_k]$, with $f_k^P(0) > 0$ and $f_k^P(\overline{G}_k) = 0$. The benefit from investment into public infrastructure reaches a maximum at $G_k = \overline{G}_k$. Public investment above this level cannot increase the attractiveness of a country for intermediate input production, since firm-specific fixed costs $f_k^0 > 0$ are independent of the level of public infrastructure provision. It is assumed that $f_k^0$ and $f_k^P$ are restricted in such a way that (11) and (12) are satisfied for all possible combinations of $G_k \in [0, \overline{G}_k]$ and $G_{k'} \in [0, \overline{G}_{k'}]$ and interior solutions result with positive supply of intermediate inputs in both economies.

In the following comparative-static analysis, we consider variations of infrastructure

\(^{11}\)Small spillover effects would not destroy our results.

\(^{12}\)In contrast to a pure subsidy for founding a new firm, infrastructure investment has a public good character. For a discussion on the robustness of our findings with respect to this assumption see Section 7.2.
parameter $G$ in country $H$ and hold fixed costs in country $F$ at $f_F$ constant. Proposition 1 summarizes the effects of public infrastructure investment on number and location of intermediate input suppliers.

**Proposition 1.** A $G_H$-induced decline of fixed costs $f_H$ has a positive effect on the number of input suppliers in country $H$ and a negative effect in country $F$. The impact on the total number of input suppliers (in $H$ plus $F$) is ambiguous. $f_H(G_H) \leq f_F$ guarantees a positive impact.

**Proof.** See Appendix A.2. ■

For any given $G_H \in [0, \overline{G}_H]$, an increase in infrastructure provision $G_H$ implies that fixed costs decline in country $H$ so that $H$ becomes a more attractive location for intermediate input production. This has two effects. First, the $G_H$-induced decline of fixed costs in country $H$ leads *ceteris paribus* to entry of additional firms and therefore to a rise in the number of input suppliers located in country $H$. Second, for constant fixed costs in country $F$, there is exit of input producers in country $F$, due to higher competition with country $H$ firms. The effect on the overall number of intermediate input producers is positive if fixed costs in country $H$ are not higher than in country $F$, but is ambiguous in general. If $f_H(G_H) > f_F$ the negative "exit" effect in low-fixed cost country $F$ may dominate the positive "new entry" effect in high-fixed cost country $H$ so that the total number of intermediate input producers may decline in response to a $G_H$-induced reduction of fixed costs $f_H$.

Next we consider the impact of public infrastructure investment on international outsourcing from the two economies. We are interested in both the volume of international outsourcing, i.e. $n_k x_{k'}^k$, $k \neq k' \in \{H, F\}$, as well as the international outsourcing intensity $\xi_k := \frac{n_k x_{k'}^k}{n_k x_k}$, which is a measure for country $k$’s exposure to intermediate goods.

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13 The comparative-static analysis is made under the assumption that public infrastructure investments are financed by lump-sum taxes, which do not have *feedback effects*. See Section 6 for the budget constraint of the government.
The impacts of public infrastructure investment on international outsourcing are summarized in Proposition 2.

**Proposition 2** A $G_H$-induced decline of fixed costs $f_H$ leads to a decline in the volume of country $H$’s international outsourcing, i.e., a reduction of $n_Fx^H_F$, and an increase in the volume of country $F$’s international outsourcing, i.e., an increase of $n_Hx^F_H$. The international outsourcing intensity decreases in country $H$ and increases in country $F$.

**Proof.** See Appendix A.2. □

For any given $G_H \in [0, \overline{G}_H]$, a higher level of public infrastructure in country $H$ induces at the same time a rise in the number $n_H$ of intermediate good varieties produced in country $H$ and a decline in the number $n_F$ of varieties produced in $F$ (see Proposition 1). In addition, there is an output effect. Lower fixed costs in country $H$ make entry easier. Thus, more locally produced varieties compete for use by the final goods producers. This drives down demand per intermediate component in country $H$, i.e., $x^H_H$ and $x^F_F$ decline. In sum, intermediate goods imports of country $H$, i.e., $n_Fx^H_H$, are reduced. The opposite happens in country $F$, where the decline in the number of locally produced varieties leads to higher demand per intermediate input, i.e., both $x^F_F$ and $x^F_H$ increase, so that country $F$’s international outsourcing $n_Hx^F_H$ is stimulated.

To understand the impact of $G^H$ on international outsourcing intensity $\xi_H = \frac{n_Fx^H_F}{n_Hx^H_H}$, recall that the ratio of $x^F_F$ to $x^H_H$ is constant, according to (8), since relative input prices are fixed by $t$ and $r$. Hence $\xi_H$ simplifies to $\xi_H = \frac{n_F}{n_H} \left( \frac{r}{t+1} \right)^{\sigma}$, which, for any given $G_H \in [0, \overline{G}_H]$, unambiguously declines in the level of public infrastructure in country $H$, according to Proposition 1. Some foreign intermediate input suppliers are replaced by

\[ \xi_k = \frac{n_k}{n_k} \frac{x^k_k}{x^k_k} \] is the better measure.
local producers in country $H$. The opposite finding holds for the international outsourcing intensity $\xi_F$.

Finally, policymakers are interested in the effects of infrastructure provision on wages. (Note that the earnings of capital owners are determined in the world market.) At this stage of our analysis we focus on gross wages. The tax burden of public infrastructure investment is taken into account in Section 6.

According to (1) and (3), marginal productivity of $L$ and thus the wage rate is a function of the CES-aggregator $X$ of intermediate components. As a consequence, wages critically depend on how many input suppliers are located in $H$ and $F$, respectively, and on the volume of intermediate inputs purchased from firms at the two locations. The following proposition summarizes the wage effects resulting when public infrastructure policy changes the attractiveness of location $H$.

**Proposition 3** A $G_H$-induced decline of fixed costs $f_H$ leads to higher wages in country $H$ and lower wages in country $F$.

**Proof.** Proposition 3 follows from (8), (10) and (13).

A decline of fixed costs $f_H$ raises the number of input producers located in country $H$ and reduces the number of input producers located in country $F$ (see Proposition 1). These firm number adjustments exhibit opposing effects on CES-index $X^H$ and, by virtue of (1) and (3), also on $w^H$. If all inputs were used to the same extent, the total effect would be ambiguous since the effect on $n_H + n_F$ is ambiguous. However, we have a home bias. According to (8), inputs coming from domestic suppliers have a higher weight in final goods production. Therefore, the positive effect on $X^H$ of the increased number of suppliers located in $H$ dominates the negative effect of a decreased number of suppliers from $F$. In sum, labor productivity and thus $w^H$ unambiguously rise, when $G_H$ is increased (as long as $G_H \in [0, G^*_H]$). The opposite effect is triggered in country $F$.

In sum, we find that public infrastructure investment by increasing the attractiveness of a country as a location for intermediate input production reduces international outsourcing of that country and has a positive impact on wages. At the same time, the public
infrastructure investments have negative effects on the partner country. The number of input producers located in country $F$ declines. This is accompanied by an increase in outsourcing from $F$ to $H$ and leads to lower wages in $F$.\footnote{Our framework also allows us to study the relationship between capital flows and the factor return to immobile labor. Since capital is used for producing $x^k$, capital flows mirror the outsourcing streams. Like in Feenstra and Hanson (1996), we can show that the country which experiences a capital inflow gains relative to the other economy, which suffers from capital outflow. However, in our model the capital flows are triggered by national infrastructure investment, an issue which is not addressed in Feenstra and Hanson (1996). For further details on how public infrastructure provision affects cross-country wage differentials, see Egger and Falkinger (2003).}

In Section 6 we extend the positive analysis presented in this section and investigate the role of public infrastructure expenditures as a policy strategy. Thereby, we assume that total income of residents, net of the tax burden of public infrastructure investment, is the objective of the government.

\section{Public Infrastructure Investment as Competitive Location Policy}

By providing a certain level of infrastructure for firms governments can influence the attractiveness of their country as a location for suppliers of intermediate inputs, the production of which is outsourced by the producers of final output. This affects the macroeconomic equilibrium, in particular the wage earned by immobile labor. Thus, the choice of $G_k$ is a policy instrument for increasing the citizens’ welfare.\footnote{It is important to keep in mind that $G_k$ represents only infrastructure for firms. Public infrastructure for households has of course different effects.} Welfare is given by national income net of tax payments for public infrastructure finance, i.e. by

\begin{equation}
W^k = w^kL^k + rK^k - T^k, \quad k = H, F.
\end{equation}

$T^k$ denotes lump-sum taxes which are used for financing public infrastructure investment $G_k$ in country $k$ and $rK^k$ is capital income of residents of country $k$. Since $L^k$, $K^k$ and $r$
are exogenously given, welfare can only be influenced if wages \( w^k \) and/or lump-sum taxes vary. Both \( w^k \) and \( T^k \) depend on the chosen level \( G_k \) of public infrastructure for firms. It is assumed that providing level \( G_k \) costs \( \mu_k G_k \) units of final output, where \( \mu_k \geq 0 \) is a constant. The higher \( \mu_k \), the more costly it is to provide \( G_k \). Since \( Y \) is the numéraire good,

\[
    T^k = \mu_k G_k, \quad k = H, F, \tag{15}
\]
gives the tax burden imposed by public infrastructure provision \( G_k \) in country \( k \).

It is clear that the optimal infrastructure choice critically depends on the functional specification of \( f^P_k (\cdot) \). For the sake of simplicity we assume that \( f^P_k (\cdot) \) is a linear function in interval \([0, \overline{G}_k] \), given by \( f^P_k (G_k) = \overline{G}_k - G_k, \quad k = H, F \).

### 6.1 The Optimal Level of Public Infrastructure Investment

According to Proposition 3, wage \( w^k \) is an increasing function of public infrastructure level \( G_k \). Let for a given level \( G_k^r \) in the partner country \( W_0^k (G_k, G_k^r) := w^k \overline{L}^k + r \overline{K}^k \), be the possible levels of gross national income in \( k \). Straightforward calculations show that, under the linear specification of \( f^P_k (G_k)\), \( W_0^k \) is an increasing and strictly convex function of \( G_k \) in interval \([0, \overline{G}_k] \). Moreover, \( T^k \) is linear in \( G_k \). Since \( \partial^2 W_0^k / \partial G_k^2 > 0 \), if \( \partial W_0^k / \partial G_k \leq \mu_k \) it is beneficial to decrease \( G_k \) as long as this is possible, i.e. until \( G_k = 0 \). If \( \partial W_0^k / \partial G_k \geq \mu_k \) it is beneficial to increase infrastructure provision until \( G_k = \overline{G}_k \) is reached. Increasing \( G_k \) beyond\(^{18}\) \( \overline{G}_k \) cannot further reduce fixed costs, rendering gross income \( W_0^k \) independent of \( G_k \) for infrastructure levels above \( \overline{G}_k \). However, welfare \( W^k (G_k, G_k^r) \) declines due to the additional tax burden induced by higher public infrastructure expenditures. In Figure 2 welfare function \( W^H (G_H, G_F) = W_0^H (G_H, G_F) - \mu_H G_H \) is drawn for a given \( G_F \) and two different cost coefficients \( \mu_1^H > \mu_2^H \) of public infrastructure provision.

\( > \)Figure 2\( < \)

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\(^{17}\)The convexity of \( W_0^k \) is preserved, as long as the shape of \( f^P_k (G_k) \) is not “too convex”. For a formal discussion on this issue, see Egger and Falkinger (2003).

\(^{18}\)The remaining fixed costs are firm-specific, recall (13).
The dotted line $\mu_H^1 G_H$ indicates a situation with low productivity in public infrastructure provision. In this case, the welfare maximizing $G_H$-decision (for a given level of public infrastructure in country $F$) is given by $G_H = 0$ as can be seen from the dotted welfare function $W^H(G_H, G_F)$ for $\mu_H^1$. (At $G_H = 0$, we have $\partial W_0^H / \partial G_H < \mu_H$. At the point where $\mu_H$ is tangential to $W_0^H$ a welfare minimum would be reached.) In contrast, if productivity in infrastructure provision is high, i.e. if $\mu_H$ is low, the welfare maximizing $G_H$-decision is given by $G_H = G_H$. This case is represented by the solid line $\mu_H^2 G_H$ and solid welfare function $W^H(G_H, G_F)$ for $\mu_H^2$. (At $G_H = G_H$, we have $\partial W_0^H / \partial G_H > \mu_H$, but a further reduction of fixed costs by increasing infrastructure investments is not feasible, according to (13).)

For any given level of public infrastructure quality $G_{k'}$ in the partner country there is a threshold $\mu_k(G_{k'})$ of the cost of infrastructure provision at which the government in country $k$ is indifferent between choosing $G_k = 0$ or $G_k = G_k$. This cost threshold is given by the condition $W^k(0, G_{k'}) = W^k(G_k, G_{k'})$ which is equivalent to $W^k_0(0, G_{k'}) = W^k_0(G_k, G_{k'}) - \mu_k G_k$. Thus,

$$\mu_k(G_{k'}) := \frac{w^k(G_k, G_{k'}) - w^k(0, G_{k'})}{G_k} L^k,$$

(16)

where $w^k(G_k, G_{k'})$ denotes the equilibrium wage in country $k$, when the infrastructure level is $G_k$ in country $k$ and $G_{k'}$ in country $k'$. Obviously, for a given level $G_{k'}$ in the partner country $k'$, the optimal choice for country $k$ is $G_k = G_k$ if $\mu_k < \mu_k(G_{k'})$ and $G_k = 0$ if $\mu_k > \mu_k(G_{k'})$, respectively. The infrastructure level $G_{k'}$ in the partner country affects $w^k$ according to our analysis in Section 5, and thus $\mu_k(G_{k'})$, according to (16). Combining these facts, we obtain the following results concerning the optimal infrastructure policy of country $k$ in response to a given infrastructure policy of partner country $k'$.\footnote{Equilibria in mixed strategies are not considered.}

**Proposition 4** Let $k, k' \in \{H, F\}$, $k \neq k'$. $\mu_k(G_{k'})$ is decreasing in $G_{k'}$ and: (i) if $\mu_k \leq \mu_k(G_{k'})$, then $G_k = G_k$ is a dominant strategy; (ii) if $\mu_k \geq \mu_k(0)$, then $G_k = 0$ is a dominant strategy; (iii) if $\mu_k \in \left(\mu_k(G_{k'}), \mu_k(0)\right]$, then $G_k = 0$ is the optimal response to $G_{k'} = G_{k'}$ and $G_k = G_k$ is the optimal response to $G_{k'} = 0$.  

20
Proof. See Appendix A.2.

The economic interpretation of Proposition 4 is as follows. If a country’s productivity in producing public infrastructure is high so that infrastructure can be improved at relatively low cost, then the country should decide for top infrastructure provision, regardless of the situation in the partner country. In contrast, for a country with relatively high cost of infrastructure provision competitive location policy in form of infrastructure investment would be counterproductive from a welfare point of view. However, in intermediate cases - with a less extreme cost structure - optimal policy depends on the other country’s position. More precisely, for countries with intermediate costs of infrastructure our analysis suggests not to imitate the partner country. Top infrastructure provision only pays if the other country has a low infrastructure level.

These results are of particular interest in the context of the discussion about core and periphery economies. They show that public infrastructure investments can explain core-periphery patterns as politico-economic equilibria - with the core country being characterized by high infrastructure investment, a large number of intermediate input producers, low international outsourcing and high productivity of labor (and therefore high wages), whereas the opposite holds true in the periphery country characterized by low taxes and a low level of public infrastructure. While part (i) and part (ii) of Proposition 4 indicate that the differentiation into core and periphery is determined by differences in the costs of public infrastructure provision $\mu_k$, part (iii) of the proposition points out that a differentiation into core and periphery also can result without such differences. Even in the case of ex ante perfectly symmetric economies, countries may ex post be different with respect to the optimally chosen level of public infrastructure provision $G_k$.\(^{20}\)

\(^{20}\)This result confirms the insights by Bucovetsky (2004). However, in line with the new economic geography literature, the existence of transport costs and the number of local producers is essential for our results, while in Bucovetsky’s contribution transport costs are not considered and the number of firms is unimportant, since there is perfect competition.
6.2 Welfare in the FTA: Is There a Need for Policy Coordination?

From the analysis in Section 5 we know that an infrastructure-induced welfare gain in country $H$ reduces wages and thus welfare in country $F$ (see Proposition 3). This negative effect on welfare in country $F$ is not considered by $H$’s government when choosing the optimal level of public infrastructure investment. As a consequence uncoordinated infrastructure policies may lead to suboptimal FTA-welfare $W^{FTA} := W_H + W_F$. Consider the case of two symmetric countries. Then, national welfare net of taxes is given by $W_k = w_k(G_k, G_k^0) \bar{L} + \tau \bar{K} - \mu G_k \equiv W(G_k, G_{k'})$. Thus, the pay-off matrix for the two possible choices of optimal infrastructure policy $G_k = 0$ and $G_k = \bar{G}$ is of the form

<table>
<thead>
<tr>
<th>$G_H = 0$</th>
<th>$G_H = \bar{G}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$G_F = 0$</td>
<td>$W(0,0); W(0,0)$</td>
</tr>
<tr>
<td>$G_F = \bar{G}$</td>
<td>$W(\bar{G},0); W(0,\bar{G})$</td>
</tr>
</tbody>
</table>

According to Proposition 4, three cases must be distinguished:

If cost $\mu$ is relatively low $G_H = \bar{G}$ and $G_F = \bar{G}$ are dominant strategies, i.e.

$$W(\bar{G},0) > W(0,0) \quad \text{and} \quad W(\bar{G},\bar{G}) > W(0,\bar{G}).$$

Total welfare resulting in the non-cooperative equilibrium is thus

$$W^{FTA} = 2W(\bar{G},\bar{G}).$$

It is easy to check that (17) is consistent with\(^{21}\) $W(0,0) > W(\bar{G},\bar{G})$ so that total welfare $W_H + W_F$ could be increased to $W^{FTA} = 2W(0,0)$ by cooperating at $G_H = G_F = 0$. This does not mean that policy coordination at $G_H = G_F = 0$ necessarily increases welfare. For instance, if $\mu$ is sufficiently low, $G_H = G_F = \bar{G}$ is also optimal from the point of view of FTA-welfare.\(^{22}\)

\(^{21}\)Note that Proposition 3 implies $W(\bar{G},\bar{G}) < W(\bar{G},0)$ and $W(0,0) > W(0,\bar{G})$.

\(^{22}\)In the case of $\mu_k = 0$, such an outcome is guaranteed. Costless public infrastructure investments are unrealistic. But the case $\mu_k = 0$ is interesting for the following reason. We can interpret an increase in $G$
Under high infrastructure cost $\mu$, we have (from part (ii) of Proposition 4)

$$W(0, 0) > W(\overline{G}, 0) \quad \text{and} \quad W(0, \overline{G}) > W(\overline{G}, \overline{G}),$$

(19)

and

$$W^{FTA} = 2W(0, 0)$$

(20)
in the non-cooperative equilibrium. Since $W(0, \overline{G}) < W(0, 0)$ and $W(\overline{G}, \overline{G}) < W(\overline{G}, 0)$, according to Proposition 3 and the definition of $W$, the inequalities in (19) imply $W(\overline{G}, \overline{G}) < W(0, 0)$. Thus, in the case of a high $\mu$ policy coordination at $G_H = G_F = \overline{G}$ would definitely decrease welfare $W^{FTA}$ to $2W(\overline{G}, \overline{G}) < 2W(0, 0)$.

In the case of intermediate cost levels $\mu$, we have

$$W(\overline{G}, 0) > W(0, 0) \quad \text{and} \quad W(0, \overline{G}) > W(\overline{G}, \overline{G}),$$

(21)

and

$$W^{FTA} = W(\overline{G}, 0) + W(0, \overline{G})$$

(22)
in the non-cooperative equilibrium. The ranking described by (21) implies $2W(\overline{G}, \overline{G}) < W(\overline{G}, 0) + W(0, \overline{G})$ but is consistent with $2W(0, 0) \leq W(\overline{G}, 0) + W(0, \overline{G})$. Thus, coordination at $G_H = G_F = \overline{G}$ cannot improve $W^{FTA}$ but coordination at $G_H = G_F = 0$ may be beneficial.

Due to the positive external scale economies of the Ethier model, attracting firms by providing public infrastructure for them has negative external effects on the partner country which loses firms. Hence, uncoordinated competitive policy may lead to "over-provision" of public infrastructure for firms. This result differs from the findings in the public economics literature on infrastructure provision and capital mobility, discussed by as improvements in the quality of economic order, which relates a country's attractiveness for intermediate input production to characteristics like property rights. A higher quality of economic order increases both national and FTA-income. A more detailed discussion on this issue can be found in Egger and Falkinger (2003).

23 Proposition 3 implies $W(\overline{G}, \overline{G}) < W(\overline{G}, 0)$. Moreover, according to (21), $W(\overline{G}, \overline{G}) < W(0, \overline{G})$.

24 On the one hand we have $W(0, 0) < W(\overline{G}, 0)$ due to (21), but on the other hand $W(0, 0) > W(0, \overline{G})$, according to Proposition 3.
Sinn (2003). In that literature, positive scale economies (external to the individual firm) are not considered so that the equilibrium under fiscal competition (between identical economies) is efficient.\footnote{However, the possibility of overprovision of public goods is not new in the literature of tax competition. In the absence of external scale economies overprovision may be a problem if tax \textit{harmonization} intensifies infrastructure competition (see Sinn, 2003, p. 45). Moreover, Sørensen (2004) shows that in the presence of lump sum transfers, tax competition results in overprovision of public goods. Finally, in Justman et al. (2001) entry and exit of regions in the location market can explain excessive investment in infrastructure.}

>Figure 3<

Figure 3 summarizes our results about the non-cooperative policy equilibria and the possibilities to improve welfare by coordinating the provision of public infrastructure for firms. Sometimes though not always policy coordination can improve overall welfare compared to non-cooperative competitive location policy.\footnote{This is in contrast to Bougheas et al. (2003), where coordination should always increase efficiency. In contrast to Bucovetsky (2004), an equilibrium with underprovision of public infrastructure for firms cannot arise.} In particular, an agreement to refrain from top infrastructure provision may be beneficial. This does not mean that coordination at zero public infrastructure is optimal. It is straightforward to show that coordination at some positive level of public infrastructure provision (at least in one country) may be \(W^{FTA}\)-maximizing. But then, as an immediate consequence of the convexity of welfare function \(W\), such welfare-maximizing coordination leads to a core-periphery outcome (with \(G_k \neq G_{k'} \leq \bar{G}\)) and not to harmonization in public infrastructure provision. Hence, \(W^{FTA}\)-maximizing coordination may exhibit adverse distributional effects, if there are no supplementary measures to redistribute coordination gains.

This result is of particular relevance for the recent discussion on how to promote national infrastructure projects in the enlarged EU25 area. In view of our results, the optimal allocation of EU infrastructure expenditures does not necessarily lead to identical infrastructure quality in all member countries. Rather, if distributional justice in the \(FTA\) is at the agenda, it \textit{may} be more efficient to exploit agglomeration rents by allowing for
core-periphery patterns in the EU and to redistribute these rents among union members. This is a further argument against the current design of Structural Funds in the EU. As put forward by Bougheas et al. (2003, p. 904), these funds do not account for coordination failures in the national provision of public infrastructure, but are aimed at economic growth and the recovery of regions that are underdeveloped by comparison with the European community average. However, even the goal of a (more or less) uniform level of infrastructure quality is disputable since it comes at cost of efficiency if agglomerative forces are at work. Moreover, our results indicate that there is no need to compensate for national underprovision of public support for firms. To the contrary, if there is need for coordination at all, the problem is that national governments are inclined to do too much for making settlement of firms attractive. This should be taken into account when deciding about the Structural Funds after their expiration in 2006.

7 Discussion

The aim of this section is twofold. First, we investigate in which way our results depend upon the simplifying assumption that public infrastructure expenditures reduce fixed costs but let marginal costs of input production unaffected. Second, we discuss firm subsidies as an instrument of competitive location policy (in contrast to public infrastructure investment).

7.1 Public Infrastructure Investments and variable production costs

The analysis in Sections 5-6 builds upon the assumption that higher public infrastructure expenditures lower fixed costs but do not affect variable costs of input production. To see how important this simplifying assumption is for our results, we briefly discuss the role of public expenditures that aim at reducing variable production costs. Such a modification makes the analysis much more complicated and we are not able to provide a full analytical
treatment. To gain insights into the main mechanisms at work, we first consider a situation without international outsourcing, for which analytical results can be derived. For the more challenging model variant with intermediate input trade, we refer to simulation results.

Infrastructure investment which lowers variable production costs leads to lower intermediate input prices, according to the constant markup rule in the Ethier model (with constant elasticity of substitution between input varieties). As a consequence, the contribution margin declines and firms must sell a larger volume of output to cover the given level of fixed costs. This tends to reduce the number of input producers that can survive in the market. At the same time, the price reduction leads to an increase in the demand for differentiated inputs. This makes it easier to cover fixed costs and has a positive effect on the number of firms. In general, it is not clear, which of the two effects dominates (see Holtz-Eakin and Lovely, 1996). However, since the factor return to capital is exogenous in our model, condition \(0 < \alpha < \rho < 1\) is sufficient for a positive firm number effect.\(^{27}\) Summing up, in the model variant without intermediate goods trade both output per firm and the number of input producers increase if public infrastructure investment lowers the variable cost of input production. Hence, CES-index \(X\) and, by virtue of (1) and (3), also the factor return to immobile labor are positively affected by such a policy intervention.

In a set of simulations we have investigated the robustness of these findings under international outsourcing of input production.\(^{28}\) The numerical results show that effects on domestic firm number and wages identified above extend to a setting with intermediate goods trade. Opposite effects are triggered in the foreign economy, where intensified competition leads to an exit of input producers and the wage rate declines. This is, due to the existence of transport costs and the associated home bias in the use of intermediate inputs for final goods production. (Note the similarity to the results in Section 5.) More-

\(^{27}\) For formal details, see Section 2 of Egger, H., and J. Falkinger, 2002, Industry Concentration, International Outsourcing and Economic Fundamentals, mimeo. This working paper is available under the following link: http://www.wwi.unizh.ch/research/wp/wp_egger/Egger_Falkinger.pdf.

\(^{28}\) The program code for the simulations in Mathematica 5.0 is available from the authors upon request.
over, if input producers serve both the local and the foreign market, they do not only
adjust the level of output to a reduction in variable production costs but also react by
changes in their production pattern (i.e. \( x'_k / x'_{k'} \) rises). Finally, simulation results confirm
that the welfare effects of infrastructure investment, reducing variable production costs
are qualitatively the same as those derived in Section 6.

7.2 Subsidies as an Alternative to Public Infrastructure Investment

So far our analysis has not allowed for any rivalry in the use of public infrastructure by firms. Although a complete analysis of impure public infrastructure goods provision is
beyond the scope of our paper, we want to address an extreme form of rivalry in the use
of public expenditures, namely firm subsidies. Suppose that the government subsidizes
fixed costs \( f^0_k \) of each firm locating in country \( k \) by an amount \( G_k < f^0_k \). Thus,

\[
f_k (G_k) = f^0_k - G_k
\]

and

\[
T^k = n_k (G_k) G_k, \quad k = H, F,
\]

where \( n_k (G_k) \) is the equilibrium number of firms under fixed costs \( f_k (G_k) \). (Again, we
focus on interior solutions so that \( n_k > 0 \).) It is straightforward to show that \( T^k \) is an
increasing function in \( G_k \). Evaluating \( W^k = W^0_k - T^k \) at \( G_k = 0 \) we get\(^{29}\)

\[
\frac{\partial W^k}{\partial G_k} \bigg|_{G_k=0} > \frac{\partial T^k}{\partial G_k} \bigg|_{G_k=0}.
\]

Hence, it is always beneficial for an individual country to provide some subsidy to foster
entry of intermediate goods producers. Two forces are responsible for this result: The
\(^{29}\) \( \frac{\partial T^k}{\partial G_k} \bigg|_{G_k=0} = n_k (0) \), according to (24), and \( \frac{\partial W^k}{\partial G_k} \bigg|_{G_k=0} = \frac{(B-1)\phi C^k}{1 - (\frac{1}{\phi C^k})^{\frac{1}{\kappa}} \left( \frac{1}{x^*_{k'}} \right)^B} \bigg|_{G_k=0} \), according to
(10), (14) and the fact that \( B = \tilde{B} + 1 \). Note further that \( A^k < (B - 1)\phi C^k \), because of \( \alpha < \rho < 1 \). Combining these facts with (9) we get (25).
external economies of scale arising from the positive impact of the number of firms on productivity, and the positive home-market effect of firm location, induced by the transaction costs for intermediate goods trade. Since welfare in the partner country $k'$ is negatively affected by the fixed cost subsidy in $k$, firm subsidies are a controversial political issue in a free trade agreement. Interestingly, we have\(^{30}\)

$$\left. \frac{\partial \left( W^k_0 + W^{k'}_0 \right)}{\partial G^k_k} \right|_{G^k_k=0} > \left. \frac{\partial T^k} {\partial G^k_k} \right|_{G^k_k=0},$$

so that subsidizing entry of intermediate goods producers in country $k$ a bit is also beneficial from the perspective of the FTA. Nonetheless, policy coordination may be necessary to avoid overprovision of national firm subsidies. In addition, supranational redistribution may be required if equalization of locational attractiveness is a political goal, like for instance in the EU.\(^{31}\)

8 Concluding Remarks

In this paper we set up a model with one final good and differentiated intermediate inputs that are assembled by the use of immobile labor. We investigate how the location of intermediate input suppliers, international outsourcing and wages are affected by decisions on public infrastructure investment in two member countries of a FTA. We find that national public infrastructure investment, which reduces fixed costs for intermediate input production, raises the number of input suppliers, reduces international outsourcing activities of final goods producers and leads to higher wages in the home country. The

\(^{30}\frac{\partial \left( W^k_0 + W^{k'}_0 \right)}{\partial G^k_k} \bigg|_{G^k_k=0} = \frac{(B-1)\phi C^k}{A^k} n_k(0), \text{ according to (9), (10), (14) and the facts that } B = \bar{B} + 1 \text{ and } C^{k'} = \left( \frac{C^k}{C^k} \right)^B. \text{ Using } A^k < (B - 1) \phi C^k \text{ we conclude } \left. \frac{\partial \left( W^k_0 + W^{k'}_0 \right)}{\partial G^k_k} \right|_{G^k_k=0} > n_k(0) = \left. \frac{\partial T^k} {\partial C^k} \right|_{G^k_k=0}.\)

\(^{31}\text{The role of subsidies as a public input has been discussed in } \text{Kind et al. (2000). In their analysis subsidies (i.e., a negative tax rate on capital) as an outcome of fiscal competition are most likely in a symmetric equilibrium, in which production is not concentrated. In contrast to this, our analysis points to the role of firm subsidies for explaining core-periphery patterns in industrial production. To put it differently, subsidies can explain ex-post differences of ex-ante symmetric countries.}\)
opposite holds in the partner country, where the number of produced varieties and the return to the immobile factor decline, whereas international outsourcing is stimulated.

In a second step we investigate the role of public infrastructure investment as a competitive location policy of national governments which aim to maximize gross national income minus (lump-sum) tax payments. Since governments do not take into account the negative effects of location policy on the FTA partner country, policy coordination may result in a higher overall FTA-welfare level. More specifically, non-cooperative policies may result in overprovision of public infrastructure for firms. Moreover, there are distributional conflicts. In particular, core-periphery patterns can arise even among ex ante symmetric countries. Indeed, core-periphery patterns may also be the result of FTA-income maximizing policy coordination.

To study the robustness of our results with respect to the assumption on the cost effects of infrastructure provision, we have discussed public expenditures which aim at reducing variable costs of input production. It turns out that such a modification does not change our main qualitative results. We have also investigated the role of firm subsidies as an instrument of competitive location policy. Thereby, it is shown that some subsidization of entry of intermediate goods suppliers is beneficial for both the individual country and the FTA. However, policy coordination may be required to avoid overprovision of subsidies or to reach the goal of equalization of locational attractiveness.

Concerning policy implications for regional trading blocs like the EU, our analysis provides the following insights. Generally, structural funds that are aimed at economic growth and the recovery of regions should explicitly account for coordination failures of national infrastructure provision and potential efficiency losses of a uniform level of infrastructure quality. More specifically, the analysis suggests three conclusions: First, an optimal infrastructure policy from an integrated point of view may result in significantly different levels of national infrastructure qualities paired with side payments to reach distributional goals within the union. Second, there is no need to compensate at the EU level for national underprovision of public infrastructure for firms. Third, national measures of subsidizing firm entry are not necessarily inefficiency generating distortions.
to be hindered by a central authority. However, to avoid overprovision of subsidies in the strategic locational competition between governments, some upper bound of firm subsidies may be required.

Appendix

Appendix A.1: Derivation of Equilibrium Prices, Quantities, Firm Numbers and Wages

The first-order conditions for (5) and (6) give us $x_{k}^{k} = (\rho D_{k}/r)^{\sigma}$, $x_{k'}^{k'} = (\rho D_{k'}/(r + t))^{\sigma}$ and thus

$$x_{k'}^{k} = x_{k}^{k} \left(\frac{r}{r + t}\right)^{\sigma},$$

(A.1)

with $k \neq k' \in \{H, F\}$. Because of iso-elastic demand, equilibrium prices are given by

$$p_{k}^{k} = \frac{r}{\rho} \quad \text{and} \quad p_{k}^{k'} = \frac{r + t}{\rho}. \quad (A.2)$$

This implies

$$p_{k}^{k'} = p_{k}^{k} \frac{r + t}{r}. \quad (A.3)$$

Profits of a firm in $k$ are given by

$$\pi_{k} = (p_{k}^{k} - r) x_{k}^{k} + (p_{k}^{k'} - r - t) x_{k}^{k'} - f_{k}, \quad (A.4)$$

so that in view of (A.1) the zero-profit condition reduces to

$$x_{k}^{k} = a_{k} - b x_{k}^{k'},$$

(A.5)

with $a_{k} := \frac{f_{k}}{p_{k}^{k} - r} = \frac{\rho f_{k}}{(1 - \rho)r}$ (use (A.2)) and $b := \frac{p_{k}^{k'} - r - t}{p_{k}^{k} - r} \left(\frac{r}{r + t}\right)^{\sigma} = \left(\frac{r}{r + t}\right)^{\sigma - 1}$ (use again (A.2)).

In an analogous way,

$$x_{k'}^{k'} = a_{k'} - b x_{k}^{k}, \quad (A.6)$$

with $a_{k'} := a_{k} \frac{f_{k'}}{f_{k}}$. Solving the system of equations given by (A.5) and (A.6), we get

$$x_{k}^{k} = \frac{a_{k} - a_{k}b}{1 - b^{2}} = \frac{\left[ f_{k} - f_{k'} \left(\frac{r}{r + t}\right)^{\sigma - 1}\right]}{1 - \left(\frac{r}{r + t}\right)^{2(\sigma - 1)}}, \quad (A.7)$$
$\phi := \frac{p}{(1-\rho)}$ and $k \neq k' \in \{H,F\}$.

Next, we derive the equilibrium number of $\gamma_{\text{rms}}$. Since firms within countries are symmetric we have $X^k = \left[n_k \left(x^k_r\right)^{\rho} + n_{k'} \left(x^k_{r'}\right)^{\rho}\right]^{1/\rho}$, with $k \neq k' \in \{H,F\}$. In view of (A.1) this reduces to

$$X^k = x^k_k \left[n_k + n_{k'} \left(\frac{r}{r+t}\right)^{\frac{1}{\rho}}\right]^{1/\rho}. \quad \text{(A.8)}$$

Moreover, using (A.2) and the definition of $P^k_X$ we get

$$P^k_X = \left(\frac{r}{\rho}\right)^{1-\sigma} \left[n_k + n_{k'} \left(\frac{r+t}{r}\right)^{1-\sigma}\right]. \quad \text{(A.9)}$$

Since $1 - \sigma = -\frac{\rho}{1-\rho}$ we conclude from this

$$X^k = x^k_k \left(P^k_X\right)^{\frac{1}{\rho}} \left(\frac{r}{\rho}\right)^{\frac{1}{\rho}}. \quad \text{(A.10)}$$

Using (A.2) in demand function $x^k_k = \left(p^k_T\right)^{-\frac{1}{\sigma}} \frac{\alpha Y^k}{P^k_X}$, we get $x^k_k = \left(\frac{r}{\rho}\right)^{-\sigma} \alpha Y^k / P^k_X$ which in view of $Y^k = (X^k)^{\alpha} \left(L^k\right)^{1-\alpha}$ and (A.10) reduces to

$$x^k_k = \alpha^{\frac{1}{1-\sigma}} L^k \left(\frac{r}{\rho}\right)^{-\frac{1}{\sigma}} \left(P^k_X\right)^{\frac{\alpha-\sigma}{\rho(1-\sigma)}}. \quad \text{(A.11)}$$

In view of (A.9) this can be rewritten as

$$x^k_k = \left(\frac{\alpha \rho}{r}\right)^{\frac{1}{1-\sigma}} (N_k)^{\frac{\alpha-\sigma}{\rho(1-\sigma)}} L^k, \quad \text{(A.12)}$$

with $N_k := n_k + n_{k'} \left(\frac{r}{r+t}\right)^{\sigma-1}$. An analogous expression holds for $x^k_{k'}$. After straightforward transformations, (A.12) can be rewritten as

$$n_k + n_{k'} \left(\frac{r}{r+t}\right)^{\sigma-1} = A^k \left(1/x^k_k\right)^B \quad \text{(A.13)}$$

and in a similar way we obtain

$$n_{k'} + n_k \left(\frac{r}{r+t}\right)^{\sigma-1} = A^k' \left(1/x^k_{k'}\right)^B \quad \text{(A.14)}$$

with $k \neq k' \in \{H,F\}$. $B = \frac{\rho(1-\alpha)}{\rho-\alpha}$ and $A^k = \left(\frac{\alpha \rho}{r}\right)^{\frac{\alpha}{\rho(1-\alpha)}} \left(L^k\right)^B$ have been used. (A.13) and (A.14) give us (9).
In a final step, we derive equilibrium wages. Using \( X^k = x^k \left[ n_k + n_{k'} \left( \frac{r}{r+r_t} \right)^{\sigma-1} \right]^{1/\rho} \), \( k \neq k' \in \{H,F\} \), and \( n_k + n_{k'} \left( \frac{r}{r+r_t} \right) = A^k \left( \frac{1}{x^k} \right)^B \), according to (A.13), we obtain

\[
X^k = (A^k)^{1/\rho} \left( \frac{1}{x^k} \right)^{\tilde{B}/\alpha},
\]

where \( \tilde{B} = \alpha \left( \frac{B}{\rho} - 1 \right) > 0 \). Then, (10) directly follows from (1), (3) and (A.15).

**Appendix A.2: Proof of Propositions 1, 2 and 4**

In the following derivations, fixed costs in country \( F \) are given by \( f_F \) and \( G_H \in [0, \overline{G}_H] \) holds.

**Proof of Proposition 1**

Use (8), (9) and (13) to find

\[
\frac{dn_H}{dG_H} = \frac{A^H B \phi \left\{ \left( \frac{1}{x_H^k} \right)^{B+1} + \left( \frac{r}{r+r_t} \right)^{2(\sigma-1)} \left( \frac{r}{r_H} \right)^B \left( \frac{1}{x_H^k} \right)^{B+1} \right\}}{\left[ 1 - \left( \frac{r}{r+r_t} \right)^{2(\sigma-1)} \right]^2} \frac{df^p_H}{dG_H} > 0\quad (A.16)
\]

and

\[
\frac{dn_F}{dG_H} = \frac{A^H B \phi \left\{ \left( \frac{r}{r+r_t} \right)^{\sigma-1} \left( \frac{1}{x_H^k} \right)^{B+1} + \left( \frac{r}{r+r_t} \right)^{\sigma-1} \left( \frac{r}{r_H} \right)^B \left( \frac{1}{x_H^k} \right)^{B+1} \right\}}{\left[ 1 - \left( \frac{r}{r+r_t} \right)^{2(\sigma-1)} \right]^2} \frac{df^p_H}{dG_H} < 0.\quad (A.17)
\]

Moreover,

\[
\frac{d(n_H + n_F)}{dG_H} = \frac{A^H B \phi \left\{ 1 - \left( \frac{r}{r+r_t} \right)^{\sigma-1} \left\{ \left( \frac{1}{x_H^k} \right)^{B+1} - \left( \frac{r}{r+r_t} \right)^{\sigma-1} \left( \frac{r}{r_H} \right)^B \left( \frac{1}{x_H^k} \right)^{B+1} \right\} \right\}}{\left[ 1 - \left( \frac{r}{r+r_t} \right)^{2(\sigma-1)} \right]^2} \frac{df^p_H}{dG_H}.\quad (A.18)
\]

Since \( \frac{df^p_H}{dG_H} < 0 \), \( \frac{d(n_H + n_F)}{dG_H} \gtrless 0 \) if and only if \( \left( \frac{r}{r_H} \right)^{B+1} \gtrless \left( \frac{r}{r_H} \right)^B \left( \frac{r}{r+r_t} \right)^{\sigma-1} \). According to (12), \( \left( \frac{r}{r_H} \right)^B > \left( \frac{r}{r_H} \right)^B \left( \frac{r}{r+r_t} \right)^{\sigma-1} \). However, this is only sufficient for \( \left( \frac{r}{r_H} \right)^{B+1} > \left( \frac{r}{r_H} \right)^B \left( \frac{r}{r+r_t} \right)^{\sigma-1} \).
\[
\left( \frac{r}{r+t} \right)^{\sigma-1} (r \, r + t)^{2(\sigma-1)} dG_H \leq 0 \text{ if } x_F^H \geq x_H^F, \text{ i.e., according to (8), if } f_F \geq f_H. \text{ Thus, } \frac{d(n_H + n_F)}{dG_H} > 0 \text{ if } f_H(G_H) \leq f_F \text{ and ambiguous otherwise.}^{32}
\]

**Proof of Proposition 2**

**Step 1:** Public infrastructure investment and the volume of international outsourcing:

Use (8) and (13) to obtain

\[
\frac{dx_H^H}{dG_H} = \frac{\phi}{1 - \left( \frac{r}{r+t} \right)^{2(\sigma-1)}} \frac{df_H^P}{dG_H} < 0 \quad (A.18)
\]

and

\[
\frac{dx_F^F}{dG_H} = -\left( \frac{r}{r+t} \right)^{2\sigma-1} \frac{dx_H^H}{dG_H} > 0, \quad (A.19)
\]

according to (A.1) and (A.6). Then, \( \frac{d(n_H x_H^H)}{dG_H} = \frac{dn_H}{dG_H} x_H^F + n_H \frac{dx_H^F}{dG_H} > 0 \) directly follows from (A.16). In a similar way, use (A.17) and \( \frac{dx_H^F}{dG_H} = \left( \frac{r}{r+t} \right)^{2}\sigma \frac{dx_H^H}{dG_H} < 0 \) to find \( \frac{d(n_F x_F^F)}{dG_H} = \frac{dn_F}{dG_H} x_F^H + n_F \frac{dx_F^H}{dG_H} < 0. \)

**Step 2:** Public infrastructure investment and the international outsourcing intensity:

According to (8), \( \xi_H = \frac{n_F^H}{n_H x_H^H} \) can be written as \( \xi_H = \frac{n_F}{n_H} \left( \frac{r}{r+t} \right)^{2\sigma} \) and \( \xi_F = \frac{n_H}{n_F} \left( \frac{r}{r+t} \right)^{2\sigma}. \) Then, \( \frac{d\xi_H}{dG_H} < 0 \) and \( \frac{d\xi_F}{dG_H} > 0, \) follow from (A.16) and (A.17). □

**Proof of Proposition 4**

Using \( f_k^P(G_k) = \overline{G}_k - G_k, k = H, F, \) in (13) and substituting (8) for \( x_k^k \) in (10) we get from (16)

\[
\frac{d\overline{G}_k}{dG_{k'}} = -BC_k^x \left( \frac{r}{r+t} \right)^{2(\sigma-1)} \left[ \frac{1}{x_k^x} \left( \frac{r}{r+t} \right)^{2(\sigma-1)} \right] < 0, \quad (A.20)
\]

for all \( G_{k'} \in [0, \overline{G}_k], k \neq k' \in \{H, F\}. \) This and the fact that \( \mu_k(G_{k'}) \) was defined as the threshold at which the government is indifferent between \( G_k = 0 \) and \( G_k = \overline{G}_k \) establish the proposition. □

\(^{32}\text{The ambiguity in the sign of } \frac{d(n_H + n_F)}{dG_H} \text{ for } f_F < f_H(G_H) \text{ has been shown in a simulation analysis. The respective parameter values and the program code for Mathematica 5.0 are available from the authors upon request.}\)
References


Final goods market in RoW

Country H

$Y^H$

$L^H$

$X^H$

Country F

$Y^F$

$L^F$

$X^F$

intermediate goods trade

capital mobility

capital mobility

Capital market in RoW

Figure 1: Basic model assumptions

$W^H$

$W_0^H(G_H, G_F)$

$\mu^1_H G_H$

$\mu^2_H G_H$

$W^H(G_H, G_F)$ for $\mu^1_H$

$W^H(G_H, G_F)$ for $\mu^2_H$

$0$

$G_H$

$G_H$

Figure 2: $W^H(G_H, G_F)$ for a given $G_F$
$G = \overline{G}$
is a dominant strategy

$G_k = \overline{G}$ if $G_k = 0$
is a dominant strategy

no coordination gains

coordin. at $G_k \neq \overline{G}$

no coordination at $G_k = \overline{G}$, $> 0$

no coordination gains

Figure 3: Public infrastructure investment and the gains from policy coordination