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Strategic competition with public infrastructure: Ineffective and Unwelcome?

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Abstract

Countries invest in international infrastructure in an effort to attract firms. Acquiring the position of a hub would make this effort successful. We use a model of international trade with monopolistic competition, increasing returns to scale and transport costs to analyse policy competition through infrastructure investment.

For a small or backward country the strategic effect of attracting firms is less important than for large or advanced countries. A country that acquires a hub-position sees its welfare improve. The other countries may gain or lose; they benefit from cheaper international trade but suffer from the relocation of firms. In the case of line infrastructure the spoke countries will invest to eradicate the hub position, whereas in the case of point infrastructure they will not. Policy competition is more likely to deliver too much infrastructure investment when transport costs are low and the strategic effect is more important. A globalizing world may thus call for international co-ordination.

Keywords: Infrastructure, Industrial Location, Monopolistic Competition, International Trade

JEL codes: F12, H4, R12

1 Introduction[1]

The coordination of (capital) taxes is recurring theme within the European Union. Pleas for coordination are motivated by the fear that footloose firms play governments off against each other; in an attempt to attract firms governments set tax rates lower than they would otherwise do.[2] That policy competition naturally extends to other factors that are important for location and investment decisions of firms is perhaps less recognised. Location and investment decisions do depend not only on corporate taxes but also on the quality of the labour force and other (non-tradeable) inputs like infrastructure, macroeconomic stability and regulation. Infrastructure is one of the key locational factors, since firms prefer good access to suppliers and customers. Not surprisingly therefore countries invest in infrastructure in an effort to increase their attractiveness as a location for firms. This raises the concern that countries may invest too much. A priori, however, the concern for overinvestment is not self-evident. Investments in infrastructure also have positive external effects on other countries. As roads go two ways, investment by one country makes international trade cheaper for other countries. So, two opposing considerations emerge: strategic competition for firms may induce too much investment in public infrastructure whereas a positive externality on international trade may imply too little investment. The *first* question this paper takes up is whether coordination of infrastructure investment is necessary.[3] We study this question within a trade and geography model for three countries. The paper's main contribution to this issue is that in a world with low transport costs and high firm mobility competition among countries is likely to result in too much investment in infrastructure. This suggest that there is a role for policy coordination (in order to downplay competition in infrastructure).

The European Union could indeed try to coordinate infrastructure investments. This is, however, not exactly what it does. The EU stimulates the provision of public infrastructure through the Cohesion Fund and the Structural Funds. The motivation for this policy, however, is not policy competition or the lack thereof but to reduce inequality. An important aim of the Cohesion Fund is to improve infrastructure in the poorest countries in the EU. One of the Structural Funds (ERDF) has a similar aim for the poorest regions of the EU.[4] However, despite

[1] Harry Garretsen, Charles van Marrewijk, Ruud de Mooij and Theo van de Klundert are acknowledged for comments on a previous version of the paper.

[2] See Zodrow and Mieszkowski (1986) and Bucovetsky and Wilson (1991). Gorter and De Mooij (2001) provide a recent overview.

[3] Literature which formally addresses this concern is scarce. An exception is Keen and Marchand (1997) who analyse the division of public expenditure over public investment and consumption if there is policy competition.

[4] The joint budget of these funds amounts to 213 billion Euro for the period 2000-2006.

these funds, regional disparities within the EU are stable or, if anything, have widened.[5] This brings us to a *second* question addressed in this paper: can infrastructure investments effectively reduce regional disparities?

How can infrastructure investment positively affect economic development and – if investments in backward areas are relatively high – reduce regional inequality? In one view infrastructure is an essential input in the production process (see for example Ashauer, 1989, and Barro, 1989). Hence, increasing the stock of infrastructure has an analogous impact on economic development as increasing any other type of capital stock, and may thus help to reduce regional disparities. A different view is that improved infrastructure enhances competition between firms and thereby increases economic development (see Aghion and Schankerman, 2000).

However, the recent theories on location – the 'new economic geography' – warn that better infrastructure does not necessarily improve the position of a lagging region. In particular, Martin and Rogers (1995) argue that improving a connection between two regions with different home markets can persuade firms to locate near the large, rich market and to export to the small, poor market. Thereby, better infrastructure may bring larger regional disparities.[6]

This paper maintains that even within the approach of Martin and Rogers investment in infrastructure could be an effective regional policy as long as it (considerably) improves the position of country or region in the international transport network, i.e. as long as it gives a country or a region the position of a hub (a location that is relatively well connected to other locations) .[7,8] To this observation that we add two insights. First, improving the position of a small or backward region in the transport network may still cause an outflow of firms unless the hub position is strong. Second, endogenous policy responses in the spokes are likely to undo position of a hub.

To derive these results we apply and adapt theories of international trade and economic geography, that rely upon the Dixit-Stiglitz formulation for production and consumption functions. More specifically, in this paper we combine work of Venables (1987) and Krugman (1993) and associate this with the policy competition literature initiated by Zodrow and

[5] The distribution of regional per capita incomes in Europe became more equal after the second World War; this process came, however, to a halt after 1980(Fagerberg and Verspagen 1996). This conclusion depends, among others, on the countries included in the sample. A more complete account of the subtleties involved in measuring convergence in the EU is beyond the scope of this paper, see Ederveen et al. (2002) and the references therein.

[6] There is actually a fourth view on the effect of infrastructure spending, a view the European Commission endorses when evaluating the Structural Funds, and that is that the demand effect is important (see the discussion in Martin, 1995, on the EU policy evaluation).

[7] In the remainder of the discussion we use countries to denote either regions or countries where it causes no confusion. Crucial is that mobility of labour is relatively low between different areas.

[8] Opposite to Martin and Rogers (1995)we consider countries as part of a network instead of as one of the two ends of a line.

Mieszkowksi (1986). Besides, the analysis in this paper has several features in common with Puga and Venables (1997). They use a similar structure with three countries and transport costs whereas their model differs considers forward and backward linkages among firms. More substantial are the differences in interpretation of the 'iceberg' transport costs. In their focus reductions in transport costs are the results of *trade liberalisation*, whereas in our focus they are brought about by investments in *infrastructure*.[9] Whereas they inevitably consider multilateral actions, we consider unilateral actions to lower transport costs. Consequently, we are able co-ordinated and unco-ordinated policy games in which incentives to invest are well defined and policy actions are endogenous.

The model distinguishes three countries or regions, one small, poor and two (similar) large, rich countries or regions. To address our two questions – (i) Is coordination of infrastructure investment necessary? (ii) Can infrastructure investments reduce regional disparities? – we consider two experiments. In section 3 we address the second question by an exogenous policy reform experiment. One country – one of the large countries or the small country – obtains lower transport costs to and from the other two countries, whereas the transport costs between these other two countries remain unaltered: we denote this setting a hub-configuration. In a hub configuration firms may want to relocate to the hub to benefit from the lower transport cost. Our first result is that we show that in such a configuration a large or advanced country becomes a hub but a small or backward country not necessarily. The reason is that working against the hub-effect there is a home-market effect: firms want to produce near the largest market. The hub-effect dominates the latter effect only if the difference in transport costs is substantial. This suggests that regional policies are ineffective if they only lead small, marginal differences in transport costs.

In a policy competition experiment, in section 4, we explicitly take the incentives to invest in infrastructure into account. Our second major result is that a hub-configuration is not an obvious outcome. With line infrastructure (think of roads and railways) we show that a hub-configuration is not an equilibrium outcome. Investment responses of other countries are likely to undo this configuration. Thus, a symmetric equilibrium with equal transport costs between countries of different size or prosperity is a stable one, even if countries face different natural conditions. This result justifies the assumption of identical transport costs between different countries that is common in the theories of economic geography and international trade (see for example Fujita et al. (1999) [10]).

Only in case of point infrastructure (a harbour or an airport) a hub position is an equilibrium outcome. Investment in the hub country tend to depress investment in the spoke countries. Finally, by taking the investment incentives and costs into account we can also address the first

[9] In our interpretation it is natural to think of changes in the 'iceberg' as caused by unilateral actions. With trade liberalization lowering import barriers for both countries clearly involves bilateral action.

[10] Chapters 6 and 15 explicitly use many countries and identical transport costs between them.

question whether co-ordination is necessary. We show that competition in infrastructure among countries delivers a sub-optimal outcome. Investment may be too little as well as too much investment in infrastructure, depending on the initial level of transport costs.

The relevance of the result that only with point infrastructure a hub configuration is sustainable can be illustrated by analysing the quality of infrastructure in European regions over time. From our theoretical exercise derive several predictions: (1) with competition in line infrastructure regions are not able to establish a hub position and, instead, tend to a common infrastructure quality (σ- and β-convergence); (2) only regions that have the advantage of point infrastructure may escape the tendency of convergence towards a common quality.

We use data from Di Palma (1990) on relative infrastructure quality[11] of European NUTS-2 regions for 1970 and 1985 to estimate a growth-initial level equation.[12] The data are in line with the predictions. Indeed, they point to σ- and β-convergence. To give an indication for σ-convergence we calculated the standard deviation of the log of the relative infrastructure quality: in 1970 this was 0.8 whereas the number dropped to 0.6 in 1985. The results in Table 1.1 give an indication for β-convergence. The basic regression in column I shows that regions that were initially relatively low in the infrastructure-quality distribution moved up.

Table 1.1 Regression results (dependent variable relative change in infrastructure quality)

	I	II	III
constant	1.42	1.49	1.51
	-6.53	-6.84	-7.06
log ($INFR_{1970}$)	-0.31	-0.33	-0.33
	(-6.52)	(-6.81)	(-7.05)
dummy point infrastructure		0.11	
		-2.57	
dummy harbour			0.19
			-4.91
dummy airport			0.02
			-0.43
R^2-adj.	0.52	0.53	0.55

White heteroscedasticity-consistent standard t-statistics below the parameter estimate

[11] The data we use is not a perfect indicator of infrastructure quality only, but it is sufficiently close to that for the purpose of illustrating our point. We do not intend to interpret our empirical work as more than an illustration. The infrastructure quality indicator is a synthetic indicator based on the aggregation of four categories: transport (roads, railway, ports, airports), communications (telephones, telex), energy (electro transmission lines, electric plants, oil pipeline, petrol refineries, gas pipelines and education (number of university students, number of students of high professional schools)

[12] We estimate $\hat{INFR}_{1985-1970} = c + \beta INFR_{1970}$, where a hat denotes a growth rate and INFR is infrastructure quality. We use 118 regions/observations.

The results in Table 1.1 also illustrates the distinct role for point infrastructure. In the regression in column II we add a dummy that is one for a region with important point infrastructure and zero otherwise (we selected the regions with the 15 largest harbours and the 15 largest airports).[13] Controlling for the presence of point infrastructure increases the rate of β-convergence (the coefficient for log ($INFR_{1970}$)) and shows that regions with important point infrastructure tend to converge to the upper part of the infrastructure-quality distribution. The final column separates out two types of point-infrastructure; harbours and airports. The regression shows that only regions with'natural' point infrastructure move toward a significantly different steady state.

The remainder of the paper is organised as follows. Section 2 presents the model. Section 3 discusses the effects of exogenous changes in the quality of infrastructure on welfare. The section also examines whether a hub configuration always induces firms to the hub country. Section 4 explores endogenous policy competition. Section 5 concludes.

[13] See Eurostat (2000).

2 The model

2.1 Overview of the model

The model describes a world with three countries, two goods, and one factor. Each country can produce two tradeable goods, X and Y. The first is a composite good of different varieties. The production of each variety is subject to increasing returns to scale, and the producers engage in monopolistic competition. By assuming an identical and constant elasticity of substitution between all different varieties – the simplest version of the model in Dixit and Stiglitz (1977) – and identical technologies, we obtain symmetry across varieties within a country. This we take into account from the start. In addition to a composite good X, each country produces a homogenous good Y. It is produced under constant returns to scale in a sector with perfect competition. The price of this good is normalised to unity.

In two respects differences among the three countries may arise. First, the countries may differ in their endowment of effective labour, L. This could reflect the size as well the quality of the labour force. One of countries (S) is small or backward, whereas the other two (L_1 and L_2) are equally large or advanced. Labour is inelastically supplied, and labour markets clear instantaneously. Second, transport costs for bilateral trade flows of differentiated products may differ. The homogenous good is also tradeable but without transport costs.[14] The analysis assumes incomplete specialisation with the result that factor price equalisation (FPE) prevails.

2.2 Consumers

The utility function of representative consumer in country j, with $j \in c = \{S, L_1, L_2\}$, is $U_j = \gamma \log(X_j) + (1-\gamma)\log(Y_j)$. The household budget constraint is $E_j = w_j L_j$, where E_j is total expenditure and w_j is the wage rate. The first step of a two-stage optimisation yields that expenditure on the two goods is a constant fraction of total expenditure, $P_{X_j} X_j = \gamma E_j \equiv E_{X_j}$ and $Y_j = (1-\gamma) E_j \equiv E_{Y_j}$, where P_{X_j} is the price of the composite X-good and the price of the Y-good is unity.

Given the expenditure on differentiated goods, consumers maximise in the second stage:

$$X_j = N_W^{\phi} \left[\frac{1}{N_W} \sum_i^c N_i x_i^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad , \quad \varepsilon > 1 \ , \ \phi \geq 1 \ , \tag{1}$$

[14] Davis (1998) argues that the usual and convenient assumption of zero transport costs is not harmless. For the home-market effect to prevail, trade costs for the homogenous good should be 'substantially' lower than for the composite good. This is what we assume throughout.

subject to $\sum_i^c N_i p_i x_i = E_{X_j}$. Lowercase *p* denotes the consumer price of a variety, lowercase *x* consumption of a variety, N_i the number of varieties from country *i* and N_W is total number of available varieties in the world economy, $N_W \equiv \sum_i^c N_i$. Clearly, symmetry across varieties from each country has already been imposed. Specification (2.1) distinguishes between the returns to variety φ and the elasticity of substitution ε, *cf.* Broer and Heijdra (2001). Optimisation gives country *j*'s demand for country *i*'s goods:

$$x_{ij} = \left(\frac{p_{ij}}{P_{X_j}} \right)^{-\varepsilon} X_j N_W^{\phi(\varepsilon-1)-\varepsilon} \quad . \tag{2}$$

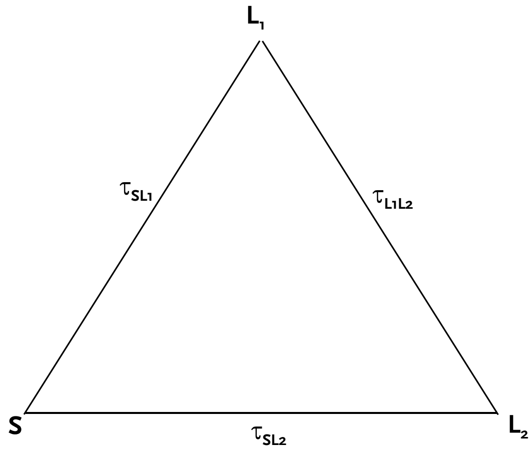
Demand for goods from country *i* by country *j* decreases with the price that *j*'s producers of varieties charge consumers in market *i* relative to the price index in that market. To obtain this price index, substitute **(2.1)** in **(1.1)**:

$$P_{X_j} = \left[\sum_i^c N_i p_{ij}^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}} N_W^{\frac{\varepsilon}{\varepsilon-1} - \phi} \quad . \tag{3}$$

2.3 Producers

A producer of a specific variety supplies three markets: the home market and two foreign markets. Delivering goods to the latter two markets is subject to iceberg transport costs: only a fraction of the shipments arrives at the destination. So, produced and consumed volumes differ. The figure 2.1 below provides an overview.

Figure 2.1 International transport costs between the three countries



The production function of a firm in country i for consumer goods in market j is $x_{ij} = \tau_{ij} L_{ij}$, where τ_{ij} is the share of goods that is produced in i and arrives in j: $\tau_{ii} = 1$ and $0 < \tau_{ij} < 1 \ \forall \ i \neq j$. Hence, a higher τ indicates lower transport costs and better infrastructure.

Facing the downward-sloping demand curve (2.2), firms set the price such that it is a constant mark-up over unit costs:

$$p_{ij} = \frac{\varepsilon}{\varepsilon - 1} \frac{w_i}{\tau_{ij}} . \tag{4}$$

Firms incur a fixed cost B in terms of labour. Profits of a representative firm in country i are equal to sales revenues in the three markets minus the variable and fixed labour costs.:

$$\Pi_i = \sum_j^c p_{ij} x_{ij} - w_i \left(\sum_j^c L_{ij} + B \right) . \tag{5}$$

After some manipulation we obtain the following expression for the maximised zero-profit condition (substitute the three production functions, the demand equations, prices equations (2.3) and (2.4) in (2.5) and set the latter equal to zero):

$$\sum_j^c \tau_{ij}^{\varepsilon - 1} X_j P_{X_j}^{\varepsilon} - w_i F = 0 . \tag{6}$$

F is a combination of constants and the number of varieties in the world.[15]

To economise on notation we introduce the variable $Z_j = X_j P_{X_j}^{\varepsilon} = E_{X_j} P_{X_j}^{\varepsilon - 1}$. We label this variable ‘effective market size’. It is large, either if local expenditure E_{X_j} is high and/or if the local price index P_{X_j} is high. Equation (2.2) shows that demand for a variety increases with the local price index. The price index will turn out to be high when the number of local competitors is low or, in other words, when local competition is weak.

A country produces the homogenous Y-good as long as the price of this good p_Y does not fall below the wage in that country. Since the Y-good is the numeraire and the analysis assumes incomplete specialisation, the wage rate in each country is one: $w_i = p_Y = 1 \ \ \forall \ i$.

The consequences is that expenditure on the X-good and Y-good are a function of parameters and exogenous variables only, $E_{X_i} = \gamma L_i$ and $E_{Y_i} = (1 - \gamma) L_i$.

[15] $F = N_W^{-\phi(\varepsilon - 1) + \varepsilon} B \varepsilon^{\varepsilon} (\varepsilon - 1)^{1 - \varepsilon}$. Later we will show that N_W can be considered as a parameter as long as an incomplete specialisation holds.

2.4 Labour market

Labour markets clear instantaneously and the resource constraints are always obeyed:

$$L_i = L_{Y_i} + N_i\left(\sum_j^c L_{ij} + B \right) , \tag{7}$$

where the term between parenthesis is the labour demand of a representative firm in the *X*-sector.

2.5 Equilibrium

To characterise the equilibrium attention is here confined to a configuration in which the dimensions of the model remain limited. More specifically, the small or backward country has equal transport costs from and to its two neighbours, $\tau_{SL_1} = \tau_{SL_2} = \tau_{SL}$.[16] The transport costs between the large or advanced countries are $\tau_{L_1L_2} = \tau_{LL}$. These two countries are similar in every respect. This configuration is simple but sufficient to allow us to consider the effect of better infrastructure and lower transport costs on the small or backward country.

The small or backward country is assumed to have or attain a position as a hub (the second inequality), but transit of goods is ruled out (the first inequality): $\tau_{SL}^2 < \tau_{LL} \le \tau_{SL}$. To save on notation we introduce a slightly different measure for transport costs $t_{ij} \equiv \tau_{ij}^{\varepsilon - 1}$. This does not affect the inequalities: $t_{SL}^2 < t_{LL} \le t_{SL}$.

The zero-profit conditions for the hub country and for (one of) the (two) spoke countries become (cf. equation 2.6):

$$Z_S + 2t_{SL}Z_L = F, \tag{8}$$

$$t_{SL}Z_S + (1 + t_{LL})Z_L = F. \tag{9}$$

Profits dictate location choices. Each firm has a higher share on the domestic market than on foreign markets. A country becomes therefore a more attractive location when its effective market size increases (Z_S in equation 2.8). It also becomes more attractive when access to foreign markets improves (t_{SL} in that same equation), leading to a higher share in those

[16] In section 3.1 we will show that improving two connections yields more than twice the benefits of improving just one connections. Hence, symmetry turns out to be an optimal outcome from the perspective of the hub country.

markets. In equilibrium firms should not have an incentive to relocate. Since the hub offers better access to foreign markets than the two spokes, the effective market size in the hub country is in equilibrium smaller than in the other two countries. More technically, the ratio Z_S/Z_L decreases when t_{SL} increases. This ratio also decreases when t_{LL} decreases, i.e when the transport costs between the two spokes become higher. This deteriorates access of firms in one of the L countries to the other L country. Thus to maintain at zero profit, the effective market size in L countries should increase or the effective market size in the hub country S should decrease. As long as $1 + t_{LL} - 2t_{SL} > 0$, not all firms locate in the hub country. Finally, without transport cost differences the ratio Z_S/Z_L is one and the effective market size is the same in each country.

Effective market size combines two factors: local expenditure and the local price index, $Z_j = E_{X_j} P_{X_j}^{\varepsilon-1}$. Labour income and thus expenditure are *de facto* exogenous ($w_i = p_Y = 1 \quad \forall\ i$ and labour supply is exogenous), so that the effective market size determines the price index of the X-good.

Without transport cost differences and thus with equal effective market sizes, the small or backward country has a higher price index than the large or advanced countries. The reason is that, for firms to be willing to produce in the small or backward country, lower local expenditure is to be compensated for by a lower number of local competitors and thus a higher market share in the local market. The consequence is that real per capita income in terms of the X-good is lower in the small country than in the other two countries.

When transport cost differences arise and effective market sizes change, only the price indices for the X-good change. When the small or backward country attains the position as a hub, t_{SL} falls below t_{LL}, its effective market size decreases and the price index decreases as well. Real per capita income in terms of the X-good thus rises.

The zero-profit conditions determine indirectly, through the price indices for the X-good, the number of varieties that each country produces. Given the price indices the number of firms in each country follows from the definition of these indices (2.3):[17]

$$P_{X_S}^{1-\varepsilon} = G\left(N_S + 2\, t_{SL} N_L\right) , \tag{10}$$

$$P_{X_L}^{1-\varepsilon} = G\left(t_{SL} N_S + (1+t_{LL})\, N_L\right) , \tag{11}$$

[17] Use (4.1) and $w = 1$ to solve for the prices of varieties from different countries.

where

$$G = \frac{\varepsilon}{1 - \varepsilon} N_W^{(1-\phi)(\varepsilon-1)} . \tag{12}$$

These two equations together determine N_S and N_L. In fact, from (2.11) and (2.12) follows an explicit expression for the total number of varieties in the world economy N_W, the sum of varieties in the small country and the two large countries:

$$N_W = \frac{\gamma(L_S+2L_L)}{\varepsilon B} . \tag{13}$$

The total number of available varieties increases with the world supply of labour L_S+2L_L, the expenditure share of the composite good γ and decreases with the elasticity of substitution ε and the fixed cost in terms of labour B. More important is that does not depend on transport costs or on the pattern of specialisation for the X-good. A intuitive way to understand this starts with the observation that as a result of Cobb-Douglas preferences a constant fraction of the world labour supply is devoted to the production of Y-goods and, hence, to the production of X-goods. Furthermore, from the zero-profit condition follows the equilibrium level of employment per firm in the X-sector, εB.[18] This zero-profit level of employment is the same in each country and independent of trade costs (due to constant mark-up pricing and iceberg transport costs). Thus, from total employment in the X-sector and the employment per firm then follows the total number of varieties. Since N_W is insensitive to changes in transport costs, it makes G and F constants in the subsequent analysis. Besides, the expression (2.13) may replaces one of two equations for price indices, (2.10) or (2.11).

Figure 2.2 provides a schematic overview of the model and its equilibrium for given levels of bilateral transport costs. The upper-right quadrant shows the zero-profit conditions for the hub and one of the spokes (equations 2.8 and 2.9). The curves both slope downward, saying that; if the effective size of the markets that firms serve abroad increases this allows for a smaller domestic market to maintain at zero profit.[19] The intersection of the two lines determines the effective market size in each country and, in the lower-right quadrant, the consumer price index

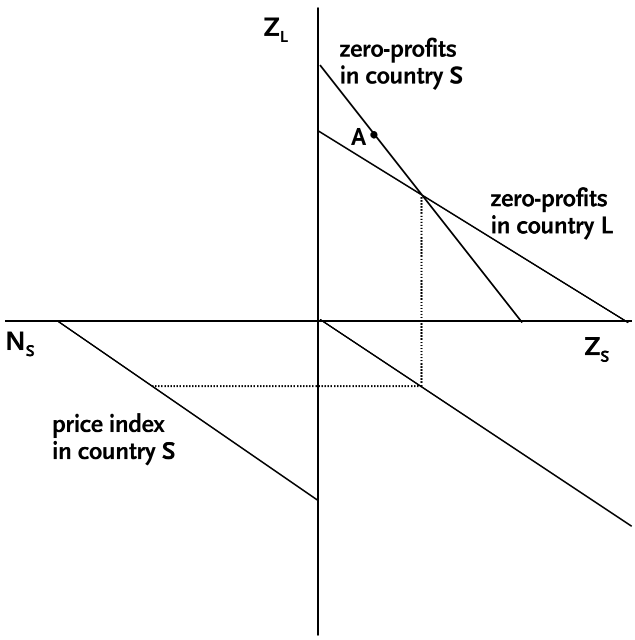
[18] To see this, substitute the production function and (4.1) in (5.1) to find zero-profit variable labour cost as $\sum L_{ij} = (\varepsilon - 1)B$ and note that total employment is B plus the variable labour cost.

[19] The relative steepness of the zero-profit curve for the small country is explained by the fact the profits (for both the small and the large country) are relatively sensitive to changes in the effective size of the home market.

in the hub country. The lower-left quadrant show that, given the total number of varieties in world economy, the number of varieties from this country follows (equations 2.10 and 2.12).

When the transport costs between the two spokes rise (τ_{LL} decreases) the zero-profit line for country *L* shift upwards. A larger effective market size in country *L* must compensate the deteriorated access to other markets. Point A represents the new equilibrium. The position of country *S* as a hub becomes stronger. It will see the price index fall and produce a larger number of varieties.

Figure 2.2 Overview of the model



The next section discusses the effect of symmetrically lower transport cost from and to the hub country (higher t_{SL}). Special attention is given to the consequences for the number of firms and economic welfare in each country.

3 A hub configuration: strategic and welfare effects

3.1 The strategic effect of better infrastructure

The term ‘strategic’ has different connotations. One is that an infrastructure project has strategic effects once it attracts foreign firms and investment. This seems to be a central idea in the hub strategy. The hub is a location where firms prefer to invest and to produce. A clustering of activities may arise from which the host country is assumed to benefit. We follow this idea, and determine the effect of symmetrically lower transport costs from and to the small country, $t_{SL} \geq t_{LL}$ ($\equiv$ a hub configuration), on the number of firms in the small country.

The analysis in this section assumes exogenous changes in transport costs. This allows us disregard, for the time being, the investment cost in infrastructure and to focus on the gross benefits of lower transport costs. In the next section investment costs are explicitly introduced and the incentive for each country to invest in infrastructure follows from cost-benefit considerations.

Since the exogenously lower transport cost does not increase the number of firms in the world economy, the hub lures away firms from the two spokes. In this sense the countries are involved in a zero-sum game.

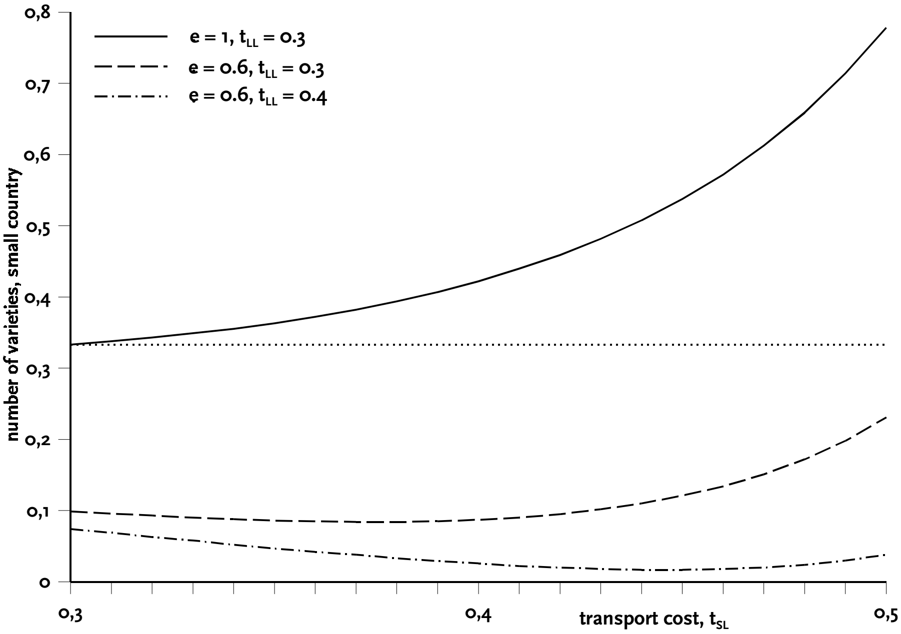
To determine the strategic effect, an explicit expression for the small country’s share in the total number of varieties is helpful. Solving the model yields the following expression (see the appendix for the derivation):

$$n_S = \frac{N_S}{N_W} = \frac{e}{2+e} + \frac{2t_{SL}}{2+e}\left(\frac{e}{1+t_{LL}-2t_{SL}} - \frac{1}{1-t_{SL}}\right). \qquad (1)$$

where e is short-hand notation for E_{XS}/E_{XL}, which is identical to the relative size of the small or backward country to one of the other countries in terms of labour L_S/L_L. According to this expression the share n_S is independent of the total number of varieties in the world N_W.

A closer look at this expression provides useful insights into the relation between the relative number of firms n_S on the one hand and the relative size e and transports costs t_{SL} on the other hand. Let us start simple. If countries are equal in size, e=1, and all transport costs are identical, firms are evenly dispersed across the three countries: $n_S = 1/3$. Furthermore, it is not difficult to show that size always has a positive effect on the number of firms, $\partial n_S / \partial e > 0$. In fact, the number of firms varies disproportionally with size: if the difference in transport costs is negligible, $t_{SL} = t_{LL}$, then share in the total number of firms n_S is lower than the share in the world labour supply, i.e. lower than $e/e{+}2$.[20] This is the home-market effect that is familiar in recent theories of international trade and economic geography (see for example Krugman, 1980). In the case of identical transport costs $t_{SL} = t_{LL} = t$, it is simple to show that the home-market effect becomes stronger the lower transport costs are, $\partial^2 n_S / \partial e \partial t > 0$. This is a finding that is also underlined in Krugman (1993).

Figure 3.1 Strategic effect for a small country



Interfering with the home market effect is the hub effect. Firms take the hub into consideration as a location for production since the transport costs to other markets than the home market are relatively low. In Figure 3.2 the upper curve illustrates the hub effect. In this figure the (relative) number of firms n_S is plotted against the transport cost from and to the hub country t_{SL}, leaving the transport costs between the two spoke countries t_{LL} unaltered. The upper curve is drawn under the assumption that $t_{LL} = 0.3$, so that t_{SL} is equal to or higher than t_{LL}, and that the countries are equal in size, $e = 1$. In the case of equal sizes the home market effect does not play a role and only the hub effect is present. Clearly, the lower the transport cost from and to the hub are, the higher the number of firms will be.

For a small or backward country the hub effect and the home market effect work against each other. The dotted curve in the middle illustrates this. This curve is drawn under the assumption that again $t_{LL} = 0.3$ but that $e = 0.6$. In this particular configuration lower transport cost make firms initially leave rather than enter the hub country. The reason is that the home market effect dominates, and becomes stronger the lower the transport costs are. For firms it

[20] Use $e = L_S/L_L$ to see that $e/e{+}2$ is the share of the small country in the population: $L_S/(2L_L + L_S)$.

becomes easier to supply to the small or backward country from abroad. The disadvantage of producing in a large or advanced country thus becomes less, whereas the advantage of producing in this country – to be close to a large market – remains in tact. However, further lowering of transport costs induces firms to choose domicile in the small or backward country. If the difference in transport costs t_{SL}-t_{LL} becomes sufficiently large, the hub effect dominates the home market effect. Finally, the curve at the bottom for $e = 0.6$ and $t_{LL} = 0.4$ underlines that the small or backward country must offer an advantage in the form of substantially lower transport costs to expect a positive effect on the number of firms. Lower transport cost to and from the small or backward country when they are initially higher than the costs between the other two countries, will only make firms leave.

PROPOSITION 1

A sufficient condition for the small or backward country to attract firms and to expect a positive strategic effect is:[21]

$$\frac{t_{SL} - t_{LL}}{(1 - t_{SL})} > (1 - e)$$

This condition has a very simple interpretation: the difference in transport cost (t_{SL}-t_{LL}) – indicating the degree to which the small country is already a hub – should exceed the home market advantage of the large county. The latter is decreasing in the relative size of the small country. The difference in transport cost is 'normalised' by the level of transport cost from the small to the large economies (1-t_{SL}).

The analysis in this subsection has shown that a small or backward country cannot always expect a positive strategic effect. A hub configuration not necessarily convinces firms to stay in, let alone, to come to this country. This provides a clear warning for regional policies within a nation state or within the European Union. The (intermediate) objective of these policies is often to improve business conditions through investment in infrastructure and, in this way, to attract firms and jobs. This objective will not be met unless the backward region or country already has a substantial advantage in transporting goods.

Evaluation of regional policies, however, should not concentrate on the strategic effect of attracting firms alone. It is welfare and the change therein that eventually matters. This is an issue to which we turn to in the next subsection.

[21] This sufficiency inequality follows directly from inspection of equation (3.1). The necessary condition is straightforward to derive, but rather uninformative.

3.2 The welfare effects of a hub configuration

To evaluate a hub strategy, welfare is an appropriate measure. The indirect utility function is: $v_i = V(P_{X_i}, P_Y, E_i)$. The model in section 2 shows how changes in transport costs translate into changes in the price index for the composite *X*-good, directly and indirectly through changes in the number of local varieties. However, transport costs and changes therein do not affect the other two variables. The homogenous *Y*-good is the numeraire, and its price is set equal to one, $P_Y = 1$. Furthermore, in the case of incomplete specialisation the wage in each country corresponds to the price of the *Y*-good, $w_i = P_Y = 1 \; \forall \; i$. The consequence is that the changes in the price index P_{X_i} adequately reflect changes in welfare, apart from investment costs. It is more convenient to concentrate on a transformed price index $P_{Xi}^{1-\varepsilon}$ than on the indirect utility function v_i itself.

For now, the welfare effects only incorporate the benefits of exogenous changes in transport costs, and ignores investment costs. Costly improvements in infrastructure are dealt with in section 4.

Lower transport costs have two effects on welfare. The first is what we label the import price effect. Better infrastructure results in lower transport costs: less of the 'iceberg' melts away in transport. Hence, given the location of firms and import patterns, the effective price of imports falls. The fall in price leads to an increase in welfare *ceteris paribus*. The second is the strategic effect of attracting firms. Domestic varieties are cheaper than foreign ones, since international transport entails (extra) costs. Shifting from foreign to domestic production thus leads to a fall in the consumer price index of the X-good, and raises welfare *ceteris paribus*.

A hub country will always benefit from symmetrically lower transport costs if the strategic effect is positive. The previous subsection, however, showed that this effect is not always positive for the small or backward country. Are the benefits still positive when the import price effect and the strategic effect pull in a different direction? A similar question arises for the spoke countries when the hub country does attract firms.

To see which of the two effects dominate, we have to derive the effect of symmetrically lower transport costs from and to the hub country on the (transformed) price indices. Solving the two zero-profit conditions (2.8) en (2.9) and using the definition of effective market size gives explicit expressions for the (transformed) prices indices for the hub country and one the spoke countries:

$$P_{X_S}^{1-\varepsilon} = E_{X_S} Z_S^{-1} = \frac{1 + t_{LL} - 2t_{SL}^2}{1 + t_{LL} - 2t_{SL}} \frac{\gamma L_S}{F}, \tag{2}$$

and

$$P_{X_L}^{1-\varepsilon} = E_{X_L} Z_L^{-1} = \frac{1 + t_{LL} - 2t_{SL}^2}{1 - t_{SL}} \frac{\gamma L_L}{F} . \tag{3}$$

The expressions for the price indices make clear that the home market effect works at the disadvantage of the small or backward country. A smaller effective labour force leads to a higher consumer price index and lower real income (in terms of the X-good). Furthermore, partially differentiating the expressions to t_{SL} reveals the welfare effects of changes in symmetrically lower transport costs from and to the hub country.

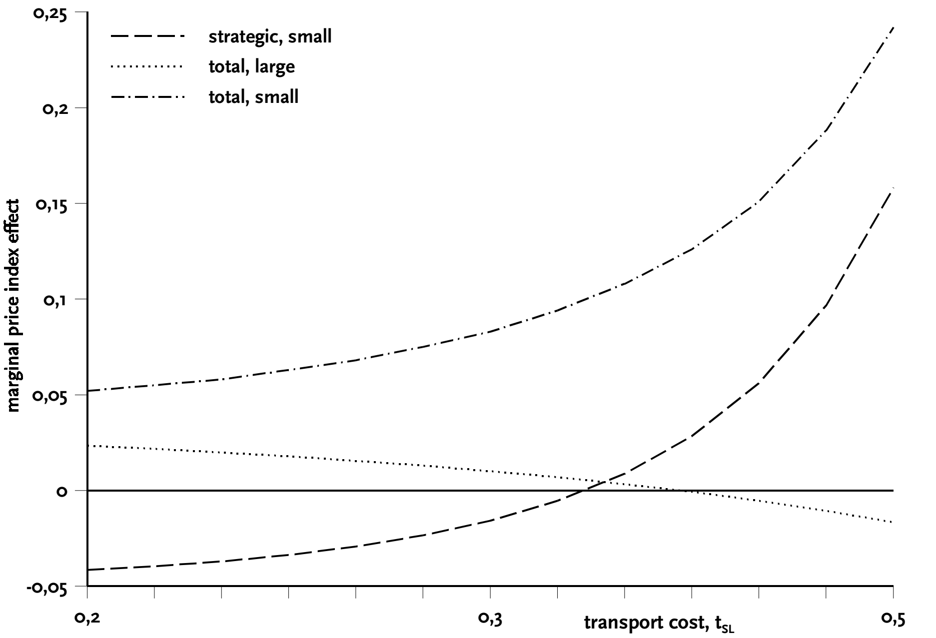
For the hub country, we can show that the import price effect always dominates the, possibly negative, strategic effect. This is summarised in the following proposition.

PROPOSITION 2

> *Lower transport costs to and from the small or backward country, that is t_{SL} increases while t_{LL} remains constant, leads to a lower price of the composite X-good in the small or backward country. Hence an exogenous improvement increases welfare in the small or backward country unambiguously.*

The appendix contains a proof of this result. It is rather straightforward. Figure 2 illustrates the strategic effect and total welfare effect. The horizontal axis plots the quality of infrastructure (recall: a higher t means lower transport costs). The vertical axis shows changes in the transformed price index. A positive number thus indicates that better infrastructure leads to a lower price for the X-good and to a higher real income. The solid curve represents the total welfare effect for the small country. It lies entirely above the horizontal axis, in line with the result above. The strategic effect – the dashed curve in Figure 2 – is only positive if the small country is not too small or if the small country has a strong position as a hub (t_{LL} = 0.3).

Figure 3.2 Welfare effects of a hub configuration



Augmenting the hub position has also two, possibly counteracting effects on the spoke countries. First, they benefit from cheaper imports from the hub country, since less goods are wasted in the transport from the small country to the two large countries. This is also an import price effect. Second, the two countries see firms enter or leave, depending on the sign of the strategic effect. This is thus the counterpart of the strategic effect for the small country. Figure 3.2 shows that either effect may dominate. The two countries may benefit but may also loose from a hub position of the small or backward country. A closer look at the expression for P_{X_L}, equation (3.3), gives the following result:

PROPOSITION 3

Lower transport costs to and from the hub country, t_{SL} increases while t_{LL} remains constant, leads to a lower or to higher price of the composite X-good for the spoke countries. Around a symmetric equilibrium, in which transport cost between any pair countries is the same $t_{SL} = t_{LL} = t$, the spoke countries benefit from marginally higher t_{SL} if $t < ½$, and lose if $t > ½$.

Important is that the spoke countries may either gain or lose. The level of the transport costs are decisive. The strategic effect becomes stronger the lower the transport costs are (and the higher t is). This effect will (eventually) work against the spoke countries.

3.3 A sustainable hub? The benefit of undoing the hub configuration

In the hub configuration one of the countries is *relatively* well-connected to the other countries. An important question is whether the spoke countries are likely to respond with (more) infrastructure investment. In other words, may the hub position of one country stimulate the other countries to undo it?

To answer these questions we consider the gross benefits of marginally lower transport cost between the two spoke countries and marginally higher t_{LL}.[22] These benefits take the form of a lower price index for the composite good X or, equivalently, a higher transformed price index $P_{X_L}^{\varepsilon-1}$. More specifically, from the equation (3.3) for $P_{X_L}^{\varepsilon-1}$ follows,

$$\frac{\partial P_{XL}^{1-\varepsilon}}{\partial t_{LL}} = \frac{1}{1-t_{SL}} \frac{\gamma L_L}{F} > 0 . \tag{4}$$

This shows that the marginal gross benefits of improving the connection between the two spoke countries will rise if the hub position strengthens.

$$\frac{\partial^2 P_{XL}^{1-\varepsilon}}{\partial t_{LL} \partial t_{SL}} = \frac{1}{(1-t_{SL})^2} \frac{\gamma L_L}{F} > 0 . \tag{5}$$

PROPOSITION 4

Strengthening the hub position of one country, raising t_{SL}, raises the gross benefits of marginally lower transport costs between the two other countries, i.e the gross benefits of raising t_{LL}. This suggests that a hub position is not sustainable since it is likely to be undermined by investment in infrastructure elsewhere.

PROOF This result immediately follows from equation (3.5). A stronger hub position in one country implies for other two countries a larger strategic effect that is associated with an improved connection between them. This raises the incentive for the spoke countries to invest. More generally, if one connection improves (exogenously), the incentive for improving the remaining connection rises. The analysis in section 4 will demonstrate this formally. This section will focus on countries' endogenous investment decisions, based on cost-benefit considerations. Before that, we discuss how effects of lower transport costs change when the

[22] We abstain from a discussion of the coordination problem between the two large countries. The problem arises since each country may take the position of a free rider and may wait for the other country to improve the connection between them.

hub country stops producing the Y-good and completely specialises in the production of the X-good.

3.4 Complete specialisation in the small country

The small country may specialise completely in the production of the X good. This implies that the production of the Y good ceases to be profitable and that FPE no longer holds. A full characterisation of the equilibrium is rather tedious. However, it is simple to explain the effects of a hub configuration in the case of complete specialisation. Four effects of a hub configuration are distinguished.

First, under complete specialisation the hub configuration does not have strategic effects in the sense that it attracts firms. Given the optimal firm size in terms of employment, determined in equilibrium by the fixed costs in terms of employment B and the elasticity of substitution ε, the number of firms in the small country follows directly from the size of the effective labour force L_S. The number of firms is thus equal to the ratio of the labour force L_S and optimal employment at firm level (compare equation 2.13).

Second, the hub configuration still makes the small country a relatively more attractive location, as a consequence the wage rate is bid up. The loss of a higher wage rate must offset the gain of relatively low(er) transport costs, to just fulfill the zero-profit condition. One might say that the strategic effect has taken a different form: not the number of firms but the wage rate increases. This increases income but also the prices of goods produced in the small country. The analogous increase of prices and income does not affect welfare. However, import prices are unaffected (P_Y) (or even fall). The increase in the real wage rate implies an increase in welfare.

Third, the hub configuration has an import-price effect. Less resources are wasted during transport, the import prices fall effectively and welfare increases.

Fourth, the total number of firms in the world in no longer independent of the level of transport costs if one or more countries specialise. The intuition is most clearly expressed by reiterating why the world number of firms was 'predetermined' in the first place: with incomplete specialisation and Cobb-Douglas preferences, a given part of income ($(1 - \gamma) L_i w_i$) determines the demand for Y goods. As long as wages are unity, a similar part of the world labour supply is employed in the production of Y-goods. The remaining labour force produces X-goods. The supply of labour to the X-sector determines, given the optimal employment per firm, the number of firms and varieties. In case of complete specialisation, wage income in the specialised country rises through lower transport costs. With the price of the Y-good P_Y unaltered, the demand for Y goods increases, leaving incompletely specialised countries with less labour for the X sector. Hence, the number of varieties in the world becomes lower. This effect of the hub configuration tends to reduce welfare if $\phi>1$, that is, if a love for variety is present.

Since the first effect can be ignored and the second and the third effect are positive, the hub configuration will certainly generates positive gross benefits if $\phi=1$ and the fourth effect is neither negative nor positive. However, if ϕ is larger than one, the fourth effect becomes negative. Conceivably, ϕ may become sufficiently large to make the hub configuration unrewarding, even for the small country.

4 Policy competition in infrastructure

For firms a hub is an attractive location, since they can exploit economies in production and at the same time serve distant markets at relatively low (transport) cost. For a country being a hub is attractive as well. Agglomeration of producers and consumers brings the benefit of lower transport costs. A country could thus want to obtain the position of a hub through investment in infrastructure. The danger for that country, however, is that other countries would react by initiating investment projects, that undo the hub position. In section 3 we have already discussed that the incentive to improve the infrastructure for spoke countries rises. Thus, the danger is real. This also brings into question the efficacy of (European) regional policies.

To study in subsection 4.1 under what circumstances a hub position is sustainable and regional policies are effective, we consider endogenous policy actions. More specifically, each country consider costs and benefits to decide upon investment plans, where costs and benefits depend on investment plans in other countries

The concern with policy competition is that countries are played off against each other. In their aim to attract firms a country could overreact and invest too much in infrastructure. To address this concern, we consider in subsection 4.2 not only policy competition but also co-ordination of investment efforts.

4.1 Competing for firms

In the Dixit-Stiglitz type of model infrastructure investment has at least two important effects. The direct effect of investment is to lower the price of imported goods, and the indirect, strategic effect is to change the location of firms. In this section attention is confined to these two effects and their implications for the country's incentives to invest. We ignore other considerations that could arise from the specific character of investment projects. More specifically, we make two important simplifying assumptions. First, the quality of infrastructure between country *i* and *j* is an additive function of investment by these two countries, $t_{ij} = \bar{\tau}_{ij} + \tau^i_{ij} + \tau^j_{ij}$, where τ^i_{ij} is investment of country *i* in infrastructure between *i* and *j* and $\bar{\tau}_{ij}$ represents the quality of infrastructure in the starting situation (assumption A1). In other words, investments of different countries are perfect substitutes.[23] The consequences of this assumption are briefly discussed later. Second, investing in infrastructure takes up a fraction of the labour force: $1 - e^{-C(\tau^i_{ij}, \tau^i_{ik})}$,

[23] When complementarities in both countries' investments would exist, asymmetric equilibria of the following nature could be constructed. If the one country expects that the other two countries invest heavily in their mutual connection, the country will have little incentive to invest in its connections as the other two countries will not invest much in these (rightly so, because the country does not invest much). This assumption rules out such an equilibrium.

where $\partial C / \partial \tau^{i}_{i.} > 0$, $\partial^2 C / \partial \tau^{i\,2}_{i.} \geq 0$ (assumption A2). Thus to achieve a same level of quality is cheaper for a small or backward country than it is for a large or advanced country. This is not unreasonable if one realises that a small country has less distance to cover to the border than a large country or that a backward country may need less capacity than an advanced country. The assumption is perhaps inadequate when one considers specific investment projects. For example, it rules out economies or diseconomies of scale. Most important is that this assumption fits with the aim to the focus on the different, direct and indirect benefits of infrastructure investment for different countries, and not on the costs.[24]

Each country weighs the costs and benefits of investing in the connection with its two neighbours. Obviously, investing entails a cost (in terms of labour). However, incurring the investment costs will affect the location and the number of firms. Higher investment costs imply lower spending and less profits. Given the number of firms and varieties, this induces local firms to relocate and raises the local consumer price index for the X-good (see the zero-profit conditions in section 2). Each country incorporates this effect of investment costs on the price index P_X but is assumed to ignore the effect on the total number of available varieties in the world economy. A country considers itself to have a negligible effect on the world economy.

The direct benefits of infrastructure investment are lower international transport costs and, thus, lower prices of imported goods. However, a better infrastructure quality will also affect location of firms, which through a lower (higher) price index for the X-good brings indirect benefits (costs).

Country *i* balances marginal costs and benefits to derive the optimal level of investment in infrastructure between *i* and *j* (a formal representation of the maximisation problem is given in the appendix):

$$\left(1+\frac{\gamma}{\varepsilon-1}\right)\frac{\partial C(t^{i}_{ij},t^{i}_{ik})}{\partial t^{i}_{ij}} = \frac{\gamma}{\varepsilon-1}\left(\frac{2(-t_{ij}+t_{ik}t_{jk})}{\Delta}+\frac{1}{1-t_{ij}-t_{ik}+t_{jk}}\right), \tag{1}$$

where

$$\Delta = 1-t^2_{ij}-t^2_{ik}-t^2_{jk}-2\,t_{ij}t_{ik}t_{jk}.$$

Since the investment costs affect the local price index, the term $\frac{\gamma}{\varepsilon-1}$ appears on both sides of the equation. The first-order condition has two noticeable features. First, exogenous differences in the quality of infrastructure only affect the marginal benefits and not the marginal costs. Second, both marginal costs and benefits do not depend on the effective labour force. This

[24] Investment costs have effects on local demand (see, Martin and Rogers, 1995) and could for this reason, if non-scaled , imply asymmetric equilibria.

feature derives from the assumption about the cost function (assumption A2) as well as from the zero-profit conditions. This feature allows an equilibrium that is completely symmetric in investment efforts and the resulting infrastructure quality, as will be shown later.

Comparing the first-order conditions for the same country and for same connection proves to be instructive,

$$\left(1+\frac{\gamma}{\varepsilon-1}\right)\left[\frac{\partial C}{\partial t_{ij}^{i}}-\frac{\partial C}{\partial t_{ik}^{i}}\right]=\frac{\gamma}{\varepsilon-1}\frac{2\left(-t_{ij}+t_{ik}\right)t_{jk}}{\Delta} \tag{2}$$

$$\left(1+\frac{\gamma}{\varepsilon-1}\right)\left[\frac{\partial C}{\partial t_{ij}^{i}}-\frac{\partial C}{\partial t_{ij}^{j}}\right]=\frac{\gamma}{\varepsilon-1}\frac{2\left(t_{ik}-t_{jk}\right)}{\left(1-t_{ij}-t_{ik}+t_{jk}\right)\left(1-t_{ij}-t_{jk}+t_{ik}\right)} \tag{3}$$

Equation (4.2) shows how a country allocates its investment efforts across the transport connections. It confirms that country tries to pursue a hub strategy.

LEMMA 1

Given investment in other countries country i will invest such that the international transport costs with other two countries is the same, $t_{ij}=t_{ik}$.

The intuition for the result is that symmetric investment efforts gives country *i* a hub position and fully exploit the opportunities to attract firms.

Furthermore, equation (4.2) and (4.3) show a complete symmetry in investment efforts (τ) and infrastructure quality (t) is an equilibrium outcome. If infrastructure quality is everywhere the same, equation (4.2) shows that each country chooses the same level of investment for the two different connections and equation (4.3) shows that two different countries choose the same level of investment for a similar connection.[25] Without exogenous differences in the quality, a completely symmetric equilibrium results.

PROPOSITION 5

Without exogenous differences in the quality of infrastructure, $\bar{\tau}_{ij}=\bar{\tau},\ \forall i,j$, *and under assumptions A1 and A2 the completely symmetric outcome,* $t_{ij}=t,\ \forall i,j$, *is an equilibrium.*

[25] This assumes a regular cost function such that, for example, $\partial C/\partial\tau_{ij}^{i} \geq \partial C/\partial\tau_{ik}^{i}$ when $\tau_{ij}^{i} > \tau_{ik}^{i}$.

If the cost function is sufficiently convex in its arguments, the completely symmetric outcome is a locally stable equilibrium. However, the equilibrium is not necessarily globally stable. The reason is the marginal benefits of investment τ^i_{ij} may rise when transport costs fall and t_{ij} rises. Increasing marginal benefits are even more likely when a country pursues a hub strategy.

In the next subsection a hub strategy is further explored. Important is the reaction of other countries. This reaction could very well undermine the potential of a hub strategy. The (investment) costs of the strategy may then not outweigh the benefits. Besides, exploring the hub strategy allows us to consider the efficacy of (European) regional policies. The aim of these policies is to improve the relative position of a backward region. To achieve this, the costs may exceed benefits.

A hub strategy: endogenous policy reactions

To explore the consequences of a hub strategy we present two opposite cases. In the first case, the marginal costs of investing is the same for each line of in the transport network: $\partial C / \tau^i_{ij} = \partial C / \partial \tau^i_{ik}$. Investment efforts are thus perfect substitutes. In the second case, investment efforts are perfect complements. More specifically, investment efforts are by assumption equal: $\tau^i_{ij} = \tau^i_{ik}$. With these cases the distinction between line and point infrastructure is introduced. Up to now we have assumed that countries can choose which connection to improve. This is adequate when considering investments in roads or rail tracks. Investments in harbors or airports require a different view. This type of investment improves a point in the transport network and thus the lines that go through this point. In other words, if country *i* invests in point infrastructure, the connections with both neighbours equally improve.

The small or backward country *S* is assumed to pursue a hub strategy, starting from a completely symmetric equilibrium. The other countries react in line with the first-order conditions (4.1). Table 4.1 illustrates the consequences of a hub strategy by presenting simulation results. The upper part of the table contains the results for the case of line infrastructure with perfect substitutable investment efforts, whereas the lower part contains the results for the case of point infrastructure. In each case country *S* raise τ^S_{SL} from 0.1 to 0.2.

In the first case the other two countries react by investing more in the connection between them than in their connection with the hub country *S*, $\tau^L_{LL} > \tau^L_{SL}$. However, for each connection the level of investment rises. This reflects that the general fall in transport costs leads to higher marginal benefits. The reaction of the two countries is such that in fact the country *S* does not obtain a hub position, $t_{SL} = t_{LL}$.

The table also shows a subsidy. It is the potential compensation that country *S* should receive to make it indifferent between the symmetric outcome and the hub strategy. A positive subsidy implies that the hub strategy does not pay off in terms of welfare. It is also an indication for the financial contribution to investment projects of a supranational organisation like the European

Union, that would improve the relative position of a backward country or region. Clearly, in the case of line infrastructure and perfect substitution of investment efforts, the subsidy is huge. The hub strategy does not result in a hub position and strategic benefits do not emerge. The subsidy rate is less 100 percent, since the country S benefits from the general decline in transport costs.

Table 4.1 The consequences of a hub strategy

	symmetry	hub strategy			
line infrastructure					
τ^{S}_{SL}	0.1	0.125	0.150	0.175	0.20
τ^{L}_{LL}	0.1	0.114	0.129	0.147	0.17
τ^{L}_{SL}	0.1	0.103	0.109	0.119	0.14
t_{SL}	0.7	0.728	0.759	0.794	0.84
t_{LL}	0.7	0.728	0.759	0.794	0.84
subsidy (% of costs)	-	88.2	89.2	90.1	90.6
point infrastructure					
τ^{S}_{SL}	0.1	0.125	0.150	0.175	0.2
τ^{L}_{LL}	0.1	0.077	0.526	0.025	0.0
τ^{L}_{SL}	0.1	0.077	0.526	0.025	0.0
t_{SL}	0.7	0.702	0.703	0.700	0.7
t_{LL}	0.7	0.655	0.605	0.549	0.5
subsidy (% of costs)	-	45.0	42.7	39.2	35.9

To simulate the policy game a specific cost function has been used, $C_i = (1 - \tau^{i}_{ij} - \tau^{i}_{ik})^{-\delta}$ with δ=2.5. The subsidy is the potential compensation for the difference between total costs and benefits as percentage of the total costs.

In the case of point infrastructure the investment efforts in the spoke countries are by assumption the same, $\tau^{L}_{LL} = \tau^{L}_{SL}$. In response to the hub strategy their investment efforts decline. The intuition is that a spoke country cannot undo the hub position of country *S*. At best, it can invest such that the other spoke country becomes a non-hub.[26] Therefore, a spoke country cannot expect a large strategic benefit. Their incentive to invest is lower the stronger the hub position of country *S* is. Therefore, the hub strategy is effective, $t_{SL} > t_{LL}$.

In the current case the subsidy is much lower than in the first case. The hub country is successful in attracting firms and sees therefore its price index fall. However, the required subsidy is still positive and significant.[27] The reason is that even though the hub country invests heavily, its connections hardly improve: t_{SL} remains close to its starting value of 0.7. So, the hub

[26] This points at a co-ordination failure among the spoke countries.

[27] The subsidy rate declines, which reflects increasing marginal benefits as the hub position becomes stronger.

country does not have the direct benefit of lower import prices but has only the indirect, strategic benefit.

The two cases learn that the sustainability of a hub position depends crucially on the possibilities of substitution among investment efforts. Put more loosely, when countries compete through investment in line infrastructure a hub position tends to be eradicated but when countries compete through investment in point infrastructure a hub position is sustainable. In both cases, however, the hub strategy does not necessarily pay off. In the case of line infrastructure policy reactions undermine the hub position whereas in the case of point infrastructure the hub position chokes off investment elsewhere, leading to higher import prices. Finally, the simulations suggest that a general income transfer is much more effective than a specific subsidy to infrastructure investment for raising real income in the backward country.

Hub position and natural advantage

A symmetric situation in which neither country takes the position of a hub and the transport costs between any pair of countries is the same, seems the only relevant equilibrium. This, however, assumes that exogenous differences in quality of infrastructure are absent. Clearly, this not always adequate. Countries face different, natural and geographic circumstances that will have immediate consequences for their efficiency to transport goods and persons. Most obvious examples are countries that are land-locked. Cross-country growth regressions reveal that these land-locked countries have performed worse than other countries.[28] Another example is the accessibility of ports. Rotterdam is a rather unique port, that can receive large ships much easier than competing ports like Hamburg in Germany or Antwerp in Belgium. Besides, the rivers make it possible to ship goods efficiently from the Rotterdam port to its hinterland.

To discuss the consequences of different natural conditions, we again distinguish between the two opposite cases: line infrastructure with perfect substitutable investment efforts and point infrastructure. Specifically, we study the effects of small changes in the exogenous quality $\bar{\tau}$ near the symmetric equilibrium.

The case of line infrastructure with $\partial C / \tau^i_{ij} = \partial C / \partial \tau^i_{ik}$ is relatively straightforward. Countries invest such that transport costs between any pair countries remain identical. This implies that exogenous differences in infrastructure quality are exactly offset by endogenous differences in investment efforts. Even if a country is a natural candidate for a hub position, it will not attain that position. This result is of course related to assumption A1, according to which investment efforts and the exogenous quality do not interact.

[28] See, for example, Gallup, Sachs and Mellinger (1999).

The case of point infrastructure with $\tau^i_{ij} = \tau^i_{ik}$ is somewhat more complicated. In this case the two first-order conditions for each country (see equation (4.1)) collapse into one, by summing the marginal costs and the marginal benefits. Let us denote the marginal benefits in the case of point infrastructure b^i. Assume that the small or backward country S gets a natural advantage, i.e. the exogenous quality of its connections $\tau_{SL1} = \tau_{SL2} = \tau_{SL}$ improves whereas the exogenous quality of the connection between the two large or advanced countries $\bar{\tau}_{LL}$ remains the same: $\bar{\tau}_{SL} > \bar{\tau}_{LL}$. The appendix shows that the marginal benefits for country S increase and the marginal benefits for a country L declines: $\partial b^S / \partial \bar{\tau}_{SL} > 0$ and $\partial b^L / \partial \bar{\tau}_{SL} < 0$. In response, investment in country S will rise and investment in the other countries will fall: a man-made advantage magnifies the natural advantage.

PROPOSITION 6

In the case of point infrastructure a natural advantage, $\bar{\tau}_{SL} > \bar{\tau}_{LL}$, leads to an asymmetric equilibrium, $t_{SL} > t_{LL}$. Investment in infrastructure magnifies the natural advantage: $t_{SL} - t_{LL} > \bar{\tau}_{SL} - \bar{\tau}_{LL}$.

For a proof, see the appendix. What is the intuition for this result? In the case of point infrastructure, a country cannot shift its investments between the two connections. A spoke country therefore cannot obtain symmetry and, as shown by Lemma 1, symmetry is preferable. Therefore, the incentive to invest is smaller for the spoke country if the hub country gets a (larger) marginal natural advantage. Thus the difference in t_{SL} and t_{LL} party arises from natural conditions and partly from man-made conditions.

4.2 Coordinating infrastructure investment

In the introduction we discussed one positive and one negative externality of infrastructure investments. First, a positive externality arises since governments ignore the benefits of better infrastructure for neighbouring countries. Second, a negative externality is that governments play a (zero-sum) game of luring firms away from neighbouring countries.[20] In this section we illustrate these issues by presenting a different policy game in which government co-ordinate their investment efforts in line infrastructure.[21]

Through coordination countries incorporate the direct and indirect effect of investment on the price indices. For a clear interpretation other considerations are left out. So, countries are still

[20] The term 'zero-sum' is not completely appropriate as the investment costs make it a game with a negative-sum: countries ignore that less resources are left to produce differentiated varieties. This is also a negative externality.

[21] The coordination of point-infrastructure investment is left for future research.

assumed to ignore the effect of investment costs on the total number of varieties and to disregard the distortion in the relative price (resulting from monopoly power in the X-good sector). Coordination follows from Nash-bargaining among the three countries in which each country is given an equal weight. The outcome of the bargaining process is a completely symmetric equilibrium. To evaluate the co-ordinated and the competitive equilibrium we compare for similar investment efforts the marginal benefits. This leads to the following proposition.

PROPOSITION 7

For similar investment efforts the marginal benefits are higher in the competitive equilibrium than in the coordinated equilibrium when $t > ½$ and lower than $t < ½$. Policy competition thus leads to overinvestment when transport costs are low and underinvestment when transport costs are high.

The proof is in the appendix. Proposition 7 is closely related to proposition 3. At high levels of transport costs the strategic indirect effect is weak, and the main benefits of lower transport costs are lower import prices. Strategic competition would then lead to less investment than coordination. However, the strategic effect becomes stronger the lower transport costs are. Eventually it is gives a too strong incentive to investment in infrastructure and leads to overinvestment.

5 Conclusions

The model distinguishes three neighbouring countries, one small or backward and two (similar) large or advanced countries. We consider an experiment in which one country obtains lower transport costs to and from the other two countries, whereas the transport costs between these other two countries remain unaltered: a hub-configuration. Firms want to relocate to benefit from the lower transport cost. We show that in such a configuration a large or advanced country becomes a hub but a small or backward country not necessarily. The reason is that the home-market effect works against the hub effect: firms want to produce near the largest market. The hub-effect dominates the home-market effect only if the difference in transport costs is substantial. This suggests that regional policies are ineffective if they only marginally affect differences in transport costs.

That one country obtains a hub position is not necessarily good for the other two countries. They may directly benefit from lower transport cost, through cheaper imports. However, they may indirectly lose through the relocation of firms. Domestic products disappear, and are replaced by foreign counterparts. Transport costs make the foreign products more expensive than domestic ones. Whether the other countries lose or not, the benefit of undoing the hub-configuration increases.

To account for reactions of the different countries we explicitly consider their incentive to invest in infrastructure. From this, an interesting difference between line and point infrastructure emerges. Suppose that countries compete by investing in line infrastructure. If one country obtains a hub position, the other two counties may respond by investing less in the connection with this country and more in the connection between the two countries. The endogenous reactions may effectively neutralise the hub position. In other words, identical transport costs between any pair of countries is a configuration that is often assumed in the literature and arises in a fairly standard model with endogenous investment decisions.

This changes if countries compete by investing in point infrastructure, which is similar to investing simultaneously in two lines. If then one country invests to obtain a hub position, the other two counties respond by investing less. The hub configuration is thus sustainable. The hub position can originate from a (slight) natural advantage, but is reinforced by a man-made advantage.

Competition among countries may deliver too little as well as too much investment in infrastructure. On the one hand countries have the strategic consideration that investing in infrastructure will lure firms from competing countries and towards the investing country. This would imply too much investment. On the other hand countries overlook that investing in infrastructure brings down the cost of international trade for the other countries. This would imply too little investment. The strategic interaction among countries becomes stronger the lower transport costs are. So, in a world with low transport costs and high firm mobility competition among countries is likely to results in too much investment in infrastructure.

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Appendix

Solving the general model

The model introduced in section 2 boils down to equation (2.5) that is repeated here:

$$\sum_{j}^{c} \tau_{ij}^{\varepsilon-1} X_j P_{X_j}^{\varepsilon} - w_i F = 0 \ . \tag{A.1}$$

We use variables $Z_j = X_j P_{X_j}^{\varepsilon} = E_{X_j} P_{X_j}^{\varepsilon-1}$ and $t_{ij} \equiv \tau_{ij}^{\varepsilon-1}$ to write the following system of equations:

$$\begin{bmatrix} 1 & t_{ij} & t_{ik} \\ t_{ij} & 1 & t_{jk} \\ t_{ik} & t_{jk} & 1 \end{bmatrix} \begin{bmatrix} Z_i \\ Z_j \\ Z_k \end{bmatrix} = \begin{bmatrix} w_i^{\varepsilon} F \\ w_j^{\varepsilon} F \\ w_k^{\varepsilon} F \end{bmatrix} \tag{A.2}$$

or in short-hand notation $Tz = f$. The determinant of matrix T is
$\Delta \equiv (1 - t_{jk})(1 + t_{jk}) - t_{ij}^2 - t_{ik}^2 + 2 t_{jk} t_{ij} t_{ik}$. We can solve for the effective market size as:

$$Z_i = P_{X_i}^{\varepsilon-1} E_i = \left(\frac{(1 - t_{jk})(1 + t_{jk} - t_{ij} - t_{ik})}{\Delta} \right) w_i^{\varepsilon} F \ . \tag{A.3}$$

Define for later reference: $\omega_i = (1 - t_{jk})(1 + t_{jk} - t_{ij} - t_{ik})$. Introducing the wage as numeraire (and factor price equalisation) in equation (A.2) gives the expressions that we use throughout this appendix. Imposing also symmetric transport costs between the small or backward and both large or advanced countries $t_{SL1} = t_{SL2} = t_{SL}$ in (A.3) gives equation (3.2) and (3.3) in the main text that we use to derive equation (3.1) and proposition 2.

Derivation of equation (3.1)

To derive equation (3.1) we use the expressions for the transformed price index (2.10)-(2.11) and (3.2)-(3.3). Multiply both sides of (2.10)-(2.11) with E_{X_S} and E_{X_L} respectively. This gives expressions for Z_S and Z_L:

$$Z_S = N_W G\left(n_S + 2 t_{SL} n_L\right) E_{XS} \ , \tag{A.4}$$

$$Z_L = N_W G\left(t_{SL} n_S + (1 + t_{LL}) n_L\right) E_{X_L} \ . \tag{A.5}$$

Rewrite (3.2)-(3.3) as expressions for Z_S and Z_L and equalise these to (A.4) and (A.5), respectively, to obtain two equations and divide these upon each other to get:

$$e\frac{\left(n_S t_{SL} + \tfrac{1}{2}(1 - n_S)(1 + t_{LL}\right)}{\left(n_S + t_{SL}(1 - n_S)\right)} = \frac{\left(1 + t_{LL} - 2t_{SL}\right)}{\left(1 - t_{SL}\right)} , \tag{A.6}$$

where we use that $n_L = \tfrac{1}{2}(1 - n_S)$. Solving (A.6) for n_S gives equation (3.1) in the main text. Finally, combining (A.4) with (3.2) and using (A.6) (or (3.1)) allows, after considerable manipulation, to solve for N_W as equation (2.13).

Proof of PROPOSITION 2

From equation (3.2) in the main text it is simple to derive that:

$$\frac{\partial P_{X_S}^{1-\varepsilon}}{\partial t_{SL}} = 2\left(\frac{(1 - 2t_{SL})(1 + t_{LL}) + 2t_{SL}^2}{(1 + t_{LL} - 2t_{SL}^2)^2}\right)\frac{\gamma L_S}{w^{\varepsilon} F} \tag{A.7}$$

If $t_{SL} < 0.5$ the right-hand side is always positive. For $t_{SL} > 0.5$, a sufficient condition for a positive welfare effect is:

$$(1 + t_{LL}) < \frac{2t_{SL}^2}{(2t_{SL} - 1)} \tag{A.8}$$

The right-hand side of this expression is decreasing in t_{SL} to 2, hence for any t_{LL} the condition holds.□

Setting up the policy game

The government of country *i* maximises:

$$u_i = \gamma \ln X_i + (1 - \gamma)\ln Y_i \tag{A.9}$$

subject to the following constraints: $P_{X_i}X_i = \gamma E_i$, $Y_i = (1 - \gamma)E_i$ and use $z_j = X_j P_{X_j}^{\varepsilon} = E_{X_j} P_{X_j}^{\varepsilon-1}$ to substitute *Z* for the price index of the *X*-good. Substituting the constraints in (A.9) gives for country *i*:

$$u_i = \left(1 + \frac{\gamma}{\varepsilon - 1}\right)\ln\left(wL_i e^{-C(\tau_{ij}^i, \tau_{ik}^i)}\right) - \left(\frac{\gamma}{\varepsilon - 1}\right)\ln Z_i + \Gamma \tag{A.10}$$

where Γ is a combination of parameters. The first-order condition for country *i*'s optimal investment in line *ij* is:

$$\left(1+\frac{\gamma}{\varepsilon-1}\right)\partial C/\partial\tau^{i}_{ij} = -\left(\frac{\gamma}{\varepsilon-1}\right)\frac{\partial Z_i/\partial\tau^{i}_{ij}}{Z_i(.)} \qquad \text{(A.11)}$$

which says that the marginal cost of infrastructure investment should equal the marginal benefit. The rhs of this expression has a minus sign as Z positively relates the price index which is negatively related to welfare. The higher γ the less important the marginal cost term. This is simply due to the fact that a larger expenditure share on *X*-goods implies that more goods are going to be transported over the same road. An increase in ε increases the cost term: the higher the demand elasticity, the less important the home market effect, the less important transport costs are. Taking logs of (A.3) and noting that $\partial t_{ij}/\partial\tau^{i}_{ij} = \partial t_{ik}/\partial\tau^{i}_{ik} = 1 \;\forall\; i$ we can write for $\frac{\partial Z_i/\partial\tau^{i}_{ij1}}{Z_i}$:

$$-\frac{1}{(1 + t_{jk} - t_{ij} - t_{ik})} + \frac{2t_{jk}t_{ik} - 2t_{ij}}{\Delta} \qquad \text{(A.12)}$$

where we use short-hand notation for Δ introduced before. For the second transport link the analogous expression is

$$-\frac{1}{(1 + t_{jk} - t_{ij} - t_{ik})} + \frac{2t_{jk}t_{ij} - 2t_{ik}}{\Delta} \qquad \text{(A.13)}$$

Though the expressions above look complicated the game is fairly simple as all four other first-order conditions for the other countries are analogous to these. Note that the expressions hold for any country *i*. This is easily seen by recalling the identical structure of the expressions for effective market sizes (*Z*) for all countries; (A.3).

Proof of LEMMA 1

LEMMA 1

> *Given investment in other countries country i will invest such that the international transport costs with other two countries is the same,* $t_{ij}=t_{ik}$.

Note the right-hand side from equation (4.2) is decreasing in $t_{ij}-t_{ik}$ and zero if $t_{ij}-t_{ik}=0$. The left-hand side of (4.2) non-decreasing in $t_{ij}-t_{ik}$. This assumes a regular cost function such that, for example, $\partial C/\partial\tau^{i}_{ij} \geq \partial C/\partial\tau^{i}_{ik}$ when $\tau^{i}_{ij} > \tau^{i}_{ik}$. Note moreover that the marginal investment cost are equal for both lines if the quality of both lines is equal. So only a hub strategy -- equally good transport links to other countries -- is an optimal investment strategy.□

Point infrastructure

The essence of point infrastructure is that there it is not possible to differentiate investments across different connections: hence $\tau^i_{ij} \equiv \tau^i_{ik} \equiv \tau^i$ and similar for the other two countries. We simplify the cost of infrastructure investment to $wL_i(1 - e^{-C(\tau^i)})$. So, the cost function $C(.)$ is specified as the cost of the investment in an infrastructure point that connects the country to the other countries. Again we assume a well-behaved cost function.

The natural quality of point infrastructure for the hub country is $\bar{\tau}_{SL1} \equiv \bar{\tau}_{SL2} \equiv \bar{\tau}_{SL}$.[22]

Proof of PROPOSITION 6

We assume that there is a natural advantage in the hub countries' infrastructure point.

$$\bar{\tau}_{SL} > \bar{\tau}_{LL} \tag{A.14}$$

Now we are fully equipped to derive the three countries' first-order conditions,

$$\left(1+\frac{\gamma}{\varepsilon-1}\right)\partial C/\partial\tau^i = -\left(\frac{\gamma}{\varepsilon-1}\right)\frac{\partial Z_i/\partial\tau^i}{Z_i(.)} \tag{A.15}$$

Investment of country i changes both connections: $\partial t_{ij}/\partial\tau^i = \partial t_{ik}/\partial\tau^i$ and that these partial derivatives are unity, we can write for $\frac{\partial Z_S/\partial\tau^S}{Z_S}$:

$$-\frac{2}{(1 + t_{LL} - 2t_{SL})} + \frac{4t_{SL}(1 - t_{LL})}{\Delta} \tag{A.16}$$

where we use that the two large countries are symmetric by assumption (hence: $\tau^{L1} = \tau^{L2}$ and that the hub country invests equally in both connections (also by assumption) and the natural advantage is in line with the assumption of pint infrastructure, hence:
$t_{SL1} = \left(\bar{\tau}_{SL} + \tau^S + \tau^{L1}\right) = t_{SL2} = \left(\bar{\tau}_{SL} + \tau^S + \tau^{L2}\right)$.
For the two large countries the gross marginal benefits are:

$$-\frac{2}{(1 - t_{LL})} + \frac{2(t_{SL} + t_{LL})(1 - t_{SL})}{\Delta} \tag{A.17}$$

Taking the difference between the first order condition for the hub and the spoke country gives:

[22] A somewhat more precise notation of the natural quality for a connection would be: $\bar{\tau}^S_{SL1} + \bar{\tau}^1_{SL1}$; that is the sum of the two countries' natural quality of their infrastructure points. The difference is not substantial, therefore we avoid introducing this additional notation in the main text.

$$\left(\frac{\varepsilon-1+\gamma}{\gamma}\right)\left(\frac{\partial C}{\partial t_{SL}^{S}}\frac{\partial t_{SL}^{S}}{\partial \tau^{S}} - \frac{\partial C}{\partial t_{SL}^{L1}}\frac{\partial t_{SL}^{L1}}{\partial \tau^{L1}}\right) = -\frac{\partial Z_S / \partial \tau^S}{Z_S} + \frac{\partial Z_{L1} / \partial \tau^{L1}}{Z_{L1}} \tag{A.18}$$

The right hand side of (A.18) can be written as (use the two expressions for the marginal benefits derived above (A.16) and (A.17)):

$$\frac{2(t_{LL} - t_{SL})}{(1 - t_{LL})(1 + t_{LL} - 2t_{SL})} - \frac{2(t_{LL} - t_{SL})(1 + t_{SL})}{\Delta} \tag{A.19}$$

It is simple to verify that *if* $t_{SL} > t_{LL}$ expression (A.18) is positive.[23] Then, for the equality to hold the left-hand side of (A.18) should be positive: country S invests more than country L ($\tau^S > \tau^L$). Recall that we assume: $\bar{\tau}_{SL} > \bar{\tau}_{LL}$. In that case $t_{SL} = \left(\bar{\tau}_{SL} + \tau^S + \tau^L\right) > t_{LL} = \left(\bar{\tau}_{LL} + 2\tau^L\right)$ which is consistent with our point of departure ('*if* $t_{SL} > t_{LL}$'). Now, verify that symmetry is not an equilibrium. For symmetry the spoke countries need to invest more than the hub country. In symmetry the right-hand side is of (A.18) is zero. Note, however, that the left-hand side of (A.18) is negative in that case. So, this is not an equilibrium. So with point infrastructure a natural advantage is not undone by endogenous policy responses.

If the initial situation is symmetry, we can evaluate how the investment incentives are affected by the hub country gaining a marginal natural advantage. Having shown that $t_{SL} > t_{LL}$ is the result of a marginal natural advantage, we can show how this affects the incentive to invest by returning to the f.o.c (4.1). How is the right-hand side of this expression affected by a marginal increase in $\bar{\tau}_{SL}$, that is a marginal increase in t_{SL}. For the hub country the marginal return to investments increases in t_{SL}. For the spoke country the marginal return to investments decreases in t_{SL}. Thus the difference in t_{SL} and t_{LL} is due to a difference in natural advantage that is magnified by a the investments of hub country.□

Co-ordination of investment plans

The assumption that the three countries bargain over the investment plans is formalised by the following Nash maximand:

$$\underset{\tau^{S}_{SL1}\ldots\tau^{L2}_{L1L2}}{MAX} \; W = \left(U_S - \bar{U}_S\right)\left(U_{L1} - \bar{U}_{L1}\right)\left(U_{L2} - \bar{U}_{L2}\right) \tag{A.20}$$

[23] The numerator in the second term exceeds that in the first term (in absolute value) and the denominator in the second term is smaller that in the first term.

subject to $t_{ij} = \bar{\tau}_{ij} + \tau^i_{ij} + \tau^j_{ij}$ and $u_i = \gamma \ln(E_{Xi} / P_{Xi})$ and where the countries have equal bargaining power. A bar above a variable denotes the threat point, which is the situation with (uncoordinated) policy competition. Note that with costly infrastructure investment and factor price equalisation expenditure becomes: $E_i = L_i e^{-C(\tau^i_{ij}, \tau^i_{ik})}$. Take logs of the Nash maximand and use $P^{\varepsilon-1}_{Xi} = Z_i / E_{Xi}$ to write:

$$U_i - \bar{U}_i = -\left(1 + \frac{\gamma}{1-\varepsilon}\right)\left(C_i - \bar{C}_i\right) - \left(\frac{\gamma}{1-\varepsilon}\right) \ln\left(Z_i - \bar{Z}_i\right) \tag{A.21}$$

Use equation (A.3) and $\partial t_{ij} / \partial \tau^i_{ij} = \partial t_{ik} / \partial \tau^i_{ik} = 1 \ \forall \ i$ to obtain the following first-order condition:

$$\begin{aligned} \frac{\partial W}{\partial \tau^i_{ij}} = \frac{\partial W}{\partial t_{ij}} = {} & \frac{1}{U_i - \bar{U}_i}\left(-\left(1 + \frac{\gamma}{1-\varepsilon}\right)\frac{\partial C_i}{\partial t_{ij}} + \left(\frac{\gamma}{1-\varepsilon}\right)\frac{\partial Z_i}{\partial t_{ij}}\frac{1}{Z_i}\right) + \\ & \frac{1}{U_j - \bar{U}_j}\left(\left(\frac{\gamma}{1-\varepsilon}\right)\frac{\partial Z_j}{\partial t_{ij}}\frac{1}{Z_j}\right) + \\ & \frac{1}{U_k - \bar{U}_k}\left(\left(\frac{\gamma}{1-\varepsilon}\right)\frac{\partial Z_k}{\partial t_{ij}}\frac{1}{Z_k}\right) = 0 . \end{aligned} \tag{A.22}$$

The Nash bargain is fully characterised by this expression and the five analogous expressions for the other investments.

Proof of PROPOSITION 7

To compare the competitive outcome with the coordinated Nash bargain compare (A.11) with (A.22). Recall that Z is independent of country size and that C is also (constructed to be) independent of country size, hence the weights (the differences in utility between the Nash bargain and the competitive outcome) are independent of the country size and hence identical across countries. Multiply equation (A.22) with $U_i - \bar{U}_i$ and note that the first term on the right-hand side of (A.22) is identical to the competitive outcome (A11).[24] To complete the proof we only have to evaluate the net effect on the other two countries; one country facing one better connection and one country facing a better connection between the other two countries. Using that $Z_i = (\omega_i / \Delta) F$ the comparison of Nash bargain with the competitive outcome boils down to determining the sign of:

$$2\frac{\partial \Delta}{\partial t_{ij}}\frac{1}{\Delta} - \frac{\partial \omega_j}{\partial t_{ij}}\frac{1}{\omega_j} - \frac{\partial \omega_k}{\partial t_{ij}}\frac{1}{\omega_k} \tag{A.23}$$

where

[24] We ruled out all other externalities. See the introduction to section 4.2.

$$2\frac{\partial \Delta}{\partial t_{ij}}\frac{1}{\Delta} = 2(- 2t_{ij} + 2t_{jk}t_{ik})\frac{1}{\Delta} ,$$

$$\frac{\partial \omega_j}{\partial t_{ij}}\frac{1}{\omega_j} = \frac{-(1 - t_{ik})}{\omega_j} ,$$

and

$$\frac{\partial \omega_k}{\partial t_{ij}}\frac{1}{\omega_k} = \frac{-(1 + t_{ij} - t_{ik} - t_{jk}) + (1 - t_{ij})}{\omega_j}$$

Substituting these expressions in (A.23) and evaluating around a symmetric equilibrium shows that investment in the competitive equilibrium exceed those in the coordinated Nash bargain if $t > \frac{1}{2}$ □