THE ROLE OF PUBLIC INFRASTRUCTURE FOR FIRM LOCATION AND INTERNATIONAL OUTSOURCING

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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 agreement *(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. It is shown when coordination of competitive location policies is useful and when it is not.

JEL Code: F12, F15, F42, H54.

Keywords: international outsourcing, firm location, public infrastructure, welfare effects.

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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 a location change was an exceptional phenomenon. It meant that a wide range of different production stages had to be shifted from one place to another. However, technical progress in recent years has tremendously 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 degree of vertical fragmentation and international outsourcing.[1] This implies that the optimal location is chosen for individual production stages, and specialized intermediate input producers make use of competitive location advantages all over the world. Despite this salient feature of reality, a macroeconomic model that accounts for the relationship between international outsourcing and the location of intermediate input suppliers 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 intermediate input suppliers, the volume of international outsourcing and the returns to immobile production factors as a function of the economic fundamentals and of national public infrastructure provision which is used as a mean of competitive location policy.[2]

The literature on international outsourcing has so far predominantly built on tradi-

[1] Hummels et al. (2001) find for a sample of 14 economies (10 OECD memebers and four emerging markets countries) that the vertical specialization (i.e., international outsourcing) share of 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. See also Feenstra (1998) and Feenstra and Hanson (2001) for a discussion on the relvance of vertical fragmentation and international outsourcing in modern industrial production.

[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.)

tional trade models of the Heckscher-Ohlin, Ricardo and Ricardo-Viner type. In these models, perfect competition characterizes final as well as intermediate goods markets so that the location of intermediate input producers is undetermined. See for instance Arndt, 1997; Deardorff, 2001; Egger, 2002; Egger and Falkinger, 2002; Jones, 2000; Jones and Kierzkowski, 2001.[3] Recently, a few studies have addressed the relationship between industry structure and international outsourcing. However, they primarily focus on imperfect competition in the final goods market and do not deal with the location of intermediate input producers and its relation to international outsourcing decisions of final goods suppliers. See Burda and Dluhosch, 2001, 2002.

The literature on multinational firms includes locational aspects (see for instance Markusen, 2002; Markusen and Venables, 2000). However, this literature focuses on intra-firm trade, whereas in our analysis outsourced components are purchased through arm's length transactions in (imperfect) markets.[4] 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. In our analysis of international outsourcing the intermediate input suppliers decide on the location of intermediate goods production and the final goods producers decide on the volume of international outsourcing. Firm location also plays an important role in the literature on economic geography (see for instance Krugman, 1991; Baldwin and Krugman, 2002; Krugman and Venables, 1995). However, the focus again lies on final goods production. Vertical fragmentation and international outsourcing are not considered.

The idea that firms are located at some place implies that there are fixed costs which

[3] Kohler (2001) accounts for fixed network costs that are entailed by international outsourcing.

[4] Recently, several studies have analyzed a multinational's decision to enter a foreign market through foreign direct investment and subsidiary production or through international outsourcing and arm's length transaction. This decision is based on a trade off between higher production costs in the case of foreign direct investment and the costs that arise from contractual imperfections in the case of arm's length transactions. (See e.g. Grossman and Helpman, 2002a, 2002b; 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.

are invested at a certain location and not at another. Therefore, we consider imperfect competition in the intermediate goods market. Imperfections in the final goods market are ignored. Moreover, 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 investment is an important aspect of a 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, social and economic 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.

We set up a general equilibrium model with one final good and differentiated intermediate inputs. Production in the final goods sector employs internationally immobile low-skilled labor for assembling the outsourced (differentiated) intermediate inputs. They are supplied under monopolistic competition. Final goods markets as well as factor markets are competitive. Intermediate input production makes use of internationally mobile capital. We assume that two small industrialized economies characterized by identical production technologies and equal endowments 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. This attractiveness depends on the fixed costs requirements for setting up a firm. Governments can influence the location choice of intermediate input suppliers through national infrastructure policy. Higher public infrastructure investment reduces fixed costs to set up a plant in this economy and therefore raises the attractiveness of a country. (See for a similar assumption Bougheas et al., 2000.)[5]

After introducing the basic framework in Section 2 and solving the FTA-equilibrium in Section 3, Section 4 provides a comparative-static analysis about the effects of public infrastructure investment on firm location, international outsourcing and wages. In Section 5 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. In Section 6 we discuss the robustness of our findings, some considerations on wage dispersion in the FTA and a different interpretation of our results. The last section concludes.

2 Theoretical Framework

We consider economies with a single final good Y (the numéraire good) and two primary production factors: internationally immobile (low-skilled) labor L and internationally mobile K, which may be interpreted as capital or know-how. Primary factors are not directly transformed into the final good, there is also intermediate goods production. 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) intermediate input suppliers. Low-skilled 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

$$Y = X^{\alpha} L^{1-\alpha}, \ \left(X = \sum\nolimits_i x_i^{\rho} \right)^{1/\rho}, \ \rho > \alpha. \tag{1}$$

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 intermediate inputs

[5] Holtz-Eakin and Lovely (1996) use a more general approach that allows public infrastructure investment to affect both variable and fixed costs of intermediate input production. Other studies, like Bougheas et al. (1999), assume that public infrastructure investment reduces transport costs. Such an effect is not considered in our model.

employment of K is essential. For the purpose of simplicity and in order to keep the analysis tractable, we assume that the production of differentiated intermediate inputs does not require employment of factor L.[6] The production technology in the X-sector is identical for all firms and given by

$$x_i = K_i. \tag{2}$$

We follow the common approach that monopolistic competition characterizes the market for the differentiated intermediate inputs x_i. The number of intermediate inputs is determined by the zero-profit condition.

3 Equilibrium under a Free Trade Agreement

Let H and F be two industrialized economies characterized by identical production technologies and identical endowment $\overline{L}$ of the immobile factor. Moreover, an equal amount $\overline{K}$ units of the internationally mobile factor is owned by residents of H and F, 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 inputs outside the FTA.[7] Finally, we assume that both countries H and F are small economies. Then, perfect mobility of factor K implies that its factor return, r, is determined in the world market outside the FTA.[8] The

[6]See Ludema and Wooton (2000) for a similar assumption regarding the type of factor inputs in the production of sophisticated goods.

[7]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.

[8]This assumption reflects the idea that capital cannot be taxed by local governments given its high degree of international mobility.

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 $L = \overline{L}$ prevails in equilibrium. Thus, according to (1)

$$\frac{(1-\alpha)\, Y^k}{\overline{L}} = w^k, \tag{3}$$

where Y^k is the equilibrium level of final output in country $k = H, F$. Denote by $p^k_{H,i}$ ($p^k_{F,j}$) the free on board (fob) prices of the intermediate component $x^k_{H,i}$ ($x^k_{F,j}$) produced by intermediate input supplier i (j) located in country H (F, respectively) and used by a final goods producer located in market $k = H, F$. The free trade agreement allows the firms in the final goods sector to choose freely between intermediate inputs regardless of their origin. Optimal demand of $x^k_{H,i}$ ($x^k_{F,j}$) is determined by the first-order conditions for $\max_{x^k_{H,i}, x^k_{F,j}} Y - \left[\sum_i p^k_{H,i} x^k_{H,i} + \sum_j p^k_{F,j} x^k_{F,j}\right] - w_k \overline{L}$, which read:

$$\frac{\alpha Y^k}{X^k}\left(\frac{X^k}{x^k_{H,i}}\right)^{1-\rho} = p^k_{H,i}, \quad i = 1, ..., n_H;\ k = H, F, \tag{4a}$$

$$\frac{\alpha Y^k}{X^k}\left(\frac{X^k}{x^k_{F,j}}\right)^{1-\rho} = p^k_{F,j}, \quad j = 1, ..., n_F;\ k = H, F, \tag{4b}$$

where $X^k := \left[\sum_{i=1}^{n_H} \left(x^k_{H,i}\right)^\rho + \sum_{j=1}^{n_F} \left(x^k_{F,j}\right)^\rho\right]^{1/\rho}$.

Using (4a), (4b) and defining aggregate price index $P^k_X := \sum_{i=1}^{n_H} \left(p^k_{H,i}\right)^{1-\sigma} + \sum_{j=1}^{n_F} \left(p^k_{F,j}\right)^{1-\sigma}$, $\sigma = 1/(1-\rho)$, we find[9] that $p^k_{H,i} = \left(\frac{\alpha Y^k}{P^k_X}\right)^{1-\rho} \left(x^k_{H,i}\right)^{-(1-\rho)}$ and $p^k_{F,j} = \left(\frac{\alpha Y^k}{P^k_X}\right)^{1-\rho} \left(x^k_{H,j}\right)^{-(1-\rho)}$, $k = H, F$, 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 problem of an x_i-producer located in country H:

$$\max_{x^H_{H,i},\, x^F_{H,i}} \left(x^H_{H,i}\right)^\rho D_H + \left(x^F_{H,i}\right)^\rho D_F - r\left(x^H_{H,i} + x^F_{H,i}\right) - t\, x^F_{H,i} - f_H, \tag{5}$$

where $D_k := \left(\frac{\alpha Y^k}{P^k_X}\right)^{1-\rho}$, $k = H, F$, is exogenous to the single producer. Note that, according to (2), marginal production costs of intermediate goods are equal to factor price

[9] Use (4a), (4b) and the definition of X^k to see that $\sum_{i=1}^{n_H} p^k_{H,i} x^k_{H,i} + \sum_{j=1}^{n_F} p^k_{F,j} x^k_{F,j} = \alpha Y^k$. Moreover, solve (4a) and (4b) for $x^k_{H,i}$ and $x^k_{F,j}$, respectively. Show then that $P^k_X = \left(\alpha Y^k / X^k\right)^{1-\sigma}$.

r of internationally mobile K which is determined in the world market. $t > 0$ are unit trade costs (but not tariffs) for international x-transactions, equivalent for both economies. f_k are country-specific fixed costs. They 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:

$$\max_{x_{F,j}^F, x_{F,j}^H} \left(x_{F,j}^H\right)^\rho D_H + \left(x_{F,j}^F\right)^\rho D_F - r\left(x_{F,j}^H + x_{F,j}^F\right) - t\, x_{F,j}^H - f_F. \tag{6}$$

Within each market intermediate input producers are symmetric. Solving (5) and (6) we obtain a system of four first-order conditions for intermediate goods producers. Together with 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 twelve equations. They determine the twelve endogenous variables x_H^k, x_F^k, p_H^k, p_F^k, n_k, and $w^k, k = H, F$ 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 4). Equilibrium prices, quantities and numbers of intermediate input producers implied by (3)-(6) are given by the following expressions:

$$p_k^k = \frac{r}{\rho} \quad \text{and} \quad p_k^{k'} = \frac{r+t}{\rho}, \tag{7}$$

$$x_{k'}^k = x_k^k \left(\frac{r}{r+t}\right)^\sigma \quad \text{and} \quad x_k^k = \frac{\left[f_k - f_{k'}\left(\frac{r}{r+t}\right)^{\sigma-1}\right]\phi}{1 - \left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{r}{r+t}\right)^{\sigma-1}}, \tag{8}$$

$$n_k = \frac{A\left[\left(1/x_k^k\right)^B - \left(\frac{r}{r+t}\right)^{\sigma-1}\left(1/x_{k'}^{k'}\right)^B\right]}{1 - \left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{r}{r+t}\right)^{\sigma-1}} \tag{9}$$

with $k \neq k' \in \{H, F\}$. Combining these equations with (1) and (3), we get equilibrium wages. Thereby, $\phi := \frac{\rho}{(1-\rho)r}$, $A := \left(\alpha^{\frac{1}{1-\alpha}}\overline{L}\right)^B \left(\frac{\rho}{r}\right)^{\frac{B}{1-\alpha}}$ and $B := \frac{\rho(1-\alpha)}{\rho-\alpha} > 1$ are constants depending on r, $\overline{L}$ and technology parameters. For a formal derivation see Appendix A.1.

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

$$t > r \cdot \max\left[1 - \left(\frac{f_H}{f_F}\right)^{\frac{1}{\sigma-1}}, 1 - \left(\frac{f_F}{f_H}\right)^{\frac{1}{\sigma-1}}\right] \tag{10}$$

and

$$1 > \left(\frac{r}{r+t}\right)^{\sigma-1} \cdot \max\left[\left(\frac{x_H^H}{x_F^F}\right)^B, \left(\frac{x_F^F}{x_H^H}\right)^B\right]. \tag{11}$$

Roughly spoken, the two conditions are fulfilled if fixed costs f_H and f_F are not too different. In the symmetric case, i.e. if $f_H = f_F$, both conditions (10) and (11) are satisfied for any $t > 0$.

4 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 intermediate 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.[10] Of course, there is an indirect effect of infrastructure expenditures on the productivity of final goods production, due to a change in number, size and location of intermediate input suppliers.[11] 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

[10] The results of our analysis are also obtained under sufficiently small spillover effects.

[11] Such an indirect effect is also emphasized in Holtz-Eakin and Lovely's (1996) analysis of the role of public infrastructure.

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:

$$f_k(G_k) = \begin{cases} f_k^0 + f_k^P(G_k) & \text{if} \quad G_k \in [0, G_k^{\max}[\\ f_k^0 & \text{if} \quad G_k \geq G_k^{\max} \end{cases}, \quad k = H, F. \tag{12}$$

G_k represents the *quality* of public infrastructure investment. $f_k^P(G_k)$ is a negatively sloped function in interval $G_k \in [0, G_k^{\max}[$, with $f_k^P(0) > 0$ and $f_k^P(G_k^{\max}) = 0$. The benefit from investment into public infrastructure reaches a maximum at $G_k = G_k^{\max}$. 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 quality of public infrastructure. It is assumed that f_k^0 and f_k^P are restricted in such a way that (10) and (11) are satisfied for all possible combinations of $G_k \in [0, G_k^{\max}]$ and $G_{k'} \in [0, G_{k'}^{\max}]$ and interior solutions result with positive supply of intermediate inputs in both economies (i.e., $n_k > 0$, $x_H^k > 0$, $x_F^k > 0$, $k = H, F$).

In the following comparative-static analysis, we consider variations of infrastructure parameter G in country H and hold fixed costs in country F at $f_F^1 = f_F(G_F)$ 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 intermediate input suppliers in country H and a negative effect in country F. The impact on the total number of intermediate input suppliers is ambiguous. $f_H(G_H) \leq f_F^1$ guarantees a positive impact.*

Proof. See Appendix A.2. ■

[12] In contrast to a pure subsidy for founding a new firm, infrastructure investment has a public good character.

For any given $G_H \in [0, G_H^{\max}[$, an increase in infrastructure quality G_H implies that fixed costs decline in country H and 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 intermediate input suppliers located in country H. Second, for constant fixed costs in country F, there is also a shift of intermediate input producers from country F to country H. As a consequence the number of intermediate input producers increases in country H and declines in country F. 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 $f_H(G_H) > f_F^1$ a marginal decline of fixed costs in country H induces a shift of firms from low-fixed costs country F to high-fixed costs country H, which tends to lower the equilibrium number of firms. If this negative "shift effect" dominates the positive "new entry" effect, the total number of intermediate input producers declines 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 $\xi_k := \frac{n_{k'} x_{k'}^k}{n_k x_k^k}$, which is a measure for the openness of country k with respect to intermediate goods imports.[13] 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 $n_F x_F^H$, and an increase in the volume of country F's international outsourcing, i.e., an increase of $n_H x_H^F$. The*

[13] In the literature international outsourcing intensity is often measured as intermediate goods imports relative to gross production. However, a change in this measure comprises several effects, namely, (i) a change in the resource requirements per output, (ii) changes in overall (national and international) outsourcing, maybe due to technological changes in the final goods production, and (iii) variations in international relative to national outsourcing. Since we are interested in the foreign impact only, we think that $\xi_k = \frac{n_{k'}}{n_k} \frac{x_{k'}^k}{x_k^k}$ is the better measure.

international outsourcing intensity decreases in country H and increases in country F.

Proof. See Appendix A.2. ■

For any given $G_H \in [0, G_H^{\max}[$, a higher quality 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 makes firm entry easier. Thus, more 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^H decline.[14] In sum, intermediate goods imports of country H, i.e., $n_F x_F^H$, 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_H^F increase, so that country F's international outsourcing $n_H x_H^F$ is stimulated.

For the international outsourcing intensity $\xi_H = \frac{n_F x_F^H}{n_H x_H^H}$ both overall local production $n_H x_H^H$ and overall import of intermediate inputs $n_F x_F^H$ are relevant. Whereas an increase in public infrastructure investment unambiguously leads to a reduction of intermediate goods imports $n_F x_F^H$, there are two opposing effects on the overall level of local production in country H. The number of varieties produced in country H increases (Proposition 1), but output of an individual firm (x_H^H) declines (see discussion above). As proved in the appendix, the first effect dominates and overall local production $n_H x_H^H$ turns out to be positively related to public infrastructure investments in country H. International outsourcing intensity ξ_H therefore declines if the quality of public infrastructure in country H is improved. That means, intermediate goods imports are replaced by local production in country H. The opposite finding holds for the international outsourcing intensity ξ_F.

Finally, policy is interested in the effects of infrastructure quality on wages. (Note that the earnings of capital owners are determined in the world market.) At this stage of our analysis we cannot address net wage effects, since the question of how public

[14]Note that, according to (8), x_H^H and x_F^H vary proportionally since relative prices are fixed by t, r and ρ.

infrastructure investment is financed has not been considered so far. The tax burden of public infrastructure investment is taken into account in Section 5.

According to (1) and (3), marginal productivity of L and thus the wage rate depend on the CES-aggregator X of intermediate components. As a consequence, wages critically depend on how many intermediate 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. See Appendix A.2. ■

A decline of fixed costs f_H implies that the number of intermediate input suppliers in H increases. This dominates the negative size effect so that total home production of intermediate good suppliers located in country H, i.e., $n_H x_H^H$, increases. At the same time, there is a negative effect on outsourcing to F implying that $n_F x_F^H$ is reduced. We find that the positive effect on marginal labor productivity of the increase in home-based intermediate goods production $n_H x_H^H$ dominates the negative effect of the decline in $n_F x_F^H$. Thus, the return to immobile labor in country H increases. The opposite holds for 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. However, there are negative effects of public infrastructure investments in the partner country. These negative effects lead to a decline in the number of local intermediate input producers in country F, which cannot be offset by larger intermediate goods imports, so that wages in country F are negatively affected by higher infrastructure investment in country H.

In Section 5 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.

5 Public Infrastructure Investment as a Competitive Location Policy

By providing a certain level of infrastructure quality governments can influence the attractiveness of their country as a location for firms supplying 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 public infrastructure quality G_k is a policy instrument for maximizing the citizen's welfare. Welfare is given by national income net of tax payments for public infrastructure finance, i.e. by[15]

$$W^k = w^k \overline{L} + r\overline{K} - T^k, \quad k = H, F. \tag{13}$$

T^k denotes lump-sum taxes which are used for financing public infrastructure quality G_k in country k. Due to the symmetry of the two economies with respect to $\overline{L}, \overline{K}$ and r, differences in the welfare levels can only arise if wages w^k and/or lump-sum taxes are different in H and F. Both w^k and T^k depend on the chosen level G_k of public infrastructure quality. It is assumed that providing level G_k requires $\mu_k G_k$ units of final output. Formally, the production technology for public infrastructure is given by

$$\mu_k G_k = Y^k, \quad k = H, F. \tag{14}$$

$\mu_k > 0$ is a cost parameter. The higher μ_k, the more costly it is to provide G_k. Since Y is the numéraire good, $T^k = \mu_k G_k$ gives the tax burden implied by public infrastructure quality G_k in country k.

It is clear that the optimal infrastructure choice critically depends on the functional specification of $f_k^P(\cdot)$. For the sake of simplicity we assume that $f_k^P(\cdot)$ is a linear function

[15] Remember that there is only one consumption good, namely commodity Y, and that $r\overline{K}$ is capital income of residents of country k.

in interval $[0, G_k^{\max}]$, given by $f_k^P(G_k) = \Psi^k - G_k$, $k = H, F$. (A discussion on the robustness of our results with respect to this specification is provided in Section 6.1.)

5.1 The Optimal Level of Public Infrastructure Investment

According to Proposition 3, wage w^k is an increasing function of public infrastructure quality G_k. Let for a given level $G_{k'}$ in the partner country $W_0^k(G_k, G_{k'}) := w^k\overline{L} + r\overline{K}$, be the possible levels of gross national income in k. Straightforward calculations show that W_0^k is an increasing and strictly convex function of G_k in interval $[0, G_k^{\max}[$. Since T^k is linear in G_k, there are only two candidates for an optimal G_k decision, namely $G_k = 0$ and $G_k = G_k^{\max}$. This can be seen in figure 1, where, for a given G_F, $W^H(G_H) = W_0^H(G_H, G_F) - \mu_H G_H$ is drawn for two different cost coefficients $\mu_H^1 > \mu_H^2$ of public infrastructure provision.

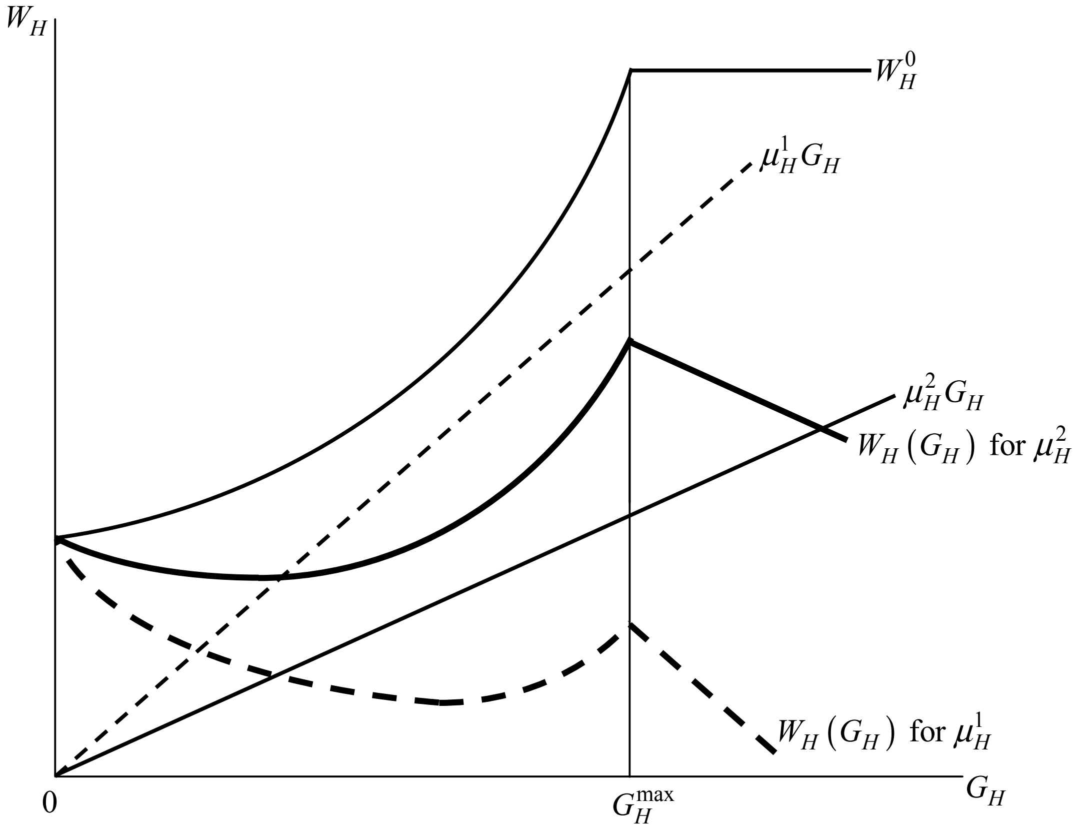

Figure 1: $W_H(G_H)$ for a given G_F

Since fixed costs of firms cannot be further reduced by increasing G_k beyond[16] $G_k^{\max}$, gross income W_0^H is independent of G_H to the right of $G_H^{\max}$. However, welfare $W^H(G_H)$ declines due to the additional tax burden induced by higher public infrastructure expenditures. 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 $W^H(G_H)$ for μ_H^1. In contrast, if productivity in infrastructure provision is high, i.e. if μ_H is low, the welfare maximizing G_H-decision is given by $G_H = G_H^{\max}$. This case is represented by the solid line $\mu_H^2 G_H$ and solid welfare function $W^H(G_H)$ for μ_H^2.

For any given level of public infrastructure quality $G_{k'}$ in the partner country there is a threshold $\overline{\mu}_k(G_{k'})$ of the cost of infrastructure provision at which the government in country k is indifferent between choosing $G_k = 0$ or $G_k = G_k^{\max}$. This cost threshold is given by the condition $W^k(0) = W^k(G_k^{\max})$ which is equivalent to $W_0^k(0, G_{k'}) = W_0^k(G_k^{\max}, G_{k'}) - \mu_k G_k^{\max}$. Thus,

$$\overline{\mu}_k(G_{k'}) := \frac{w^k(G_k^{\max}, G_{k'}) - w^k(0, G_{k'})}{G_k^{\max}} \overline{L}, \tag{15}$$

where $w^k(G_k, G_{k'})$ denotes the equilibrium wage in country k when infrastructure quality 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 $G_k = G_k^{\max}$ if $\mu_k < \overline{\mu}_k(G_{k'})$ and $G_k = 0$ if $\mu_k > \overline{\mu}_k(G_{k'})$, respectively. The infrastructure level $G_{k'}$ in the partner country affects w_k, according to our analysis in Section 4, and thus $\overline{\mu}_k(G_{k'})$, according to (15). 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'.

Proposition 4 *Let $k, k' \in \{H, F\}$, $k \neq k'$. Then: $\overline{\mu}_k(G_{k'})$ is decreasing in $G_{k'}$ and (i) if $\mu_k \leq \overline{\mu}_k(G_{k'}^{\max})$, then $G_k = G_k^{\max}$ is a dominant strategy; (ii) if $\mu_k \geq \overline{\mu}_k(0)$, then*

[16] The remaining fixed costs are firm-specific, recall (12).

$G_k = 0$ is a dominant strategy; (iii) if $\mu_k \in \left]\overline{\mu}_k\left(G_{k'}^{\max}\right), \overline{\mu}_k(0)\right[$, then $G_k = 0$ is the optimal response to $G_{k'} = G_{k'}^{\max}$ and $G_k = G_k^{\max}$ is the optimal response to $G_{k'} = 0$.

Proof. See Appendix A.2. ■

The economic interpretation of Proposition 4 is straightforward. If a country's productivity in producing public infrastructure quality is high so that infrastructure can be improved at relatively low cost, then the country should provide top quality 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. For countries with intermediate costs of infrastructure our analysis suggests not to imitate the partner country. To the contrary, top infrastructure provision only pays if the other country has poor infrastructure quality.

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[17] - with the core country being characterized by high infrastructure quality, 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 quality 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 infrastructure costs, 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 (i.e. $f_H^0 = f_F^0$, $\Psi^H = \Psi^F$, $G_H^{\max} = G_F^{\max}$ and $\mu_H = \mu_F$), countries may ex post be different with respect to the optimally chosen quality level of public infrastructure G_k.[18]

[17] In Krugman (1991) economies of scale, transport costs and the distribution of demand play an important role for the existence of a core-periphery structure.

[18] In this case, there exists a first-mover advantage for public infrastructure investment.

5.2 Welfare in the FTA: Is There a Need for Policy Coordination?

From the analysis in Section 4 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 $W^k = w^k(G_k, G_{k'})\overline{L} + r\overline{K} - \mu G_k \equiv W(G_k, G_{k'})$. Thus, the pay-off matrix for the two possible choices of optimal infrastructure policy $G_k = 0$ and $G_k = G_k^{\max} \equiv \overline{G}$ is of the form

	$G_H = 0$	$G_H = \overline{G}$
$G_F = 0$	$W(0,0); W(0,0)$	$W(0,\overline{G}); W(\overline{G},0)$
$G_F = \overline{G}$	$W(\overline{G},0); W(0,\overline{G})$	$W(\overline{G},\overline{G}); W(\overline{G},\overline{G})$

According to Proposition 4, three cases must be distinguished:
If cost μ is relatively low $G_H = \overline{G}$ and $G_F = \overline{G}$ are dominant strategies, i.e.

$$W(\overline{G},0) > W(0,0) \quad \text{and} \quad W(\overline{G},\overline{G}) > W(0,\overline{G}). \tag{16}$$

Total welfare resulting in the non-cooperative equilibrium is thus

$$W^{FTA} = 2W(\overline{G},\overline{G}). \tag{17}$$

It is easy to check that (16) is consistent with[19] $W(0,0) > W(\overline{G},\overline{G})$ so that total welfare $W^H + W^F$ could be increased to $W^{FTA} = 2W(0,0)$ by cooperating at $G_H = G_F = 0$.[20] This does not mean that policy coordination at $G_H = G_F = 0$ necessarily increases

[19] Note that Propositon 3 implies $W(\overline{G},\overline{G}) < W(\overline{G},0)$.

[20] Of course, the finding that zero public infrastructure expenditures are an efficient outcome should not be taken literally. Rather, the main result is that uncoordinated infrastructure policies can result in an overinvestment and therefore in a suboptimal level of W^{FTA}.

welfare. For instance, if μ is sufficiently low, $G_H = G_F = \overline{G}$ is also optimal from the point of view of FTA-welfare.[21]

Under high infrastructure cost μ, we have (from part (ii) of Proposition 4)

$$W(0,0) > W\left(\overline{G},0\right) \quad \text{and} \quad W\left(0,\overline{G}\right) > W\left(\overline{G},\overline{G}\right) \tag{18}$$

and

$$W^{FTA} = 2W(0,0) \tag{19}$$

in the non-cooperative equilibrium. Since $W\left(0,\overline{G}\right) < W(0,0)$ and $W\left(\overline{G},\overline{G}\right) < W\left(\overline{G},0\right)$, according to Proposition 3 and the definition of W, the two inequalities in (18) imply $W\left(\overline{G},\overline{G}\right) < W(0,0)$. Thus, in this case cooperation at $G_H = G_F = \overline{G}$ would definitely decrease welfare W^{FTA} to $2W\left(\overline{G},\overline{G}\right) < 2W(0,0)$.

In the case of intermediate cost levels μ, we have

$$W\left(\overline{G},0\right) > W(0,0) \quad \text{and} \quad W\left(0,\overline{G}\right) > W\left(\overline{G},\overline{G}\right) \tag{20}$$

and

$$W^{FTA} = W\left(\overline{G},0\right) + W\left(0,\overline{G}\right) \tag{21}$$

in the non-cooperative equilibrium. It can be shown that (20) implies[22] $2W\left(\overline{G},\overline{G}\right) < W\left(\overline{G},0\right) + W\left(0,\overline{G}\right)$ but is consistent with[23] $2W(0,0) \lesseqgtr W\left(\overline{G},0\right) + W\left(0,\overline{G}\right)$. Thus, cooperation at $G_H = G_F = \overline{G}$ cannot improve W^{FTA} but cooperation at $G_H = G_F = 0$ may be beneficial.

In sum, sometimes though not always policy coordination can improve overall welfare compared to non-cooperative competitive location policy. In particular, an agreement to refrain from top infrastructure provision may be beneficial if infrastructure costs are high. Thus, contrary to models with international spillovers uncoordinated competitive policy may lead to "*overtaxation*" with regard to taxes that are raised to provide infrastructure for firms.

[21] In the case of $\mu_k = 0$, such an outcome is guaranteed. See the discussion in Section 6.3.

[22] Proposition 3 implies $W\left(\overline{G},\overline{G}\right) < W\left(\overline{G},0\right)$. Moreover, according to (20), $W\left(\overline{G},\overline{G}\right) < W\left(0,\overline{G}\right)$.

[23] On the one hand we have $W(0,0) < W\left(\overline{G},0\right)$ due to (20), but on the other hand $W(0,0) > W\left(0,\overline{G}\right)$, according to Proposition 3.

Of course, even if FTA-welfare is maximized by uncoordinated public infrastructure decisions, there may be a need for (supranational) policy intervention in the form of redistributional measures. Without such an agreement, potential welfare losses arising from national competitive location policy may be a barrier to an FTA-formation, in particular in the case of intermediate costs of infrastructure.[24]

6 Discussion

The aim of this section is threefold. First, we investigate the robustness of our results under different specifications of $f_k^P(G_k)$. Second, we present some conclusions on how infrastructure policies affect wage dispersion in the FTA. Finally, we discuss in how far our findings would change if instead of infrastructure investment governments have a policy instrument which does not require public funding, say the "*quality of economic and social order*".

6.1 Different Specifications for $f_k^P(G_k)$

Under the linear specification $f_k^P(G_k) = \Psi^k - G_k$ used in Section 5 there are only two candidates for an optimal G_k decision of national governments: The corner solutions $G_k = 0$ and $G_k = G_k^{\max}$. This outcome critically depends on the convexity of gross national income W_0^k, as a function of G_k, in interval $[0, G_k^{\max}[$. Therefore, the relevant question with respect to the robustness of our results is: In which way is the convexity of W_0^k related to the properties of $f_k^P(G_k)$? It is straightforward to show that for any $G_{k'}$, $W_0^k(G_k, G_{k'})$ is a convex function of G_k as long as $f_k^P(G_k)$ is not "*too convex*" in interval $[0, G_k^{\max}[$. We know from Proposition 3 (proof) that $w^k = \frac{C\left(1/x_k^k\right)^{\widetilde{B}}}{\overline{L}}$, where C, $\widetilde{B}$ are constants determined by technical parameters and labor endowment. Thus,

[24] In the EU, structural funds at a supranational level help to overcome the infrastructure disadvantages of several countries and regions. See e.g. Breuss et al. (2001) for details on the agenda 2000's structural policy reform in the EU.

$W_0^k = C\left(\frac{1}{x_k^k}\right)^{\widetilde{B}} + r\overline{K}$ and in view of (8)

$$\frac{\partial^2 W_0^k\left(G_k, G_{k'}\right)}{\partial G_k^2} \gtreqless 0 \quad \text{if} \quad \frac{\left(\widetilde{B}+1\right)\phi}{1-\left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{r}{r+t}\right)^{\sigma-1}} \frac{1}{x_k^k} \gtreqless \frac{d^2 f_k^P\left(G_k\right)/dG_k^2}{\left[df_k^P\left(G_k\right)/dG_k\right]^2}. \tag{22}$$

According to (22), W_0^k is, for any $G_{k'}$, strictly convex in interval $[0, G_k^{\max}[$, if $f_k^P\left(G_k\right)$ is concave, i.e., if $d^2 f_k^P\left(G_k\right)/dG_k^2 < 0$, or if it is a linear function as assumed in Section 5. If the effect of public infrastructure G_k on the fixed costs described by $f_k^P\left(G_k\right)$ follows a sufficiently convex shape, W_0^k is concave in G_k. In this case the corner solutions $G_k = 0$, $G_k = G_k^{\max}$ are still possible candidates for an optimal infrastructure policy if μ_k is either very high or very low, respectively. However, for intermediate values of infrastructure cost μ_k the optimal infrastructure policy lies in the interior of interval $]0, G_k^{\max}[$. Figure 2 illustrates, for a given level of G_F, the optimization problem of H's government when W_0^H is concave.

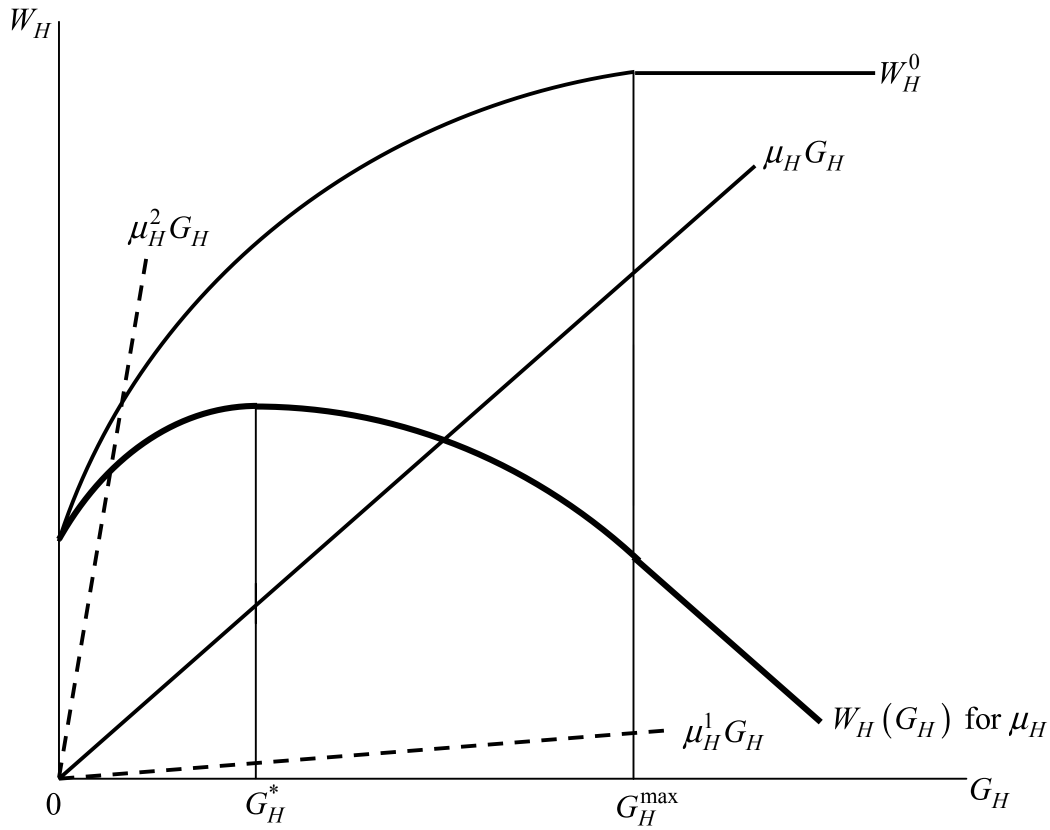

Figure 2: A concave $W_0^H\left(G_H\right)$-function

W_0^H and $\mu_H G_H$ represent gross national income and tax costs for infrastructure investments in country H. Welfare in H, represented by $W_H(G_H)$, reaches a maximum at $G_H^* \in [0, G_H^{\max}[$. $G_H = 0$ / $G_H = G_H^{\max}$ would be the welfare-maximizing policy if tax costs were equal or higher than $\mu_H^1 G_H$ / equal or lower than $\mu_H^2 G_H$ (dotted lines), respectively.

6.2 Public Infrastructure Investment and Wage Dispersion

The impact of different policy measures on wage dispersion across economies has always been an important issue in the literature on international trade. Our analysis provides insights on how infrastructure policy affects wage dispersion in a FTA. Wage dispersion is measured by the ratio w^H/w^F. We consider a situation where firm-specific fixed costs are lower in country H than in country F, i.e., $f_H^0 < f_F^0$. This is the source of wage dispersion in the absence of public infrastructure investment. In all other respects the two countries are identical. In particular, $\mu_k = \mu$ and $f_k^P(\cdot) = \Psi - G_k$, $k = H, F$. Without public infrastructure wages are higher in country H than in F due to the differential in firm-specific fixed costs. This wage gap increases if both countries improve public infrastructure quality *pari passu*.[25] The relationship between wage dispersion and variations in infrastructure quality $G_H = G_F = G$ is illustrated in figure 3. The intuition for this outcome is that the firm-specific fixed costs disadvantage of country F gets a higher weight in the wage determination if public infrastructure investment reduces fixed costs f_k^P.

[25] For a formal proof use $w^k/w^{k'} = \left(x_{k'}^{k'}/x_k^k\right)^{\widetilde{B}}$, with $\widetilde{B} = \alpha\left(\frac{B}{\rho} - 1\right)$, according to the proof of Proposition 3. In view of (8) we obtain $\frac{w^k}{w^{k'}} = \left(\frac{f_{k'} - f_k\left(\frac{r}{r+t}\right)^{\sigma-1}}{f_k - f_{k'}\left(\frac{r}{r+t}\right)^{\sigma-1}}\right)^{\widetilde{B}}$, which can finally be transformed into

$$\frac{w^k}{w^{k'}} = \left(\frac{\left(f_{k'}^P(G) + f_{k'}^0\right)\left[1 - \left(\frac{r}{r+t}\right)^{\sigma-1}\right] - \nu\left(\frac{r}{r+t}\right)^{\sigma-1}}{\left(f_{k'}^P(G) + f_{k'}^0\right)\left[1 - \left(\frac{r}{r+t}\right)^{\sigma-1}\right] + \nu}\right)^{\widetilde{B}},$$

where $f_k^P(G) = f_{k'}^P(G)$ have been used and $\nu := f_k^0 - f_{k'}^0$ denotes the firm-specific fixed costs differential between the two locations. From this we see immediately that $w^k > w^{k'}$ if $\nu < 0$. Moreover, in interval $G \in [0, G^{\max}[$, $\frac{d\left(w^k/w^{k'}\right)}{dG} > 0$ for $\nu < 0$. ■

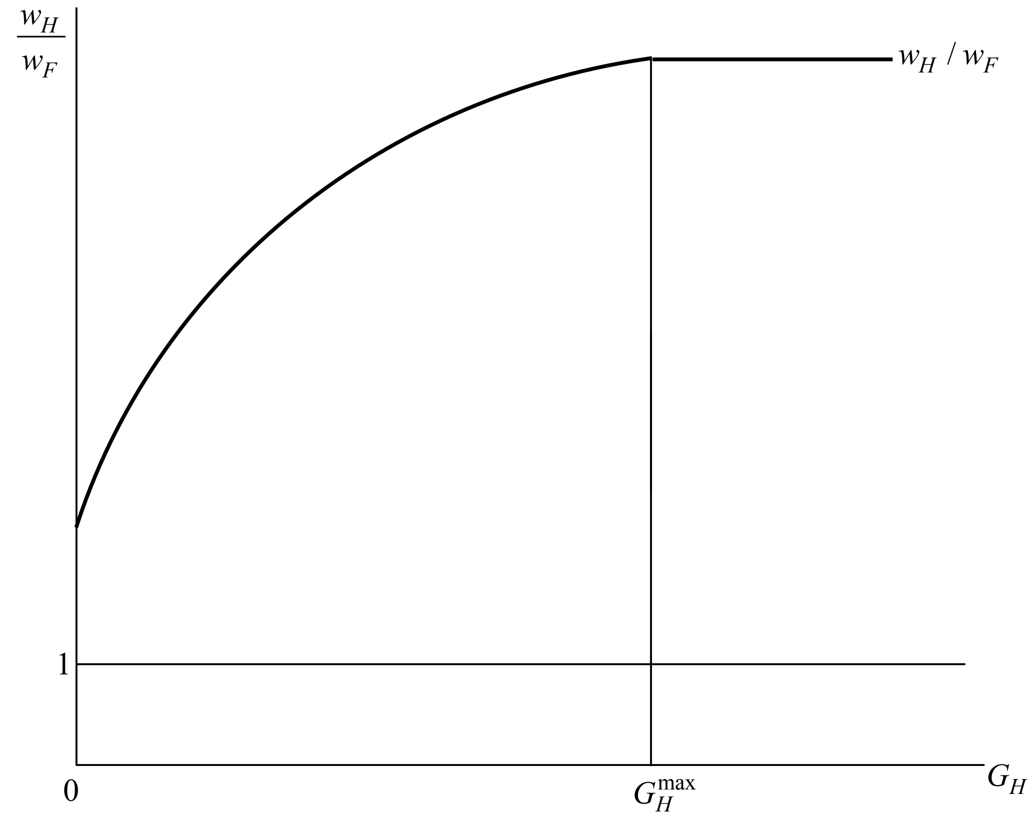

Figure 3: Public infrastructure investment and wage dispersion

Of course, this result does not mean that wage dispersion cannot be reduced through public infrastructure policies. But countries must coordinate at differentiated infrastructure policies. Suppose that the two countries considered above agree that wage dispersion is of common political concern. Then, lowering the wage dispersion requires policy coordination at $G_H < G_F$, which of course may be in conflict with the target of overall FTA-welfare maximization.

6.3 The Quality of Economic and Social Order

So far we have considered only one governmental instrument for a competitive location policy, namely public infrastructure investment. In the political discussion (especially in the context of international trade) the *quality of economic and social order* also plays an important role. Thereby, the term quality of economic order refers to a country's characteristics like market regulation, firm entry and investment rules, workplace protection, property rights legislation and so on. By social order we refer to respect of human rights, democratic support of government and other determinants of social stability. Both the economic and the social order are important factors for the decision on where to set up a firm. For example, in the absence of any property rights legislation, firms have to bear substantial (fixed) investment costs for security systems to protect their property rights. Social stability has comparable effects. The main difference to infrastructure investments is that there is no direct relationship between improvements in the quality of economic and social order and public funding.[26] To make the two policy instruments comparable, we assume that the relationship between fixed costs and the quality of economic and social order can again be represented by (12). However, tax costs T^k do not arise. This leaves the results in Section 4 unchanged. But choosing quality level $G_k^{\max}$ is now always a dominant strategy if W_0^k is the objective function of the government.[27] This is a direct consequence of Proposition 3. Since choosing top quality of economic and social order is a dominant strategy for national governments, our analysis does not indicate supranational agreements on property rights.

Although evident for national interest, income effects for the FTA are not a trivial result due to the negative effects of competitive location policy on the partner country. However, it can be shown that for any given quality level $G_{k'}$ the G_k-induced gain in country k outweighs any losses in country k'. In other words, FTA-income is maximized if both countries choose top quality of economic and social order.[28] In sum, there is no

[26] To the extent that social stability requires redistributional measures with a deadweight loss, we are back in the previous case with positive costs μ_k of public funding G_k. Obviously, the same applies when establishment of economic order has costs.

[27] Due to zero tax costs, W_0^k and W^k coincide.

[28] To see this, use $W^{FTA} = C\left\{\left(\frac{1}{x_H^H}\right)^{\widetilde{B}} + \left(\frac{1}{x_F^F}\right)^{\widetilde{B}}\right\} + 2r\overline{K}$, where $C = (1-\alpha)\,\overline{L}^{1-\alpha}A^{\alpha/\rho}$ and $\widetilde{B} = \alpha\left(\frac{B}{\rho} - 1\right)$. After straightforward calculations one obtains

$$\frac{dW^{FTA}}{dG_k} = -\frac{\widetilde{B}C\phi}{1 - \left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{r}{r+t}\right)^{\sigma-1}}\left\{\left(\frac{1}{x_k^k}\right)^{\widetilde{B}+1} - \left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{1}{x_{k'}^{k'}}\right)^{\widetilde{B}+1}\right\}\frac{df_k^P}{dG_k}.$$

need for policy coordination if the governments aim to improve the quality of economic and social order. However, redistributional measures may still be relevant in the case of asymmetric countries.

7 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 intermediate input suppliers, reduces international outsourcing activities of final goods producers and leads to higher wages in the home country. The opposite holds in the partner country, where the number of produced varieties as well as 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 on the FTA partner country, policy coordination may result in a higher overall FTA-welfare level. Moreover, distributional conflicts may arise even in ex ante symmetric countries. Such conflicts may be an important impediment to a FTA-formation if no redistributional measures are considered.

With respect to the question of wage dispersion in the FTA, we find that wage dispersion arising from differences in firm-specific fixed costs increases if countries increase public infrastructure quality *pari passu*. In other words, the goal to lower wage gaps across countries requires coordination on different infrastructure policies. In a final step,

Note that $\widetilde{B}+1=B$, according to the definition of B. Then, $dW^{FTA}/dG_k > 0$ directly follows from (9), (11) and $df_k^P/dG_k < 0$.

we compare public infrastructure investment with variations in the quality of economic and social order that defines a country's attractiveness for intermediate input production as a function of property rights legislation, social stability and so on. Since changes in the quality of economic and social order are not directly related to tax costs, improving this quality is good for both national and FTA-income.

Appendix

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

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

$$x_{k'}^k = x_k^k \left(\frac{r}{r+t}\right)^\sigma, \tag{A.1}$$

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

$$p_k^k = \frac{r}{\rho} \quad \text{and} \quad p_k^{k'} = \frac{r+t}{\rho}. \tag{A.2}$$

This implies

$$p_k^{k'} = p_k^k \frac{r+t}{r}. \tag{A.3}$$

Profits of a firm in k are given by

$$\pi_k = \left(p_k^k - r\right) x_k^k + \left(p_k^{k'} - r - t\right) x_k^{k'} - f_k, \tag{A.4}$$

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

$$x_k^k = a_k - b\, x_{k'}^{k'}, \tag{A.5}$$

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,

$$x_{k'}^{k'} = a_{k'} - b\, x_k^k, \tag{A.6}$$

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

$$x_k^k = \frac{a_k - a_{k'} b}{1 - b^2} = \frac{\left[f_k - f_{k'} \left(\frac{r}{r+t}\right)^{\sigma-1} \right] \phi}{1 - \left(\frac{r}{r+t}\right)^{\sigma-1} \left(\frac{r}{r+t}\right)^{\sigma-1}}, \tag{A.7}$$

with $\phi := \frac{\rho}{(1-\rho)r}$ and $k \neq k' \in \{H, F\}$.

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

$$X^k = x_k^k \left[n_k + n_{k'} \left(\frac{r}{r+t}\right)^{\frac{\rho}{1-\rho}} \right]^{1/\rho}. \tag{A.8}$$

Moreover, using (A.2) and the definition of P_X^k we get

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

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

$$X^k = x_k^k \left(P_X^k\right)^{\frac{1}{\rho}} \left(\frac{r}{\rho}\right)^{\frac{1}{1-\rho}}. \tag{A.10}$$

Using (A.2) in demand function $x_k^k = \left(p_k^k\right)^{-\frac{1}{1-\rho}} \frac{\alpha Y^k}{P_X^k}$, we get $x_k^k = \left(\frac{r}{\rho}\right)^{-\sigma} \alpha Y^k / P_X^k$ which in view of $Y^k = \left(X^k\right)^\alpha \overline{L}^{1-\alpha}$ and (A.10) reduces to

$$x_k^k = \alpha^{\frac{1}{1-\alpha}} \overline{L} \left(\frac{r}{\rho}\right)^{-\frac{1}{1-\rho}} \left(P_X^k\right)^{\frac{\alpha-\rho}{\rho(1-\alpha)}}. \tag{A.11}$$

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

$$x_k^k = \left(\frac{r}{\rho}\right)^{-\frac{1}{(1-\alpha)}} \left(N_k\right)^{\frac{\alpha-\rho}{\rho(1-\alpha)}} \alpha^{\frac{1}{1-\alpha}} \overline{L}, \tag{A.12}$$

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

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

and in a similar way we obtain

$$n_{k'} + n_k \left(\frac{r}{r+t}\right)^{\sigma-1} = A \left(1/x_{k'}^{k'}\right)^B, \tag{A.14}$$

with $k \neq k' \in \{H, F\}$. $B = \frac{\rho(1-\alpha)}{\rho-\alpha}$ and $A = \left(\alpha^{\frac{1}{1-\alpha}} \overline{L}\right)^{B} \left(\frac{\rho}{r}\right)^{\frac{B}{1-\alpha}}$ have been used. (A.13) and (A.14) give us (9). ■

Appendix A.2: Proof of Propositions 1-3

In the following derivations, fixed costs in country F are given by f_F^1 and $G_H \in [0, G_H^{\max}[$ holds.

Proof of Proposition 1

Use (8), (9) and (12) to find

$$\frac{dn_H}{dG_H} = -\frac{AB\phi\left\{\left(\frac{1}{x_H^H}\right)^{B+1} + \left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{1}{x_F^F}\right)^{B+1}\right\}}{\left[1-\left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{r}{r+t}\right)^{\sigma-1}\right]^2}\frac{df_H^P}{dG_H} > 0 \tag{A.15}$$

and

$$\frac{dn_F}{dG_H} = \frac{AB\phi\left\{\left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{1}{x_H^H}\right)^{B+1} + \left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{1}{x_F^F}\right)^{B+1}\right\}}{\left[1-\left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{r}{r+t}\right)^{\sigma-1}\right]^2}\frac{df_H^P}{dG_H} < 0. \tag{A.16}$$

Moreover,

$$\frac{d\left(n_H+n_F\right)}{dG_H} = -\frac{AB\phi\left[1-\left(\frac{r}{r+t}\right)^{\sigma-1}\right]\left\{\left(\frac{1}{x_H^H}\right)^{B+1} - \left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{1}{x_F^F}\right)^{B+1}\right\}}{\left[1-\left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{r}{r+t}\right)^{\sigma-1}\right]^2}\frac{df_H^P}{dG_H}. \tag{A.17}$$

Since $df_H^P/dG_H < 0$, $\frac{d(n_H+n_F)}{dG_H} \gtreqless 0$ if and only if $\left(\frac{x_F^F}{x_H^H}\right)^{B+1} \gtreqless \left(\frac{r}{r+t}\right)^{\sigma-1}$. According to (11) $\left(\frac{x_F^F}{x_H^H}\right)^{B} > \left(\frac{r}{r+t}\right)^{\sigma-1}$. However, this is only sufficient for $\left(\frac{x_F^F}{x_H^H}\right)^{B+1} > \left(\frac{r}{r+t}\right)^{\sigma-1}$ if $x_F^F \geq x_H^H$, i.e., according to (8), if $f_F \geq f_H$. Thus, $\frac{d(n_H+n_F)}{dG_H} > 0$ if $f_H(G_H) \leq f_F^1$ and ambiguous otherwise. ■

Proof of Proposition 2

<u>Step 1: Public infrastructure investment and the volume of international outsourcing:</u>

Use (8) and (12) to obtain $\frac{dx_H^H}{dG_H} = \frac{df_H^P/dG_H}{1-\left(\frac{r}{r+t}\right)^{\sigma}\left(\frac{r}{r+t}\right)^{\sigma-1}} < 0$ and $\frac{dx_H^F}{dG_H} = -\left(\frac{r}{r+t}\right)^{\sigma}\left(\frac{r}{r+t}\right)^{\sigma-1}\frac{dx_H^H}{dG_H}$. Then, $\frac{d\left(n_H x_H^F\right)}{dG_H} = \frac{dn_H}{dG_H}x_H^F + n_H\frac{dx_H^F}{dG_H} > 0$ directly follows from (A.15). In a similar way use (A.16) and $\frac{dx_F^H}{dG_H} = \left(\frac{r}{r+t}\right)^{\sigma}\frac{dx_H^H}{dG_H} < 0$ to find $\frac{d\left(n_F x_F^H\right)}{dG_H} = \frac{dn_F}{dG_H}x_F^H + n_F\frac{dx_F^H}{dG_H} < 0$.

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

According to (A.15)

$$\frac{dn_H}{dG_H}x_H^H = -\frac{AB\phi\left[\left(\frac{1}{x_H^H}\right)^B + \left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{1}{x_F^F}\right)^B\left(\frac{x_H^H}{x_F^F}\right)\right]}{\left[1-\left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{r}{r+t}\right)^{\sigma-1}\right]^2}\frac{df_H^P}{dG_H}, \tag{A.18}$$

and in view of (8) and (9)

$$n_H\frac{dx_H^H}{dG_H} = \frac{A\phi\left[\left(\frac{1}{x_H^H}\right)^B - \left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{1}{x_F^F}\right)^B\right]}{\left[1-\left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{r}{r+t}\right)^{\sigma-1}\right]^2}\frac{df_H^P}{dG_H}. \tag{A.19}$$

This gives us by straightforward calculations

$$\frac{d\left(n_H x_H^H\right)}{dG_H} = -\frac{A\phi\left[(B-1)\left(\frac{1}{x_H^H}\right)^B + E_1\left(\frac{1}{x_F^F}\right)^B\right]}{\left[1-\left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{r}{r+t}\right)^{\sigma-1}\right]^2}\frac{df_H^P}{dG_H}, \tag{A.20}$$

with $E_1 := \left(\frac{r}{r+t}\right)^{\sigma-1}\left[B\left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{x_H^H}{x_F^F}\right)+1\right]$. Due to $\frac{df_H^P}{dG_H} < 0$, $\frac{d\left(n_H x_H^H\right)}{dG_H} > 0$. Combining this with $\frac{d\left(n_F x_F^H\right)}{dG_H} < 0$ (see step 1), we have $\frac{d\xi_H}{dG_H} < 0$, where $\xi_H = \frac{n_F x_F^H}{n_H x_H^H}$ has been used.

In an analogous way, use

$$\frac{dn_F}{dG_H}x_F^F = \frac{AB\phi\left[\left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{1}{x_H^H}\right)^B\left(\frac{x_H^H}{x_F^F}\right) + \left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{1}{x_F^F}\right)^B\right]}{\left[1-\left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{r}{r+t}\right)^{\sigma-1}\right]^2}\frac{df_H^P}{dG_H}, \tag{A.21}$$

according to (A.16) and

$$n_F\frac{dx_F^F}{dG_H} = -\frac{A\phi\left[\left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{1}{x_F^F}\right)^B - \left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{1}{x_H^H}\right)^B\right]}{\left[1-\left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{r}{r+t}\right)^{\sigma-1}\right]^2}\frac{df_H^P}{dG_H}, \tag{A.22}$$

to obtain

$$\frac{d\left(n_F x_F^F\right)}{dG_H} = \frac{A\phi\left(\frac{r}{r+t}\right)^{\sigma-1}\left[(B-1)\left(\frac{1}{x_F^F}\right)^B + E_2\left(\frac{1}{x_H^H}\right)^B\right]}{\left[1-\left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{r}{r+t}\right)^{\sigma-1}\right]^2}\frac{df_H^P}{dG_H} < 0, \tag{A.23}$$

with $E_2 := B\left(\frac{x_H^H}{x_F^F}\right) + \left(\frac{r}{r+t}\right)^{\sigma-1}$. Together with $\frac{d\left(n_H x_H^F\right)}{dG_H} > 0$, this implies $\frac{d\xi_F}{dG_H} > 0$. ■

Proof of Proposition 3

According to (3), wages are given by the equation $w_k = \frac{(1-\alpha)Y^k}{\overline{L}}$, where $Y^k = \left(X^k\right)^\alpha \overline{L}^{1-\alpha}$, according to (1). Use $X^k = x_k^k\left[n_k + n_{k'}\left(\frac{r}{r+t}\right)^{\sigma-1}\right]^{1/\rho}$, $k \neq k' \in \{H, F\}$, and $n_k + n_{k'}\left(\frac{r}{r+t}\right) = A\left(\frac{1}{x_k^k}\right)^B$, according to (A.13), to obtain $X^k = A^{1/\rho}\left(\frac{1}{x_k^k}\right)^{\widetilde{B}/\alpha}$, where $\widetilde{B} := \alpha\left(\frac{B}{\rho} - 1\right) > 0$. Combine this with the fact that $\frac{dx_H^H}{dG_H} < 0$ and $\frac{dx_F^F}{dG_H} > 0$, according to (8) and (12), to establish $\frac{dw^H}{dG_H} > 0$ and $\frac{dw^F}{dG_H} < 0$. ■

Proof of Proposition 4

Assume $f_k^P(G_k) = \Psi^k - G_k$, $k = H, F$. Using (8), (12) and (15), we find for all $G_{k'} \in [0, G_{k'}^{\max}[$, $k \neq k' \in \{H, F\}$

$$\frac{d\overline{\mu}(G_{k'})}{dG_{k'}} = -\frac{\widetilde{B}C\phi\left(\frac{r}{r+t}\right)^{\sigma-1}\left[\left.\left(\frac{1}{x_k^k}\right)^{\widetilde{B}+1}\right|_{G_k = G_k^{\max}} - \left.\left(\frac{1}{x_k^k}\right)^{\widetilde{B}+1}\right|_{G_k=0}\right]}{G_k^{\max}\left[1 - \left(\frac{r}{r+t}\right)^{\sigma-1}\left(\frac{r}{r+t}\right)^{\sigma-1}\right]} < 0. \qquad \text{(A.24)}$$

(Use $w^k = \frac{C\left(1/x_k^k\right)^{\widetilde{B}}}{\overline{L}}$ with $C = (1-\alpha)\overline{L}^{1-\alpha}A^{\alpha/\rho}$ and $\widetilde{B} = \alpha\left(\frac{B}{\rho} - 1\right)$.) Remember the fact that there are only two candidates for an optimal infrastructure policy in country k, namely $G_k = 0$ and $G_k = G_k^{\max}$. Then, straightforward calculations lead from (13), (14) and (A.24) to Proposition 4. ■

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