Taxation, Infrastructure, and Endogenous Trade Costs in New Economic Geography

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Abstract

This paper presents a New Economic Geography model with distortionary taxation and endogenized trade costs. Tax revenues finance a public good, infrastructure. We show that the introduction of costly public investment in infrastructure increases agglomerative tendencies. With respect to the regions' sizes, in the periphery, the price-index for manufacturing goods decreases, whereas for the core, the price-index is rather high since the distortionary effect of taxes dominates. 'Free riding' – or, in terms of regional policy, externally funded infrastructure investment – is beneficial for the periphery, which can devote all its tax revenue to local demand support, generating a positive home market effect and driving the catch-up process.

Key words: New Economic Geography, Taxation, Endogenous Trade Costs, Infrastructure, Regional Policy

JEL classification: F12, H25, H54, R12

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1 Introduction

According to the European Commission, transport infrastructure improvements play "a key role in the efforts to reduce regional and social disparities in the European Union, and in the strengthening of its economic and social cohesion" (see Commission of the European Communities, 1999). Hence, the Commission supports and endorses the development of Trans-European Transport Networks (TEN-T) also 30 axes of priority, which now also encompass the new Eastern European member states, for instance a corridor from Tallinn via Riga and Warsaw to Bratislava and Vienna (see Commission of the European Communities, 2005). Both the European Union as well as national governments will contribute to its financing. According to the Commission of the European Communities (2005), total costs are estimated to be around 330 billion Euros in the period from 2007-2013, where more than half of these costs need to be covered by the member states and other non-EU-related sources. Those TEN-T's are a key element in the revised 'Lisbon strategy for competitiveness and employment in Europe', since the EU considers good transport infrastructure, and good accessibility for and of all its members as a key element for economic development in Europe.

The economic literature seems to support this view. According to Limao and Venables (1999), the elasticity of trade volumes with respect to transport costs is estimated at around -2.5, i.e., halving transport costs increases the volume of trade by a factor of five. This belief is also shared outside the EU: Fan and Zhang (2004) in a study on Chinese rural regions confirm that infrastructure is a key to rural development, particularly in all non-agricultural sectors. Henderson et al. (2001) point into a similar direction for African countries and regions.

In this paper, we look at the users of infrastructure, firms and consumers, and we explore the links between infrastructure and its (public) financing through taxes. The vehicle being employed in this paper is a simple New Economic Geography (henceforth: NEG) model following Krugman (1991a,b) and Fujita et al. (1999) with endogenized transport costs, where we focus on, (i) infrastructure, (ii) regional governments and taxation, and (iii) regional policy. According to Puga (2002), those models are suitable for this type of analysis, since they focus on the relations between transport costs, agglomeration, and regional disparities, which makes them especially useful for studying the role of (transport) infrastructure.

The relevance of a more detailed account of public finance issues in trade and geography models is confirmed by some significant contributions, referring both to the revenue and the spending side of a public intervention.

On the taxation side, Baldwin and Krugman (2004) show that once we take into account agglomeration issues, the standard 'race to the bottom' result of basic tax competition models (Zodrow and Mierzkowski, 1986; with stylized facts-based extensions such as Devereux et al., 2002) is reversed: as industrial concentration creates agglomeration rents for firms, they would still prefer to locate in the core, even in the presence of a higher tax rate, provided that it is not too much higher relative to the periphery. Two results are particularly interesting. First, the level of trade costs matters, as the equilibrium tax rate gap between core and periphery depends upon market integration. Second, when agglomeration forces are sufficiently strong, there is a positive correlation between the capital-labor ratio and tax rates. Such a conclusion can therefore raise the question − which we investigate in a different setting − on the consequences on agglomeration patterns deriving from endogenizing trade costs via public spending in infrastructure. The quality and composition of public expenditures has also received some attention. Brülhart and Trionfetti (2004) analyze the effects on agglomeration of the government's preferences for domestic over foreign suppliers. Using a dynamic NEG-model, they show that such a home-bias in government purchases acts as a dispersion force, thereby reducing the intensity of industrial agglomeration. Keen and Marchand (1997), instead, focus on the composition of public spending, showing that in the non-cooperative equilibrium there is an over-provision of a production function-enhancing public expenditure (such as infrastructure) and an under-provision of public consumption affecting the households' utility function (such as recreational facilities or social services).

It is important to stress that − unlike the above-mentioned contributions − we do not employ revenue maximizing governments in the choice of the optimal tax rate. We rather borrow the tools on the revenue side (distortionary taxes) and on the expenditure side (transport costs-reducing infrastructure) to focus on their joint effects on equilibrium core-periphery patterns.

Indeed, a better modelling of infrastructure and transport costs has received a considerable degree of attention in the literature.

Earlier formulations of infrastructure modelling in one-region frameworks, such as Arrow and Kurtz (1970) and Barro (1990) include it in the production function, as some sort of general public expenditure; however, these contributions can obviously not grasp the effects of public intervention on trade dynamics. In two-regions settings, Andersson and Forslid (2003) build a NEG-model where tax revenue is used to finance a public good entering the utility function, rather than the production function, and analyze how tax increases affect the distribution of workers across regions. Egger and Falkinger (2006) show that national public infrastructure investments have positive effects on the number of intermediate goods producers and the return of the immobile factor in the home country, whereas international outsourcing declines. Opposite effects occur for the other country in this model.

On the other hand, efforts to overcome the pure exogeneity of transport costs include few relevant contributions. Mori and Nishikimi (2002) establish a link with economies of density, which are supposed to be external to each firm. In their formulation, transport costs are constant up to a given threshold of aggregate trade; then, density economies come into action, and transport costs are a non-linear decreasing function of them (defined by aggregate volume of trade). A somewhat similar characterization is provided by Behrens and Gaigné (2006), who distinguish between fixed unit transport costs (determined by technology and infrastructure) and unit shipping costs, which vary with the total volume of trade and, therefore, with the spatial distribution of supply and demand[1].

[1]Other recent approaches of dealing with endogenized transport or trade costs in NEG-models include for instance Mansori (2003), Behrens et al. (2006), or Duranton and Storper

However, all these contributions do not look at the fundamental link we want to focus on, namely the direct link between public intervention and transport costs. The most relevant work in this respect has been carried out by Martin and Rogers (1995). In their model, transport costs are a decreasing function of publicly provided infrastructure, which can be distinguished between being domestic or international. Their results show that trade integration will lead firms to locate in the region with better domestic infrastructure. Differences in international infrastructure alone do not determine the allocation of industrial activities, but rather increase the sensitivity of the industrial patterns to domestic infrastructure differentials. Martin and Rogers (1995) also analyze the welfare consequences of increasing infrastructure provision through lump-sum taxation, reaching opposite conclusions on agglomeration equilibria according to the type of infrastructure being built (domestic or international).

Our contribution is inspired by this latter paper (Martin and Rogers, 1995). The endogenization of transport costs comes in two steps. First, introducing a corporate sales tax that generates revenue for the corresponding region. Local governments allocate these tax revenues between infrastructure investments and lump-sum transfers to support their consumers' incomes. Second, the infrastructure is being built using the same production technology employed in the manufacturing sector. The quantity of infrastructure provided is weighted by a scaling and efficiency parameter, which determines the exact reduction of transport costs which affects firms' decisions on location and trade. Unlike Martin and Rogers (1995), we assume that infrastructure is only international (i.e., it applies to inter-regional trade only), but it is financed by distortionary taxation on firms' sales and can only be supplied by the public authority. This last assumption allows us to ignore possible crowding-out effects on the private sector.

Our results show that public infrastructure investments lead to more pronounced agglomeration patterns, i.e. the concentration of industries is fostered, which confirms previous results obtained in different settings by Andersson and Forslid

(2008).

(2003) and Baldwin et al. (2003). This would suggest that only central regions may benefit from public policy measures related to infrastructure.

Nonetheless, this is also beneficial for the region ending up as the periphery, since also in this region, the price index for manufactured goods decreases, which is due to cheaper imported product varieties. The reduction of transport costs is very effective for high initial values of trade costs (i.e., before infrastructure investments), while there are less absolute effects when transport costs are already low. In terms of regional policy, it can be shown that it might be useful if such infrastructure investments are only financed by the central region (i.e., the periphery receiving for instance structural funds benefits by the EU, or - in terms of our model - being a free rider in infrastructure provision), since both regions benefit from such investments, while the periphery can spend its locally collected taxes for local purposes.

The remainder of the paper is organized as follows: Section 2 introduces the model, while Section 3 investigates the core-periphery patterns, as well as the effects of the infrastructure provided on trade costs and firms. Section 4 looks at the sensitivity of the model and provides additional insights regarding the major policy parameters. The last Section summarizes and concludes.

2 The Model

2.1 Households

There are two regions indexed as $\{i, j\} = \{1, 2\}$. Both regions produce two tradable goods, X and Z. Z is a homogenous agricultural good produced at constant returns to scale by a competitive industry. X-goods (manufacturing goods) are horizontally differentiated in the usual Dixit and Stiglitz (1977) manner. Firms may sell on the local market and export to the other region.

Quantities of both X and Z are indexed as follows. The first subscript denotes the region where the headquarters and the production are based, the second subscript indicates the region where the good is sold. Therefore, X_{ij} are the exports of region i-based firms to region j[2]. X_{ic} denotes the consumption of X in region i, being a CES aggregate of the individual varieties. We assume the consumer's preferences to be a nest of the homogeneous Z-good and the differentiated X-good. The utility of region i (U_i) can thus be formulated as follows:

$$\begin{aligned} U_i &= X_{ic}^{\mu}\left(Z_{ii}+Z_{ji}\right)^{1-\mu}, \\ X_{ic} &\equiv \left[n_i\left(X_{ii}\right)^{\frac{\sigma-1}{\sigma}}+n_j\left(\frac{X_{ji}}{1+\tau}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}, \end{aligned} \tag{1}$$

where μ denotes the (constant) Cobb-Douglas expenditure share for differentiated products, $\sigma > 1$ is the elasticity of substitution between varieties, and n_i shows the number of manufacturing firms headquartered in region i.

We assume that Z-goods are costlessly tradable across regions, whereas X-goods trade incurs iceberg transport costs (τ), which are symmetric for either direction of shipment. In terms of quantity, one unit of consumption of an X-variety in region j requires a firm in i to send $(1 + \tau)$ units. For convenience, quantities of X are defined as firm-specific productions for the respective foreign market. However, as in our model transport costs may vary with government expenditures and thus the amount of infrastructure being provided (as outlined below), transport or trade costs are endogenous to this model.

As usual, the consumer's maximization problem can be solved in two steps. In the first step, each variety X_{ji} needs to be chosen such that it minimizes the cost of attaining X_{ic}, whatever the consumption of X_{ic} is. In the second step, consumers allocate income between the Z-good, and the composite X-good. Let p_{ji} be the price of an X-variety in region i produced by a firm in region j. The price for the homogenous agricultural good, q_i, is indexed once, since all (indigenous and foreign) homogenous goods consumed at a single location i must face the same price q_i. We take q_1 as the numéraire. Further, P_i denotes the price aggregator, defined as the minimum cost of buying one unit of X_i at prices p_{ji} of an individual

[2] Whenever we use i and j from the set $\{1, 2\}$, this implies that $i \neq j$.

variety:

$$P_i = \min_{X_{ji}} \sum_{i,j} p_{ji} X_{ji} \quad \text{s.t.} \quad X_i = 1. \tag{2}$$

The first-stage budgeting problem leads to:

$$X_{ji} = (p_{ji})^{-\sigma} P_i^{\sigma-1} \mu Y_i \quad \forall \quad i, j \in \{1, 2\}, \tag{3}$$

where Y_i denotes total expenditures of consumers in region i, and $p_{ji} = p_j(1+\tau)$, i.e., the local goods price in region j (p_j) including transport costs $(1+\tau)$. Identical price elasticities of demand and identical marginal costs (technologies) within a region ensure that the price of a locally produced manufacturing good is equal to the mill price for exports. Hence, prices of all manufacturing goods produced in one region are equal in equilibrium. p_i denotes the price of all goods produced in region i. With these assumptions, the price aggregator, P_i, of differentiated goods *consumed* in region i can be written as

$$P_i = \left[n_i p_i^{1-\sigma} + n_j \left((1+\tau) p_j \right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}}. \tag{4}$$

Note that due to the adopted assumptions about technology, factor markets, and demand − in equilibrium − the delivered prices of indigenous (p_{ii}) and imported variants (p_{ji}, i.e., mill price including transport costs) of the manufacturing good are the same in region i. The second-stage budgeting yields the division of expenditures between the two sectors:

$$X_{ic} = \frac{\mu}{P_i} Y_i, \tag{5}$$

$$Z_{ii} + Z_{ji} = \frac{1-\mu}{q_i} Y_i \tag{6}$$

2.2 Factor Markets and Production

There is perfect competition in the Z-sector, and each firm produces under constant returns to scale using a CES production technology, employing labor (L) and land (T):

$$Z_i = \left[(1-b) L_i^{\rho_z} + b T_i^{\rho_z} \right]^{\frac{1}{\rho_z}}, \tag{7}$$

where 'b' is the coefficient for T and '$1-b$' for L, and ($-\infty < \rho_z < 1$) is the technical rate of substitution between factors L and T in Z-production. As all firms face the same factor prices and the CES production technology is homothetic and exhibits constant returns to scale, all firms in a region face the same unit input coefficients. The region-specific unit input coefficients for the two factors of Z-production can be derived by cost minimization subject to this CES technology:

$$a_{Lzi} = \left(\frac{w_{Li}}{1-b}\right)^{\frac{1}{\rho_z-1}} \left[\left(\frac{w_{Ti}^{\rho_z}}{b}\right)^{\frac{1}{\rho_z-1}} + \left(\frac{w_{Li}^{\rho_z}}{1-b}\right)^{\frac{1}{\rho_z-1}}\right]^{-\frac{1}{\rho_z}} \tag{8}$$

$$a_{Tzi} = \left(\frac{w_{Ti}}{b}\right)^{\frac{1}{\rho_z-1}} \left[\left(\frac{w_{Ti}^{\rho_z}}{b}\right)^{\frac{1}{\rho_z-1}} + \left(\frac{w_{Li}^{\rho_z}}{1-b}\right)^{\frac{1}{\rho_z-1}}\right]^{-\frac{1}{\rho_z}}, \tag{9}$$

where w_{Li} and w_{Ti} denote the nominal factor rewards of labor and land in region i, respectively.

Variable unit costs (i.e., marginal costs) c_{Zi} satisfy

$$c_{Zi} \geq a_{Lzi} w_{Li} + a_{Tzi} w_{Ti} \quad \perp \quad Z_{ii} \geq 0, \tag{10}$$

where $\perp$ indicates that at least one of the adjacent conditions has to hold with equality. This implies

$$c_{Zi} \geq q_j \quad \perp \quad Z_{ij} \geq 0. \tag{11}$$

In the X-sector, instead, there is monopolistic competition, and again each firm produces under a CES production technology, using labor and land:

$$X_i = \left[a L_i^{\rho_x} + (1-a) T_i^{\rho_x}\right]^{\frac{1}{\rho_x}}, \tag{12}$$

where 'a' is the coefficient for L and '$1-a$' for T), and ($-\infty < \rho_x < 1$) is the technical rate of substitution between factors L and T in X-production. As all firms face the same factor prices and the CES production technology is homothetic and exhibits constant returns to scale, all firms in a region face the same unit input coefficients. The region specific unit input coefficients for the two factors of X-production can be derived by cost minimization subject to this CES technology:

$$a_{Lxi} = \left(\frac{w_{Li}}{a}\right)^{\frac{1}{\rho_x-1}} \left[\left(\frac{w_{Li}^{\rho_x}}{a}\right)^{\frac{1}{\rho_x-1}} + \left(\frac{w_{Ti}^{\rho_x}}{1-a}\right)^{\frac{1}{\rho_x-1}}\right]^{-\frac{1}{\rho_x}} \tag{13}$$

$$a_{Txi} = \left(\frac{w_{Ti}}{1-a}\right)^{\frac{1}{\rho_x-1}} \left[\left(\frac{w_{Li}^{\rho_x}}{a}\right)^{\frac{1}{\rho_x-1}} + \left(\frac{w_{Ti}^{\rho_x}}{1-a}\right)^{\frac{1}{\rho_x-1}}\right]^{-\frac{1}{\rho_x}} \tag{14}$$

Additionally, X-sector firms require labor (a_{Lni}) and land to set up plants (a_{Tni}), leading to increasing returns to scale in production. Furthermore, the publicly provided and tax-financed infrastructure (I_i) in region i is produced using the same technology as we have it for manufactured goods, but without being subject to economies of scale.

Hence, factor market clearing in region i for labor (L_i) and land (T_i) requires

$$\begin{aligned} L_i &\geq a_{Lxi}n_i\left(X_{ii}+X_{ij}\right)+a_{Lni}n_i+a_{Lxi}I_i+ \\ &\quad a_{Lzi}w_{Li}\left(Z_{ii}+Z_{ij}\right) \quad \perp \quad w_{Li}\geq 0, \qquad (15) \\ T_i &\geq a_{Txi}n_i\left(X_{ii}+X_{ij}\right)+a_{Tni}n_i+a_{Txi}I_i+ \\ &\quad a_{Tzi}w_{Ti}\left(Z_{ii}+Z_{ij}\right) \quad \perp \quad w_{Ti}\geq 0. \qquad (16) \end{aligned}$$

2.3 Manufacturing Firms and Taxation

Taxes (tax_i) are introduced as a distortionary sales tax. The profit function of manufacturing firms therefore becomes slightly enlarged:

$$\Pi_i = p_i X_i \left(1 - tax_i\right) - c_{Xi}X_i - FC_{ni}, \qquad (17)$$

where Π_i are the profits of a region i firm, X_i is the firm's output and comprises of locally sold as well as exported goods ($X_{ii}+X_{ij}$), c_{Xi} are the variable unit costs, and FC_{ni} are the fixed costs of production. The distortionary effect of this tax can be seen in the resulting pricing equation (equation 18).

Variable unit costs of producing an X-variety in region i are given by $c_{Xi} = a_{Lxi}w_{Li} + a_{Txi}w_{Ti}$. There is a fixed markup over variable costs, which is determined by the elasticity of substitution between varieties. Given that under CES-utility demand for all varieties is positive, the price setting behavior by firms is given by the following equation, which is derived by profit maximization and employing the Amoroso-Robinson-relation.

$$p_i = c_{Xi}\frac{\sigma}{\sigma-1}\frac{1}{1-tax_i}, \qquad (18)$$

where p_i is the consumer price for manufactured goods[3].

[3]From the profit equation (equation 17) it becomes clear that in a scenario without taxation

Free entry and exit implies that firms earn zero profits, since operating profits are used to cover fixed costs. The corresponding zero profit condition determines the numbers of firms.

Manufacturing firms in i have to bear fixed costs of $FC_{ni} = a_{Lni}w_{Li} + a_{Tni}w_{Ti}$. The zero profit condition, therefore, implies

$$FC_{ni} \geq \frac{p_i \left(X_{ii} + X_{ij}\right)}{\sigma} \left(1 - tax_i\right) \quad \perp \quad n_i \geq 0. \tag{19}$$

2.4 Infrastructure and Transport Costs

According to the previously introduced taxation, pricing behavior, production, and number of manufacturing firms, the total tax revenues, and subsequently total government spending in a region, G_i, is

$$G_i = tax_i p_i n_i \left(X_{ii} + X_{ij}\right). \tag{20}$$

Out of these tax revenues, a fraction $0 < \kappa_i < 1$ is devoted to infrastructure building, and the remaining fraction $1 - \kappa_i$ is used for lump-sum transfers to region i's population, directly supporting their incomes.

As mentioned above, for simplicity, we assume the production technology for infrastructure to be the same as for manufacturing goods, without being subject to economies of scale. Thus, the amount of infrastructure provided by region i's government is

$$I_i = \frac{\kappa_i G_i}{a_{Lxi}w_{Li} + a_{Txi}w_{Ti}}. \tag{21}$$

We assume that both regions' infrastructure contributes to the reduction of transport costs for shipments between the two regions. Hence, the resulting endogenously determined value for transport costs is given by

$$\tau = \frac{t}{\left(I_i + I_j + 1\right)^{\beta}}, \tag{22}$$

when $tax_i = 0$, the profit function would just lose the term $(1 - tax_i)$. As a consequence, the pricing equation (equation 18) would also simply lose the tax-term, i.e. $\frac{1}{1-tax_i}$. Analogously, we obtain the producer price in the taxation-scenario. The producer price for manufacturing goods would just be the consumer price times $(1 - tax_i)$, i.e. the price in the no-tax scenario. This is because our tax is just a percentage on sales revenues.

where t is an 'initial value' for transport costs, which also corresponds to a 'no-tax scenario' without taxes and infrastructure, i.e. to the standard NEG-model with exogenously given transport costs. It may also be regarded as general impediments to trade between the two regions, or as the amount of trade costs *before* any policy interventions (i.e., public infrastructure investments in this model) take place. $0 < \beta < 1$ is a scaling parameter which reflects the 'effectiveness' of the infrastructure provided. Furthermore, note that both regions' infrastructure investments simultaneously affect the actual reduction of trade costs (τ).

2.5 Income and Real Factor Rewards

All factors are owned by the households, so that consumer income (i.e., GNP) in region i is given by

$$Y_i = w_{Li} L_i + w_{Ti} T_i + (1 - \kappa_i) G_i. \tag{23}$$

The equivalence of total factor income (Y_i, Y_j) and demand in each region implicitly balances payments between regions.

Real factor rewards (ω) are normalized by region-specific costs of living, $P_i^{-\mu} q_i^{\mu-1}$, and are thus given by:

$$\omega_{ki} = w_{ki} P_i^{-\mu} q_i^{\mu-1}, \quad k \in \{L, T\}. \tag{24}$$

3 Core-Periphery Patterns

3.1 Baseline Scenarios

In contrast to the standard NEG-model à la Krugman (1991b), production of the manufacturing good uses two input factors (L and T). In those models it is straightforward to assume that the factor used in the manufacturing sector is mobile across regions. In line with the literature, all factors are immobile in the short run. In the long run, we investigate situations where L (and manufacturing firms) is mobile across regions[4]. A long-run stable equilibrium is defined similar to Krugman (1991b) by real wage equalization across regions (i.e., $\omega_{Li} = \omega_{Lj}$). The stability of a long run equilibrium can be verified by exogenously shifting one unit of labor to the other region, and deriving the new short run equilibrium. Then, firms are allowed to enter and exit to avoid losses and exploit profits. If this reallocation of production factors results in a decline of real wages in the receiving region, the initial equilibrium can be considered as stable. Otherwise, the initial equilibrium is unstable, because even more workers have an incentive to relocate.

Figure 1 represents the standard NEG-model, i.e., a scenario without taxation, while Figure 2 is the benchmark scenario for all the subsequent alterations of our model, i.e., the standard NEG-model plus taxation (with $tax_i = 0.2$ and $\kappa_i = 1$). Figure 1 is obtained by setting both the tax rates and, consequently, the infrastructure expenditures equal to zero, and varying the initial impediments to trade (t) between 1% and 99% of the price of manufacturing goods. In all our bifurcation diagrams, λ_{Li} denotes region i's share of the mobile factor, labor.

As it can be seen from Figures 1 and 2, the equilibrium locations of industries show the well known Tomahawk-bifurcation in the terminology of Fujita et al. (1999). Moving from the right to the left in our bifurcation diagrams (Figures 1 and 2), i.e., moving from higher to lower (initial values of) trade costs, we observe one long-run stable symmetric equilibrium until $t \approx 0.38$ in the scenario without taxation (see Figure 1), and $t \approx 0.47$ in the scenario with taxation (see Figure 2) $-$ the break points (following Fujita et al., 1999)[5]. At lower trade costs, we find three interior equilibria, two stable ones and an unstable one. There are two symmetric long-run stable equilibria between $0.76 \gtrapprox \lambda_{Li} \gtrapprox 0.71$ and

[4]We have chosen the following parameter values for all of the following simulations, also in order to ensure comparability to other simulation-based NEG-models, such as Egger et al. (2007): $\sigma = 4$, $\mu = 0.35$, $\beta = 0.1$, $a = b = 0.8$, $\rho_x = \rho_z = -0.5$, $L = L_1 + L_2 = 60$, $T = T_1 + T_2 = 100$, $t = 0.7$, $tax_1 = tax_2 = 0.2$, $\kappa_1 = \kappa_2 = 1$, $\lambda_{T1} = \lambda_{T2} = 0.5$ if nothing else is mentioned, where λ_{Ti} is the size of region i in terms of land. That means, the major differences between the $X-$ and the $Z-$sector arise due to the different types of competition and different factor-intensities.

[5]In all our bifurcation diagrams we display the size of a region in terms of the mobile factor, labor, on the vertical axis, and the initial value of trade costs, t, on the horizontal axis. Solid lines denote long-run stable equilibria, while dotted lines denote unstable equilibria.

$0.29 \gtrapprox \lambda_{Li} \gtrapprox 0.24$, respectively. These two partially agglomerated equilibria turn out to be stable from $t \approx 0.39$ in the scenario without taxation (see Figure 1), and from $t \approx 0.49$ in the scenario with taxation (see Figure 2) − again, moving from the right to the left. Those two points correspond to the sustain points, again following Fujita et al. (1999). Also at low trade costs, there is one unstable symmetric equilibrium from $t \approx 0.38$, in the no-tax scenario, and from $t \approx 0.47$ in the taxation scenario. Hence, the results show that the main qualitative results from Krugman (1991b) can be replicated, i.e., there is agglomeration at low trade costs, and dispersion at higher trade costs. Due to our production technology assumptions (an immobile factor, land, is used in both sectors) there is no full-agglomeration equilibrium.

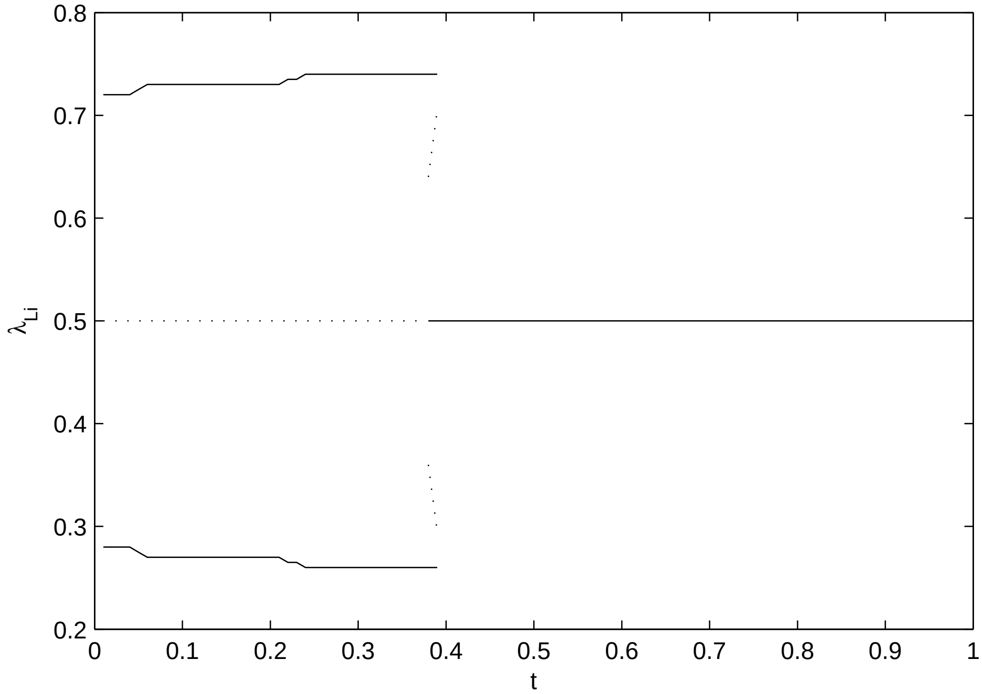

Figure 1: Standard bifurcation diagram without taxation and infrastructure, and $\lambda_T = 0.5$.

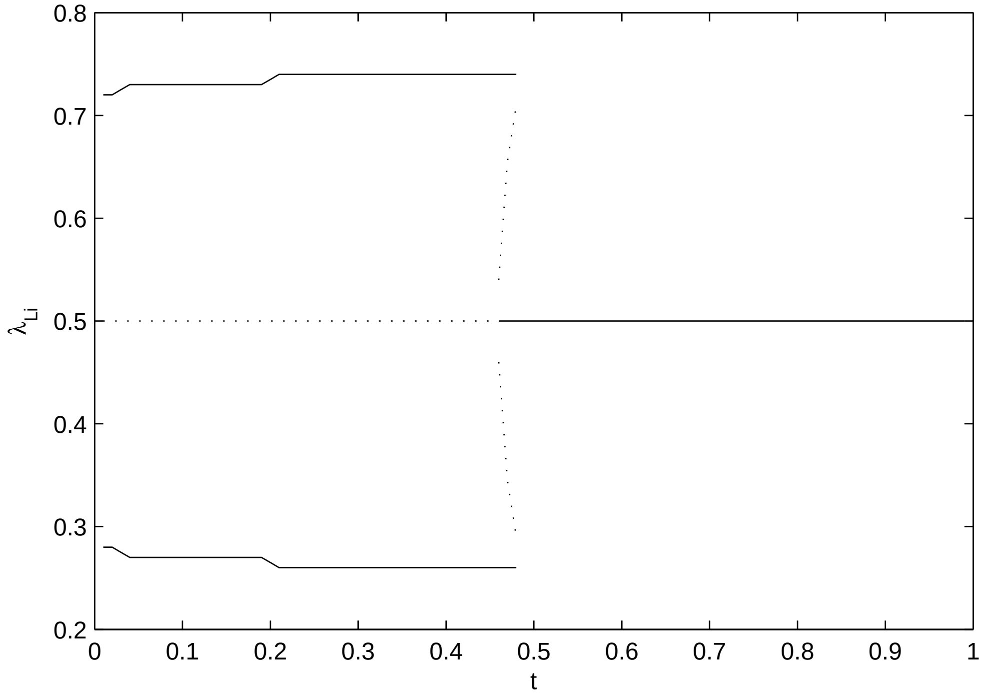

Figure 2: Bifurcation diagram with taxation and infrastructure, and $\lambda_T = 0.5$. Benchmark scenario.

The subsequent analysis of the model is conducted along several lines of investigation. After providing some intuition for the endogenized trade costs, at first the standard agglomeration structure will be evaluated, which means for this model, that the 'initial value' of transport costs t varies from 1% to 99% of the price of X-goods. Since publicly provided and tax-financed infrastructure might be viewed as quite many different things, and not merely – for instance – better roads reducing travel times, we suggest to interpret the endogenous transport costs (τ) of the present model more generally as trade costs. This is especially important in our model, since regional public authorities usually do not have the opportunity to influence 'pure' transport costs, but they rather can try to generally improve their region's competitive position. Second, we look at variations of the policy parameters which are of our primary interest, the tax rate (tax), and the fraction of government expenditures devoted to infrastructure building (κ). This is also useful to analyze the model's sensitivity to parameter changes. Thus, the main focus of the following analysis is put on investigating how the parameters which may be influenced by policy makers shape the economic landscape.

3.2 Endogenous Trade Costs

In order to provide a better intuition on the effects of the endogenized trade costs, i.e., the reduction of trade costs through infrastructure provision, the following Figure 3 shows the relation between t (initial trade costs) and τ (endogenized trade costs) for our benchmark scenario of Figure 2. We generally find that the higher the initial trade costs are, the larger the absolute effect of infrastructure, and thus the larger the reduction of trade costs will be. Hence, the absolute decrease of trade costs caused by infrastructure investments is higher if the initial impediments to trade are high. This decrease would be even stronger if the scaling and efficiency parameter β was higher, also at higher tax rates. In other words, for regions being rather remote from economic centers and having high interregional impediments to trade, it makes more sense to strengthen the infrastructure network than for quite integrated or centrally located regions where trade costs are already quite low. For a better intuition on the endogenized trade costs, Figure 3 show the relation between the initial value of trade costs (t) and the endogenized trade costs (τ).

Some of the above findings can easily be seen by inspecting the equations on infrastructure provision, equations 20, 21, and 22. Plugging equation 20 into 21, we obtain

$$I_i = \frac{\kappa_i tax_i p_i n_i \left(X_{ii} + X_{ij}\right)}{a_{Lxi} w_{Li} + a_{Txi} w_{Ti}}, \tag{25}$$

and plugging the resulting equation 25 into 22 we have

$$\tau = \frac{t}{\left[\frac{\kappa_i tax_i p_i n_i (X_{ii}+X_{ij})}{a_{Lxi} w_{Li}+a_{Txi} w_{Ti}} + \frac{\kappa_j tax_j p_j n_j (X_{jj}+X_{ji})}{a_{Lxj} w_{Lj}+a_{Txj} w_{Tj}} + 1\right]^{\beta}}, \tag{26}$$

Inspecting equation 25, public infrastructure investments are generally facilitated (i) by higher taxes since there is more money to be spent (of course we have to bear in mind that tax revenues might decrease as the tax rate or the size of a region increases − as shown in Figure 5 for values of $\lambda_{Li} \gtrapprox 0.75$), (ii) by a larger number of firms and (iii) by higher quantities being produced in a region (more firms producing higher quantities pay more taxes). Consequently, this leads to larger reductions of trade costs (see equation 26). Additionally, a higher efficiency or better quality of the infrastructure provided (i.e., a higher β), also leads to a stronger reduction of trade costs. Similarly, some external funding via transfer payments (where 'external' means external to regional budgets, which we have not included in our model) facilitates and increases regional public infrastructure provision. Clearly, infrastructure becomes more expensive, and thus its provision decreases, as the factor prices and/or the factor input requirements rise.

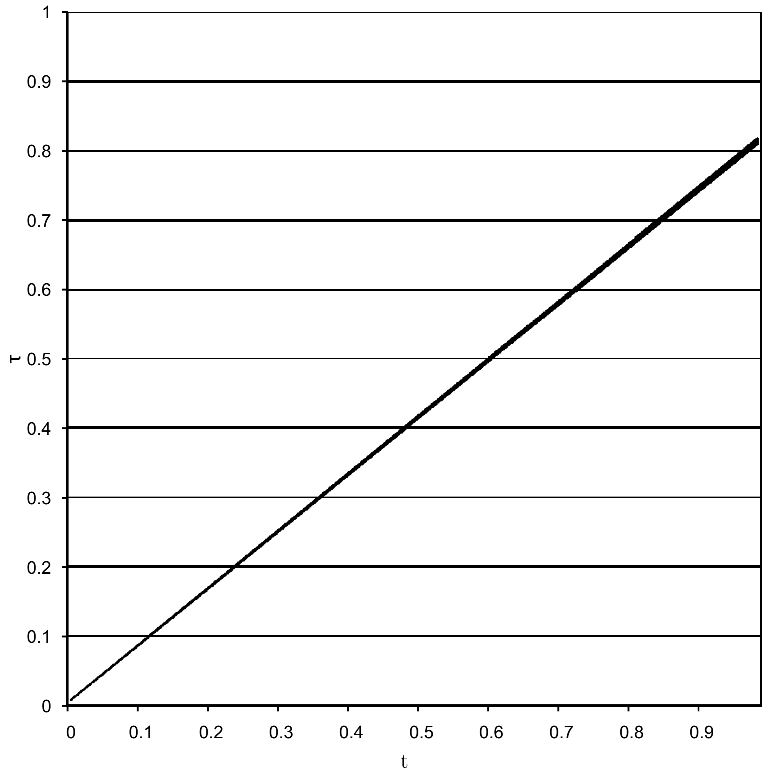

Figure 3: Relation between initial and endogenized trade costs. Benchmark scenario.

3.3 Effects of Taxation on the Agglomeration Patterns

In Figure 2, taxation and infrastructure spending are activated by setting the tax rates in both regions to $tax_i = 0.2$ and $\kappa_i = 1$. As we have shown above, the endogenization of trade costs through public infrastructure investments in this framework leads the partially agglomerated equilibrium to be sustainable for a larger range of trade costs. The infrastructure provided by the regions' governments allows the agglomerated equilibrium to remain stable for higher initial (i.e., no-tax) values of trade costs. This result confirms Baldwin et al. (2003, chapter 17), who find that infrastructure, facilitating interregional trade, leads to increased spatial concentration. They also note that this subsequently leads to higher growth in the whole economy (i.e., also in the periphery), and to a decrease in nominal income inequalities between the center and the periphery. As far as income inequalities are concerned, we find that the real wage inequalities between core and periphery decrease after the introduction of tax-financed infrastructure investments. In other words, comparing our benchmark scenario (with taxation and infrastructure) to the standard (no tax and no infrastructure) scenario, we observe that the real wages in the larger region (core) decrease and the real wages in the smaller region (periphery) increase[6]. This is a result of the combination two effects, (i) the introduction of taxation, which tends to increase manufacturing goods prices, and (ii) the reduction of trade costs due to the infrastructure investments which reduces the price of imported goods.

The share of manufacturing firms in each region is proportionate to the share of workers in each region, just as in any other standard NEG-model. The restriction that applies is, that this is only true after a certain 'size-threshold' in terms of labor-endowment is either passed (for a small region) or undercut (for a large region). This effect is driven by the fact that the agricultural sector requires some labor in its production, and the manufacturing sector requires some immobile land. As long as region i is very small in terms of labor (λ_{Li} smaller than in the 'small-region' equilibrium), it specializes on agricultural goods. If region i happens to be very large in terms of labor (λ_{Li} larger than in the 'large region' equilibrium), it specializes in manufacturing goods, and therefore attracts all workers. This, again, explains why there is not the usual full agglomeration equilibrium in our model. The share of manufacturing firms may, furthermore, be looked up in the left panel of Figure 8.

Lower trade costs due to public infrastructure investments also influence regional disparities. The price index of manufacturing goods decreases as trade costs diminish. This effect is the net result of two opposing forces, (i) lower trade costs leading to lower costs for imported goods, hence constituting a negative price index effect, and (ii) more goods need to be imported since some firms might have an incentive to relocate to the center, which in turn means that more goods have to be imported in total, resulting in a positive price index effect. The latter effect may even be strengthened by the introduction of taxation, which tends to increase the price for manufacturing goods.

[6]Note that we use the terms 'small' and 'periphery' as well as 'large' and 'center' interchangeably, where the 'large' or 'central' region refers to a situation where the region hosts more than 50% of the mobile factor in equilibrium; the terms 'small' and 'periphery' are used otherwise.

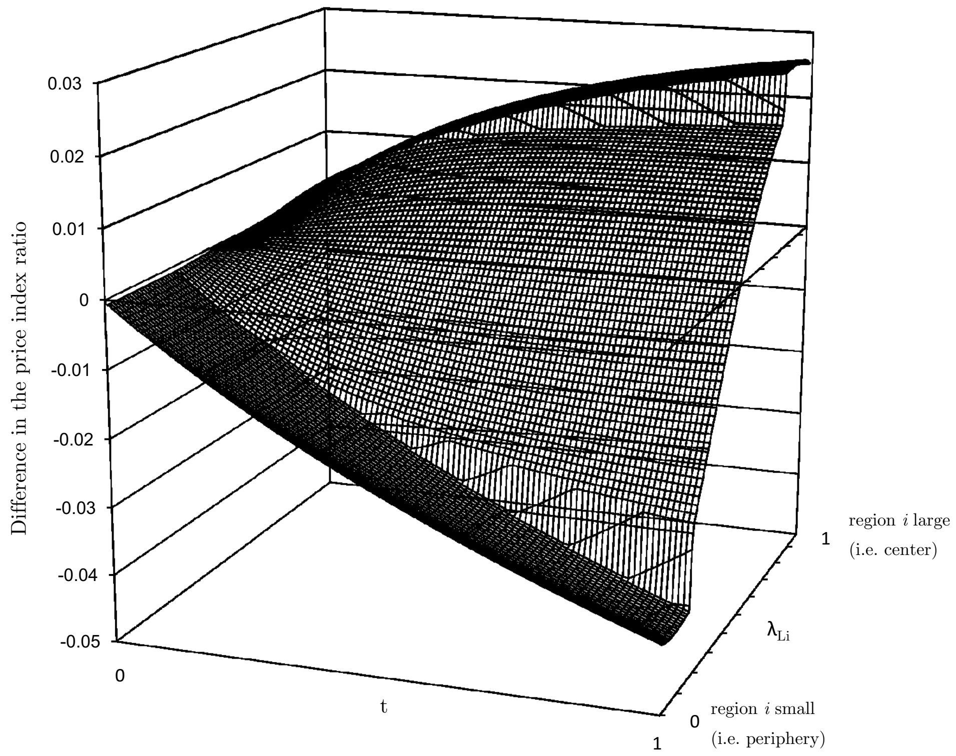

Figure 4: Difference in the price-index ratio for manufacturing goods between the scenarios with and without taxes.

Figure 4 compares the price index-differences for manufacturing goods in the benchmark case (represented by Figure 2) to the no-tax (and hence no-infrastructure) scenario (represented by Figure 1). It turns out that the differences in the price index-differential is high at high trade costs, and approach zero as trade costs diminish. As a result, public infrastructure provision by regional authorities is beneficial for the center as well as the periphery, since the prices for manufacturing goods decrease in the periphery despite hosting less firms as trade costs diminish (for the latter, see also Figure 8, left panel). Looking at Figure 4, it can be seen that at low values of t, there are almost no differences in the price indices between the small (peripheral) and the large (central) region. At higher t's, the smaller region's price index decreases compared to the no-infrastructure setting, since infrastructure reduces transport costs, and hence the price of imported goods. The larger region does not enjoy these benefits since it hosts already the major share of firms. This result confirms Kilkenny (1998) who finds that a reduction of transport costs in rural areas leads to an improvement in rural development.

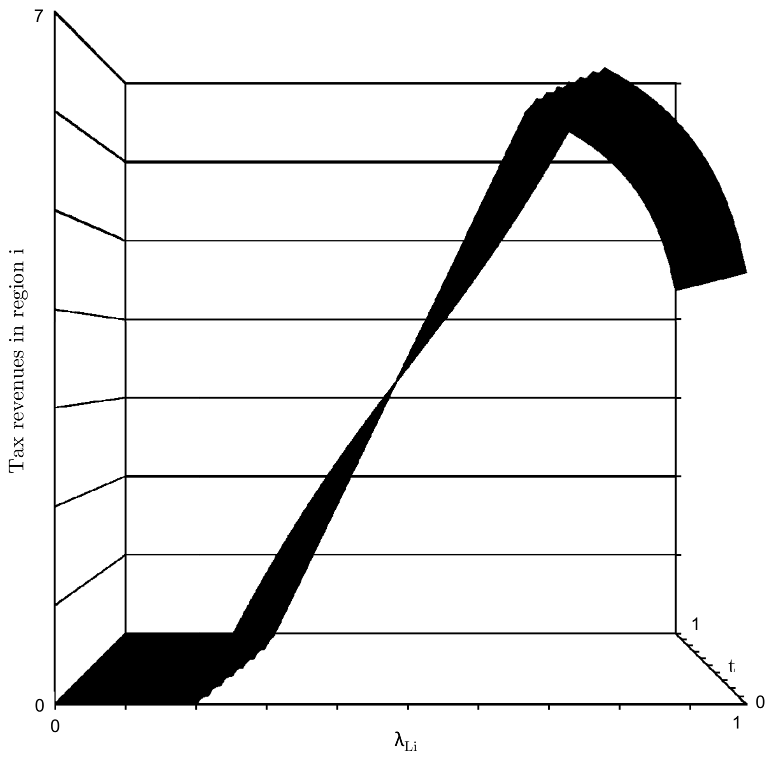

Figure 5: Tax revenues corresponding to the benchmark scenario of Figure 2.

Figure 5 looks at the amount of tax revenues collected by regional governments, which are then transformed into government spending. We find a Laffer-curve shape as the size of a region varies. Tax revenues are maximized when a region hosts approximately 75% of the workers, depending on the value of t (see Figure 5). Note that this corresponds to the long-run stable equilibrium for the larger region in Figure 2, and thus to the size in terms of labor endowment (λ_{Li}) of the larger region in the partially agglomerated equilibrium. Referring back to equation 26, this means that there is an upper (efficiency) limit on the tax rate (which also play a role in determining the core-periphery patterns), and hence tax revenues. In other words, after a certain threshold is passed, too much taxation does not lead to a further reduction of trade costs, since tax revenues then decrease again.

Increases in the exogenously given tax rate (tax) cause the agglomeration equilibrium to be sustainable for a larger range of values of t than in the benchmark case, as long as the tax rate does not become too high. Quite similar effects are observable by altering the fraction of government expenditures devoted to infrastructure provision (κ). The higher κ, the more sustainable agglomeration becomes due to the fact that more (or better) infrastructure will be provided. But also $\kappa_i = \kappa_j = 0$ does not lead to a symmetric agglomeration equilibrium only. Of course, in this case, no infrastructure can be provided to reduce trade costs, but at lower initial values of t a core-periphery structure emerges in this case, too. In the case of $\kappa_i = \kappa_j = 0$, the bifurcation diagram is very similar to the no-tax scenario (represented by Figure 1). The partially agglomerated equilibrium is just slightly more sustainable than in the no-tax-scenario, but less sustainable than in the tax-scenario (represented by Figure 2).

3.4 Free Riding - Policy Intervention

Now, we turn to a particular choice of κ, the fraction of government spending devoted to infrastructure investments. We let one region 'free ride' in infrastructure provision, i.e., we let $\kappa_i = 0$, while everything else remains symmetric. It is important to note that in our model, free riding may not be understood in the 'classical' economic sense, since we do not have any form of tax competition in our setting. The issue of free riding rather is a policy-relevant scenario. The basic idea behind this scenario is inspired by the EU's efforts to develop peripheral regions via the structural funds measures[7]. All these programs have in common the attempt to help peripheral regions to foster their economic development. The idea is to devote external sources of funding (such as EU structural funds) to infrastructure building, in order to allow those regions to utilize their own budgetary resources for other purposes − i.e., in our model, lump-sum transfers which strengthen the income base of regions. In this sense, we use the expression '*free-riding*': a situation where the region benefits from the reduction in transports costs, resulting from external infrastructure spending, without having to pay for it in terms of increased tax pressure.

If one region free rides in infrastructure provision, or has some external source of funding, i.e. $\kappa_i = 0$ while $\kappa_j > 0$, a somewhat different picture develops (see

[7]E.g., the Objective 1 or 2, but also the various Interreg programs.

Figure 6), compared to what we have obtained in our baseline scenario of Figure 2. In this situation, there is again partial agglomeration at low trade costs. However, the smaller region's equilibrium breaks as the initial trade costs approach about $t = 0.5$, while the (at low t's) larger region's equilibrium agglomeration path remains sustainable over the whole range of trade costs.

Note that as the smaller region's equilibrium breaks, the larger region's agglomeration becomes significantly less pronounced. This equilibrium becomes the only one at higher trade costs, and decreases even slightly below $\lambda_{Li} = 0.5$. This means that at higher initial trade costs, there emerges a picture which is similar to the original core-periphery pattern, but slightly asymmetric. However, the asymmetry is not as pronounced as one might have expected it to be. The free riding region is almost of equal size as the other one ($\lambda_{Li} \approx 0.48$). This is due to the fact that there is no interregional tax competition in the present setup[8], and that the region which free rides in infrastructure provision transfers its entire tax revenues lump-sum to its population generating additional income and hence additional demand. Therefore, there are always some firms having incentives to locate in the free-riding region, due to the classical home market effect. The home market effect dominates for initial values of trade costs $0.49 \lessapprox t \lessapprox 0.63$, which induces the free riding region to become larger than $\lambda_{Li} = 0.5$, i.e., the free riding regions host the larger share of the mobile factor, and hence also the larger share firms. The reverse is true for $t \gtrapprox 0.63$. Here, the infrastructure-providing region is larger than the free riding region (i.e., $\lambda_{Li} < 0.5$). This result arises because at higher trade costs, infrastructure becomes very important and the infrastructure-providing region gains an advantage due to additional factor demand from the infrastructure sector, which generates higher wages and hence provides an incentive for workers (and firms) to locate there.

Looking at this result from a social planner's perspective, we find that free riding for a small or peripheral region is beneficial. A region in need of a better con-

[8] Again, note that it is not the intention or purpose of this paper to investigate the consequences of tax competition, but to look at regional development and policy, also from the peripheral region's perspective.

nection to the 'center', therefore, should not contribute to public infrastructure investments if initially the trade costs are high (i.e., before implementing any policy measures). The reason is that the free riding region keeps their tax revenues within the region and generates additional income through the lump-sum redistribution of the tax revenues among its population. The strengthening of the income base of the citizens of the free riding region also reduces the nominal income inequalities between core and periphery, unless the free riding region happens to be the large region in the partially agglomerated equilibrium (i.e., the core). A better infrastructure, although financed by a different region, develops the connections between those regions such that it becomes possible, also for the more remotely located region, to attract additional firms. Note, that instead of tax competition, the role of competition in this model is played by the independent decision of each regional government to set its κ, i.e. to divide its government expenditures between infrastructure investment and lump-sum transfers to its respective population.

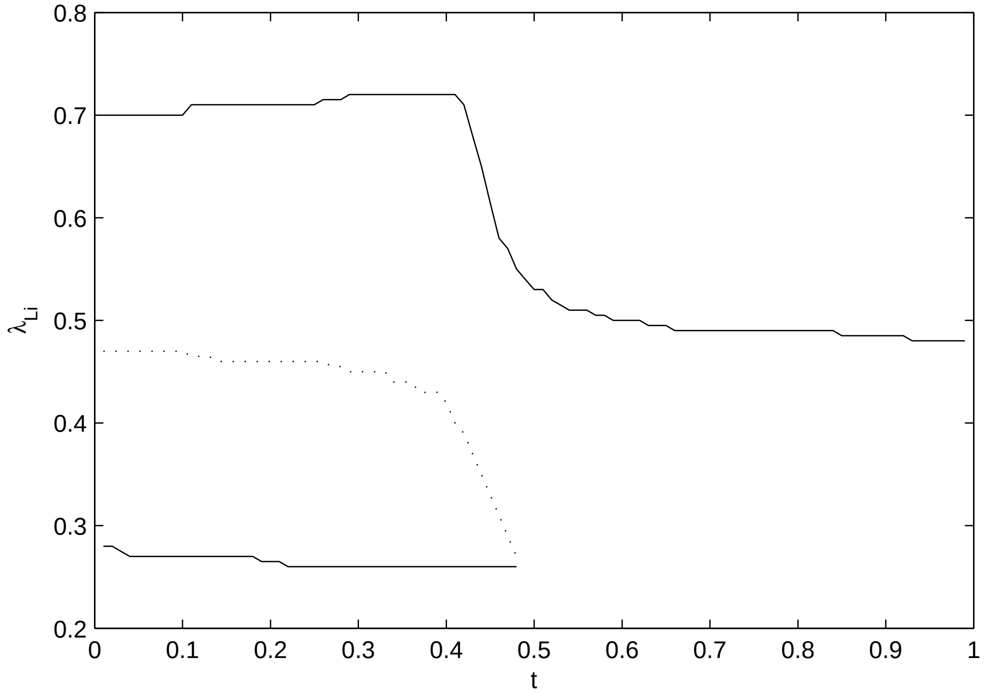

Figure 6: Bifurcation diagram with region i free riding in infrastructure provision, and $\lambda_T = 0.5$.

3.5 Asymmetric Taxation and Size of the Regions

Asymmetric taxation between the two regions exclusively leads to agglomeration in the region with the lower tax rate (region j in our case; $tax_i = 0.5$ and $tax_j = 0.2$). This is quite an intuitive result since the region with a lower tax rate attracts more firms which in turn attract more workers (see Figure 7). Note that region i always remains small in this scenario (it is the only stable equilibrium), while region j is rather large.

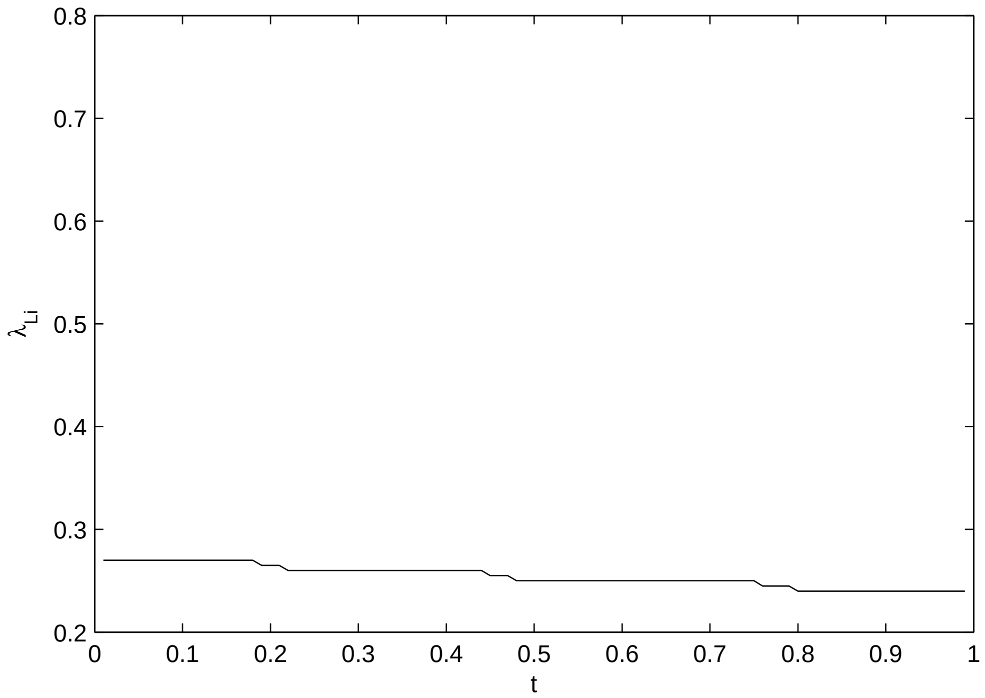

Figure 7: Bifurcation diagram with $tax_i = 0.5$, and $\lambda_T = 0.5$.

A similar result, though through a different channel, occurs when the endowment with land (T) differs across region. In this case, there is agglomeration in the region endowed with more land. This is due to the fact that both goods, X and Z, require some T in production and X-sector firms also need land as a fixed input for setting up their production plant. Only at very low initial trade costs, agglomeration in the smaller region (in terms of T) may be a long run stable equilibrium (for $t \lessapprox 0.17$ for $T_i = 0.66$).

Varying the scaling and efficiency parameter β shows that a higher β leads (i) to a more significant reduction in trade costs (τ) which in turn makes (ii) the partially agglomerated equilibrium more sustainable, also at higher initial values of trade costs (t).

Looking at region i's share of manufacturing firms and at the infrastructure provided in region i, we note several things. First, if region i has less than about 20% of the world's endowment with labor (see the λ_{Li}-axis in Figures 8 and 9, left panel in each case), there are no manufacturing firms headquartered in region

i (Figure 8), and thus there is also no infrastructure being provided by region i (Figure 9)[9]. The two right hand panels of these two figures show the same analyses for asymmetric taxation ($tax_i = 0.5$, while tax_j remains at its original value of 0.2). Figure 8 shows that due to the higher tax rate in region i, the area without any manufacturing firms in region i increases by about 50%, and hence also the area where region i is not able to provide public infrastructure. From Figure 7 we know that the only stable equilibrium configuration for workers emerges when region i hosts about 25% of the workers (in region j there are the remaining about 75%). Hence, in this asymmetric taxation-scenario, only the region with lower taxes (i.e., region j) will host manufacturing firms (for all values of t or τ). Thus, region i needs to import all of its manufacturing goods from region j. This constitutes the same result as a full-agglomeration equilibrium of a standard model, despite region i hosting some of the workers in our scenario. The tax-rate-differential (of 30 percentage points) between both regions outweighs the rather large share of workers in region i. Looking at the right panel of Figure 8, if region i was very large (i.e., at a large λ_{Li}), manufacturing firms would have an incentive to relocate to j because of the lower tax rate there, until the stable equilibrium is reached.

[9]Note that in those cases where the share of manufacturing firms in region i is zero and no infrastructure is being provided, also the tax revenues and hence government expenditures are zero.

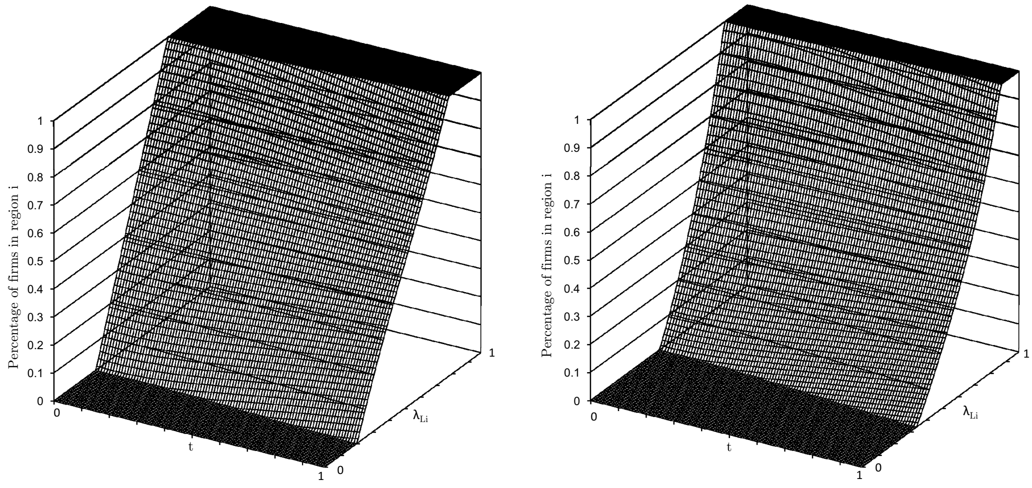

Figure 8: Share of firms in region i (left panel, benchmark case) and with $tax_i = 0.5$ and $tax_j = 0.2$ (right panel).

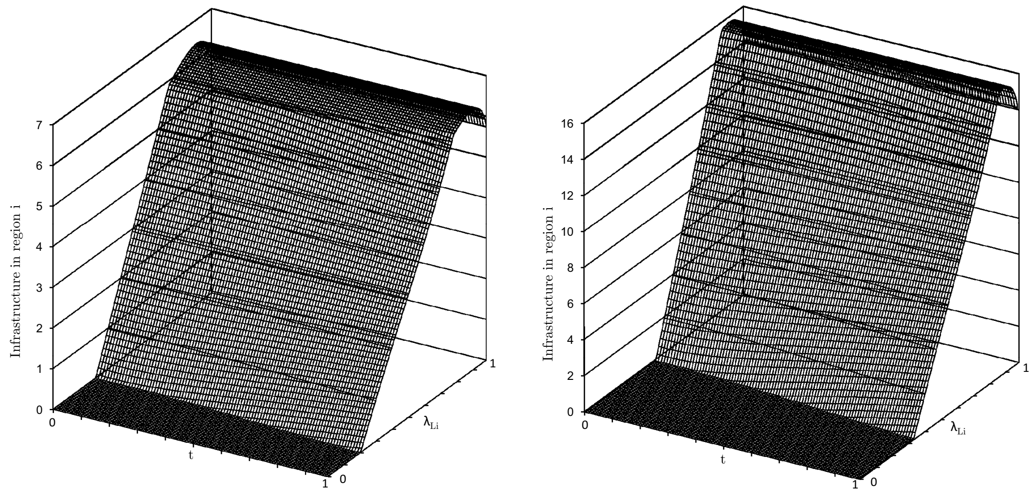

Figure 9: Infrastructure provided by region i (left panel, benchmark case) and with $tax_i = 0.5$ and $tax_j = 0.2$ (right panel).

4 Sensitivity Analysis

Moderate variations of the elasticity of substitution between varieties of the differentiated manufacturing good, σ, and the technical rate of substitution between input factors L and T, ρ, show that the model's reactions are qualitatively stable. In terms of the bifurcation loci (and bifurcation diagrams), this means that they are either vertically stretched or compressed (i.e., more or less pronounced agglomeration equilibria due to changes in σ) or shifted to the left (right) (i.e., more (less) sustainable agglomeration or dispersion equilibria for higher (lower) values of ρ), as it has to be expected qualitatively by the respective parameter change. The same applies for the income expenditure share for manufactures, μ, where a higher (lower) μ leads to stronger (weaker) agglomeration in equilibrium.

Apart from varying these modelling parameters, we also simulate variations of the two policy parameters *tax* and κ, where the main focus is placed on. We refer to these two parameters as 'policy parameters', since these two values may be chosen by the regional decision makers. Additionally, various t's for these two scenarios are being tested. Varying the tax rate (*tax*) and the fraction of government expenditures devoted to infrastructure building (κ) shows no effect as the initial trade costs are high ($t = 0.7$). We have first chosen a rather high value of t for this analysis, in order to be able to reflect the situation that may occur between centrally and peripherally located regions. As all the bifurcation diagrams show, there is always only a stable symmetric equilibrium at these values of t. At $t = 0.2$, the opposite picture develops. Here, agglomeration is a sustainable equilibrium for all values of both *tax* and κ, since trade costs are simply low enough to render agglomeration sustainable, no matter how the other parameters are configured. Hence, variations of *tax* and κ only affect more integrated economies with lower trade costs.

As the fraction of government expenditures devoted to infrastructure investments, κ, varies from 0 to 1, interesting insights may be gained as far as the development of trade costs (τ) is concerned. The equal division of the government expenditures between infrastructure investments and transfers to the population (i.e., $\kappa = 0.5$) leads to a reduction of trade costs by about 9% of the goods' price. An additional increase of κ up to $\kappa = 1$ reduces trade costs only by a further 3% [10]. Thus, a region's government needs to account for this decreasing effectiveness of infrastructure investments when deciding on its policy measures. A higher efficiency of infrastructure provision (β) increases the reduction of trade costs, while the decreasing effectiveness of infrastructure investments remains evident.

Variations of the tax rate do not show any significant changes in the core-

[10] This comparison refers to the no-tax scenario.

periphery patterns as long as they are coordinated in both regions. Also, the development of tax revenues and infrastructure provision is unaffected by coordinated changes in the tax rate. However, the effects on trade costs are noteworthy. No matter what the tax rate is, when workers (and industries) are concentrated in either of the regions trade costs are lowest (this corresponds to the partially agglomerated equilibria of Figure 2, whereas they tend to be somewhat higher when the regions are of equal size.

5 Conclusions

In this paper, we look at tax-financed public infrastructure investment and its impact on the development of regional core-periphery patterns. Associated issues are the impact of potential regional policy measures on (i) the financing-structure of those infrastructure investments, (ii) the core-periphery structure in terms of the distribution of the population and firms, and (iii) subsequently also on the income-base of the regions.

The vehicle we employ in this paper is a simple New Economic Geography model with endogenized transport (trade) costs. The endogenization of trade costs comes in two steps. First, introducing a corporate sales tax generates revenues for the regions. Regional governments allocate these tax revenues between infrastructure investments and a lump-sum transfer to their respective region's population. Second, the infrastructure is being built using the same production technology as for the manufactured good. The quantity of infrastructure provided is weighted by a scaling and efficiency parameter determines the amount by which the transport costs are being reduced. These reduced transport costs enter into the model influencing the firms' decisions on location and trade.

Our results may be summarized as follows. First, confirming the previous results by Andersson and Forslid (2003) or Baldwin et al. (2003), although in different settings, we show that the introduction of costly public investment in infrastructure leads to more pronounced agglomeration: the core-periphery pattern becomes more sustainable for a wider range of (initial) trade costs. Increasing either the tax rate or the fraction of public revenues devoted to infrastructure renders the agglomeration equilibrium even more sustainable, unless the tax rate does not become too high.

Second, the effects on prices are the following. With respect to the regions sizes, for the region ending up as periphery, generally the price-index for manufacturing goods decreases, since the negative import-price effect prevails on the positive price-index effect. This effect occurs due to the relocation of firms away from the periphery into the core (where manufacturing goods become cheaper due to specialization), and through importing these (cheaper) manufacturing goods in the periphery. Trade costs are low enough to render this possible. For the region ending up as the core, the price-index is rather high, since the distortionary effect of increased taxation (used to finance infrastructure) dominates. As trade costs approach zero, the price-index in the setting with infrastructure spending approaches the value of the same index in the setting without infrastructure spending. As trade costs increase, the former price-index decreases, thereby displaying the beneficial effects of public investment.

Third, free riding is beneficial for the periphery − in other words, centrally financed infrastructure investments promote economic development in the periphery. Put differently, regional or structural policy measures such as the EU's structural funds programs helping peripheral regions to improve their infrastructure make sense, at least to a certain extent. We show that infrastructure being financed by the central region only makes its equilibrium agglomeration path sustainable over the whole range of (initial) trade costs. Furthermore, the periphery can devote all its tax revenue to local demand support, thereby generating additional income and a positive home market effect (which actually ends up driving the catch-up process). Again, note that there is no tax competition scenario in our paper, and therefore the free riding scenario may not be interpreted in its classical sense, but we rather suggest to look at this from a policy point of view.

However, our framework lacks interregional tax competition, and the strategic interactions between core and periphery regarding infrastructure building. We feel that in this direction, enriched by public finance considerations about different types of taxation on different agents, some promising analysis can be carried out in the future – in particular in the light of the recent and future enlargement-process of the European Union.

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