

No Taxation without... Infrastructure

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Abstract

This paper presents a New Economic Geography model with distortionary taxation and endogenized transport costs. Tax revenues (i.e. government expenditures) are used to finance a public good, infrastructure. The infrastructure subsequently reduces transport costs, which thus become endogenized. This causes agglomeration to become more sustainable. There is decreasing marginal utility of infrastructure. Hence, regional policy makers need to carefully evaluate the trade-off between infrastructure provision and transfers to their population when deciding on their policy mix.

Key words: New Economic Geography; Taxation; Endogenous Transport Costs; Infrastructure;

JEL classification: F12; H25; H54; R12;

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1 Introduction

What are the economic and territorial aspects that matter most when it comes to attracting firms to a given location? Attempting to give a adequate answer to this question has engaged economists, industrial theorists, politicians, urban planners and entrepreneurs at least since the contribution of Marshall (1891). The debate took different perspectives according to the focus, ranging from economic development and growth when talking about triggering an industrial take-off in areas economically lagging behind, to industrial organization when focusing on developed areas subject to structural changes and/or sectorial shifts. Universal consensus has been reached on the importance of certain aspects, such as the protection of property rights, is widespread on others (e.g. infrastructure), whereas debate is still very much alive on issues such as the qualitative and quantitative role played by public interventions.

In this paper we follow an approach, which constitutes the basis and the motivation for a theoretical investigation, which links the firms' location decision with the different stages of production. Following a kind of heuristic approach, and taking for granted the protection of property rights¹, we imagine the firms' location decisions as being structured as follows: (i) Accessibility of the location, (ii) efficient setup of the production facilities and develop production, (iii) obtaining a good profit margin, and (iv) good access to international markets. If these points can be considered as being approximately correct, we may identify the following territorial aspects as being crucial for these stages: for points (i) and (iv) it is certainly infrastructure which is relevant, for (ii) it is the quality and qualification of the labor force as well as local public goods, and for (iii) taxation and 'territorial costs'².

This paper aims at exploring the links between those issues, leaving aside everything related to the quality of the labor force (such as education and learning),

¹Questioning this issue might be more appropriate for investigating developing countries, rather than EU regions.

²By 'territorial costs' we mean all the monetary and non-monetary costs associated with locating in a given region, for instance urban, environmental, bureaucratic costs.

which could be the exclusive topic of a future research project, hence we focus on taxation and infrastructure. The vehicle being employed in this paper is a simple New Economic Geography model following Krugman (1991a, b) and Fujita et al. (1999), where we put two things into the focus of research, (i) endogenizing transport cost, and (ii) regional governments and taxation.

In New Economic Geography, transport costs are usually modelled using the 'iceberg' assumption, formally introduced by Samuelson (1952, 1954), even though the first formulation dates back to Von Thünen (1826).

Bottazzi and Ottaviano (1996) present an overview of various attempts to deal with transport costs in international trade, and provide a general model to evaluate iceberg transport costs, and other alternatives of modelling transportation in international trade.

Anderson and Van Wincoop (2004) provide a theoretical and empirical analysis of all costs involved in shipping a good from producer to final consumer, also addressing some important measurement issues. Duranton and Storper (2005) start from the empirical observation of declining transport costs and propose a model of vertically linked industries in which providing a given level of quality to suppliers becomes more costly with distance. Their conclusion is that, due to the fact that lower transport costs imply that higher quality inputs are traded in equilibrium, trade costs can increase despite lower transport costs.

Larch (2005) provides a model of international trade with multinational enterprises with a separate and multinationalized transport sector. This allows for instance to relax the assumption that transport costs are the same for all goods, and to disentangle the production of goods and transport services. However, there are still exogenously given transport costs for shipping goods.

Kilkenny (1998) deals with transport costs in a general equilibrium model using a bilateral regional Social Accounting Matrix, specifically aimed at rural development issues. She shows the existence of an initially negative, but ultimately positive relationship between a reduction of transport costs and rural development. The basic intuition is that reducing transport costs from rural locations

may also reduce transport costs to rural areas.

All these approaches leave considerable space for introducing the present approach of endogenizing transport costs in a New Economic Geography model using tax-financed, publicly provided infrastructure. Hence, infrastructure fosters agglomeration.

Andersson and Forslid (2003) provide a New Economic Geography model with taxation and producing a public good. They use the analytically solvable model of Forslid and Ottaviano (2003) and analyze how the tax competition game between countries affects the distribution of workers. They find that even perfectly coordinated tax increases across countries destabilize the dispersion equilibrium of workers.

Baldwin and Krugman (2004) focus on international tax competition and start from the observation that in the European integration process a downward levelling of tax rates has not been observable so far, but there is rather a gradual increase in taxation as the integration process moves on. Similarly to Puga's (1999) bell-shaped agglomeration pattern which emerges during integration (i.e. disparities between regions first become large, then diminish), Baldwin and Krugman (2004) find the same for tax rates. By using a simple two-region economic geography model in which governments collect taxes from firms' profits, they challenge the result of the standard tax-competition literature predicting a race to the bottom in tax rates in order to attract firms. They insert agglomeration issues to explain the dynamics of industrial integration and tax rates in Europe. Thus, there is some theoretical ground to further investigate the relationship between tax rates and agglomeration patterns.

The present paper aims at endogenizing transport (trade) costs in a standard New Economic Geography model. The endogenization of transport 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 which 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.

It can be shown that public infrastructure investments lead to more pronounced agglomeration patterns, i.e. the concentration of industries is fostered, which confirms previous results from Andersson and Forsild (2003) or Baldwin et al. (2003). 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, since imported product varieties become cheaper. The reduction of transport costs is very effective for high initial values of trade costs (i.e. before infrastructure investments), and it shows 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 modelling - 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, Section 3 briefly lines out the analyses conducted. Section 4 investigates the core-periphery patterns, as well as the effects of the infrastructure provided on trade costs and firms, whereas Section 5 looks at the sensitivity of the model and provides additional insights regarding the major policy parameters. The last Section concludes.

2 The Model

2.1 Households

There are two regions, referred to as region 1 and 2, and indexed as $\{i, j\} = \{1, 2\}$. Both regions produce two 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 differentiated in the usual Dixit and Stiglitz (1977) fashion. Firms may sell on the local market and export to the other region, where the number of firms from region i is denoted by n_i . Therefore, X_{ij} are the exports of region i -based firms to region j ³. X_{ic} denotes the consumption of X in region i , being a CES aggregate of the individual varieties. The utility of region i (U_i) can thus be formulated as follows:

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

where μ denotes the Cobb-Douglas expenditure share for differentiated products, and $\sigma > 1$ is the elasticity of substitution between varieties.

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 (as outlined below), the transport costs are not exogenously given in this setting.

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

³Whenever we use i and j from the set $\{1, 2\}$, this implies that $i \neq j$.

variety:

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

The first-stage budgeting problem leads to:

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

where Y_i denotes total expenditures of consumers in region i . 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

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

Note that due to the adopted assumptions about technology, factor markets, and demand – in equilibrium – $p_i \equiv p_{ii} = p_{ji}$ and $p_j(1+\tau) \equiv p_{ji} = p_{ii}$. The second-stage budgeting yields the division of expenditures between the two sectors:

$$X_{ic} = \frac{\mu}{P_i} Y_i, \quad (5)$$

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

2.2 Taxation, Infrastructure, and Transport Costs

In our model we aim at endogenizing transport cost by tax-financed and publicly provided infrastructure.

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

$$\Pi_i = p_i (X_{ii} + X_{ij}) (1 - tax_i) - c_{X_i} (X_{ii} + X_{ij}) - FC, \quad (7)$$

where Π_i are the profits of a region i firm, c_{X_i} are its variable unit costs (i.e., marginal costs) and FC are fixed costs.

The distortionary effect of this tax can be seen in the resulting pricing equation:

$$p_i = c_{X_i} \frac{\sigma}{\sigma - 1} \frac{1}{1 - tax_i} \quad (8)$$

Hence, the total tax revenues, and subsequently total government spending in region i is

$$G_i = tax_i p_i n_i (X_{ii} + X_{ij}) + TR_i, \quad (9)$$

where TR_i are transfers by other administrative bodies to region i 's government, such as contributions by the European Commission's structural funds to regional development policy measures. These transfers are exogenous to the model, i.e. public spending in region i can be higher than its actual budget without incurring a deficit.

From 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. For simplicity, we assume that the production technology for infrastructure is the same as for manufacturing goods, but without being subject to economies of scale. Thus, the amount of infrastructure being provided by region i 's government is

$$I_i = \frac{\kappa_i G_i}{a_{Lxi} w_{Li} + a_{Txi} w_{Ti}}. \quad (10)$$

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

$$\tau = \frac{t_i}{(I_i + I_j + 1)^\beta}, \quad (11)$$

where t_i is an 'initial value' for transport costs, which also corresponds to a 'no-tax equilibrium' without taxes and hence infrastructure, i.e. to the standard new economic geography model with exogenously given transport costs. It may also be regarded as general impediments to trade between the two regions. $0 < \beta < 1$ is a scaling parameter which also reflects the 'effectiveness' of the infrastructure provided.

2.3 Factor Markets, Production and Income

There is perfect competition in the Z -sector, and each firm produces under constant returns to scale using a CES technology, employing labor (L) and land (T) (where ' b ' is the coefficient for T and ' $1 - b$ ' for L), with an elasticity of substitution of $1/(1 - \rho_z)$ and $(-\infty < \rho_z < 1)$. As all firms face the same factor prices and the CES technology is homothetic, all firms in a region face the same unit input coefficients. The region specific unit input coefficient for the two factors of Z -production can be derived by cost minimization subject to this CES technology:

$$a_{Lzi} = \left(\frac{w_{Li}}{1-b} \right)^{\frac{1}{\rho_z-1}} \left[\left(\frac{w_{Ti}^{\rho_z}}{b} \right)^{\frac{1}{\rho_z-1}} + \left(\frac{w_{Li}^{\rho_z}}{1-b} \right)^{\frac{1}{\rho_z-1}} \right]^{-\frac{1}{\rho_z}} \quad (12)$$

$$a_{Tzi} = \left(\frac{w_{Ti}}{b} \right)^{\frac{1}{\rho_z-1}} \left[\left(\frac{w_{Ti}^{\rho_z}}{b} \right)^{\frac{1}{\rho_z-1}} + \left(\frac{w_{Li}^{\rho_z}}{1-b} \right)^{\frac{1}{\rho_z-1}} \right]^{-\frac{1}{\rho_z}} \quad (13)$$

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

$$c_{Zi} \geq a_{Lzi}w_{Li} + a_{Tzi}w_{Ti} \quad \perp \quad Z_{ii} \geq 0, \quad (14)$$

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

$$c_{Zi} \geq q_j \quad \perp \quad Z_{ij} \geq 0. \quad (15)$$

There is monopolistic competition in the X -sector, and again each firm produces under a CES technology, using labor (L) and land (T) (where ' a ' is the coefficient for L and ' $1 - a$ ' for T), with an elasticity of substitution of $1/(1 - \rho_x)$ and $(-\infty < \rho_x < 1)$. As all firms face the same factor prices and the CES technology is homothetic, all firms in a region face the same unit input coefficients. The region specific unit input coefficient for the two factors of X -production can be derived by cost minimization subject to this CES technology:

$$a_{Lxi} = \left(\frac{w_{Li}}{a} \right)^{\frac{1}{\rho_x-1}} \left[\left(\frac{w_{Li}^{\rho_x}}{a} \right)^{\frac{1}{\rho_x-1}} + \left(\frac{w_{Ti}^{\rho_x}}{1-a} \right)^{\frac{1}{\rho_x-1}} \right]^{-\frac{1}{\rho_x}} \quad (16)$$

$$a_{Txi} = \left(\frac{w_{Ti}}{1-a} \right)^{\frac{1}{\rho_x-1}} \left[\left(\frac{w_{Li}^{\rho_x}}{a} \right)^{\frac{1}{\rho_x-1}} + \left(\frac{w_{Ti}^{\rho_x}}{1-a} \right)^{\frac{1}{\rho_x-1}} \right]^{-\frac{1}{\rho_x}} \quad (17)$$

Additionally, X -sector firms require labor (a_{Lni}) and land to set up plants (a_{Tni}), leading to increasing returns to scale in production.

Factor market clearing in region i for labor (L_i) and land (T_i) requires

$$L_i \geq a_{Lxi}n_i(X_{ii} + X_{ij}) + a_{Lni}n_i + a_{Lxi}I_i \quad \perp \quad w_{Li} \geq 0, \quad (18)$$

$$\begin{aligned} T_i &\geq a_{Txi}n_i(X_{ii} + X_{ij}) + Z_{ii} + Z_{ij} + \\ &a_{Tni}n_i + a_{Txi}I_i \quad \perp \quad w_{Ti} \geq 0. \end{aligned} \quad (19)$$

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, equation (8) shows the price setting behavior by firms

$$p_i = c_{Xi} \frac{\sigma}{\sigma - 1} \frac{1}{1 - tax_i}. \quad (20)$$

Free entry 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.

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

$$FC_{ni} \geq \frac{p_i(X_{ii} + X_{ij})}{\sigma} (1 - tax_i) \quad \perp \quad n_i \geq 0. \quad (21)$$

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

$$Y_i = w_{Li}L_i + w_{Ti}T_i + (1 - \kappa_i)G_i \quad (22)$$

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:

$$\omega_{Li} = w_{Li}P_i^{-\mu}q_i^{\mu-1} \quad (23)$$

$$\omega_{Ti} = w_{Ti}P_i^{-\mu}q_i^{\mu-1}. \quad (24)$$

3 Analyzing the Model

The analysis of the model is conducted along several lines of investigation. First, the standard agglomeration structure will be evaluated, which means for this model, that the 'initial value' of transport costs, i.e. the value of t that would apply for a scenario without taxes, varies from 1 to 99% of the price of X -goods. Since publicly provided and tax-financed infrastructure might be interpretable as quite many different things, not just, say, better roads reducing travel time, and hence physical transport costs between places, 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. Secondly, we look at variations of the parameters which are of our primary interest, the tax rate (tax), and the fraction of government expenditures devoted to infrastructure building (κ). This also serves to analyze the model's sensitivity to parameter changes. Thus, the main focus of the following analyses is put on investigating how the parameters which may be influenced by policy makers shape the economy. In contrast to the standard new economic geography models 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 is mobile across regions⁴.

⁴We have chosen the following parameter values for our simulations: $\sigma = 4$, $\mu = 0.35$, $\beta = 0.1$, $a = b = 0.8$, $\rho_x = \rho_z = -0.5$, $L = L_1 + L_2 = 60$, $T = T_1 + T_2 = 100$, $t = 0.7$ if constant, $tax_i = tax_j = 0.2$ if constant, $\kappa_i = \kappa_j = 1$ if constant.

4 Core-Periphery Patterns, Firms, and Trade Costs

Varying the initial impediments to trade (t) between 1 and 99% of the price of manufacturing goods gives the usual bifurcation diagrams as in standard new economic geography analyses (see Figure 1)⁵. 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 there is no full-agglomeration equilibrium. However, there is still partial agglomeration at lower initial values of trade costs, and a symmetric equilibrium at higher values of t . 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 for higher initial (i.e. no-tax) values of trade costs the agglomerated equilibrium to remain stable. The no-tax, no-infrastructure bifurcation diagram corresponds to Figure 2. This result confirms Baldwin et al. (2003, chapter 17), who find that infrastructure which facilitates interregional trade leads to increased spatial concentration. Baldwin et al. (2003, chapter 17) 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.

– Figures 1 and 2 –

The lower trade costs due to public infrastructure investments influence also 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, 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.

⁵In all the bifurcation diagrams, solid lines denote long-run stable equilibria, whereas dotted lines depict unstable equilibria.

Comparing the ratios of the price indices for manufacturing goods in the benchmark case to the no-tax (and hence no-infrastructure) scenario, it turns out that the differences in price index ratios is high at high trade costs and approaches zero as trade costs approach zero. 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 also in the periphery despite hosting less firms as trade costs diminish (for the latter, see also Figure 9).

– Figure 3 –

Looking at the tax revenues, which are subsequently government expenditures, we find a Laffer-curve shape as the size of a region varies. The maximum tax revenues are reached when a region hosts approximately around 75% of the workers (see Figure 4). Note that this corresponds to the size of the larger region in the partially agglomerated equilibrium of Figure 1.

– Figure 4 –

Changes in the exogenously given tax rate (*tax*) cause the agglomeration equilibrium to be sustainable for a larger range of values of t , provided that the tax rate does not become too high (see Figure 5). Quite similar effects to changes in the tax rate are observable when 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 a $\kappa_i = \kappa_j = 0$ does not lead to a symmetric equilibrium only. Of course, in this case no infrastructure can be provided to reduce trade costs, but at lower initial values of t also in this case a core-periphery structure emerges.

– Figure 5 –

If one region free rides in infrastructure provision, i.e. $\kappa_i = 0$ (while $\kappa_j > 0$), a somewhat different picture develops (see Figure 6). 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 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 $\lambda_L = 0.5$. 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 that pronounced as one might have expected it. Note that the free riding region is almost of equal size as the other one ($\lambda \approx 0.48$). This is due to the fact that there is no interregional tax competition in the present setup, and that the region which free rides in infrastructure provision transfers its 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.

Looking at this result from a social planner's perspective, we find that free riding for a smaller, or a peripheral region is beneficial. A region which should be better connected to central regions by implementing regional policy measures should, therefore, not contribute to public infrastructure investments if initially the trade costs are high. This is due to the fact 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. 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.

– Figure 6 –

Asymmetric taxation between the two regions exclusively leads to agglomeration in the region with the lower tax rate (region j in this case). This is a quite

intuitive a result since the region with a lower tax rate attracts more firms which in turn attract more workers (see Figure 7). A similar result, though through another 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 ($t \lesssim 0.18$) also agglomeration in the smaller region (in terms of T) may be a long run stable equilibrium (see Figure 8).

– Figures 7 and 8 –

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 firms and 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 9 and 10, left panel in each case), there are no firms headquartered in region i (Figure 9), and thus there is also no infrastructure being provided by region i (Figure 10). 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 initial value of 0.2). Figure 9 shows that due to the higher tax rate in region i , the area without any firms in region i increases by about 50%, and hence also the area where region i is not able to provide public infrastructure⁶.

– Figures 9 and 10 –

Turning to the endogenized trade costs (τ), and investigating the influence of the public infrastructure provision on the reduction of trade costs, we generally

⁶Note that in those cases where the share of firms in region i is zero and no infrastructure is being provided, also the tax revenues and hence government expenditures are zero.

find the following. The higher the initial trade costs are, the larger the effect of infrastructure, and thus the larger the reduction of trade costs will be (see Figure 11). Take low initial impediments to trade of $t = 0.21$ as an example. As Figure 11 shows, the actual trade costs (τ) in the presence of public infrastructure investments result to be at $\tau \approx 0.17$. In contrast, at higher impediments to trade, say $t = 0.91$, $\tau \approx 0.74$. Hence, the absolute decrease of trade costs caused by infrastructure investments is higher if the initial impediments to trade are high. Furthermore, 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 trade costs, it makes more sense to strengthen the infrastructure network than for quite integrated or centrally located regions where trade costs are already quite low.

Some of the above findings can easily be seen by inspecting equations 9, 10, and 11. Plugging equation 9 into 10, we obtain

$$I_i = \frac{\kappa_i [tax_i p_i n_i (X_{ii} + X_{ij}) + TR_i]}{a_{Lxi} w_{Li} + a_{Txi} w_{Ti}}, \quad (25)$$

and plugging the resulting equation 25 into 11 we have

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

Hence, from equation 25, public infrastructure investments are generally facilitated by higher taxes (since there is more money to be spent), a larger number of firms and higher quantities being produced in the respective region (more firms producing higher quantities pay more taxes). Consequently, this also leads to larger reductions of trade costs (see equation 26). Additionally, a higher efficiency of the infrastructure provided (i.e., a higher β), also leads to a stronger reduction of trade costs. Also some external funding (where 'external' means external to regional budgets) 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.

5 Sensitivity Analysis

The sensitivity of the model can be analyzed in several ways, which also provide additional insights. Apart from doing the fairly standard simulation exercise of varying transport costs (which means varying the initial impediments to trade, t , in this paper), we also simulate variations of the two policy parameters tax and κ . Additionally, various t 's for these two scenarios are being tested.

5.1 Variations of μ , σ and ρ

Variations of the elasticity of substitution between varieties of the differentiated manufacturing good, σ , and the technical rate of substitution between input factors, ρ show that the model's reactions are very stable. In terms of the core-periphery patterns, this means that they are either stretched or compressed (i.e., more or less pronounced agglomeration) or shift to the left or to the right (i.e., more or less sustainable agglomeration or dispersion) as it has to be expected by the respective parameter change. The same applies for the income expenditure share for manufactures, μ , where a higher μ leads to stronger agglomerations in equilibrium.

5.2 Variations of the tax rate and the government expenditures for infrastructure

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 the analyses, in order to be able to reflect the situation that may occur between central and peripheral regions. As all the bifurcation diagrams from before show, there is always a stable symmetric equilibrium only at these values of t . Hence, variations of tax and κ only affect more integrated economies with lower trade costs.

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.

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. Figure 12 (left panel) shows that an 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 0.09. An additional increase of κ up to $\kappa = 1$ reduces trade costs only by a further 0.03 points. Thus, a region's government needs to account for this decreasing utility of infrastructure investments when deciding on its policy measures. The right panel of Figure 12 shows that a higher efficiency of infrastructure provision (β) increases the reduction of trade costs, while the decreasing utility of infrastructure investments remains evident.

– Figure 12 –

Variations of the tax rate do not show any significant changes to core-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, trade costs are lowest when workers (and industries) are concentrated in either of the regions, whereas they are comparatively high when the regions are of equal size (see Figure 13).

– Figure 13 –

6 Conclusions

In this paper we have endogenized transport (trade) costs in a standard New Economic Geography model. The endogenization of transport 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.

It can be shown that public infrastructure investments lead to more pronounced agglomeration patterns, i.e. the concentration of industries is fostered, which confirms previous results from Andersson and Forsild (2003) or Baldwin et al. (2003). 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, since imported product varieties become cheaper. The reduction of transport costs is very effective for high initial values of trade costs (i.e. before infrastructure investments), and it shows only little 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 modelling - 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. Moreover, there is a decreasing utility of infrastructure investments, which means for regional policy makers that they carefully have to decide on how to choose their policy mix between supporting infrastructure investments and transfers to the population.

7 References

- Andersson, F. and R. Forslid (2003): Tax Competition and Economic Geography, *Journal of Public Economic Theory* 5(2), pp. 279-303.
- Anderson, J.E. and E. van Wincoop, E. (2004): Trade Costs, *NBER Working Paper* 10480.
- Baldwin, R.E., Forslid, R., Martin, P., Ottaviano, G.I.P., and F. Robert-Nicoud (2003): *Economic Geography and Public Policy*, Princeton University Press, Princeton.
- Baldwin, R.E. and P. Krugman (2004): Agglomeration, Integration, and Tax Harmonization, *European Economic Review* 48, pp. 1-23.
- Bottazzi, L. and G.I.P. Ottaviano (1996): Modelling Transport Costs in International Trade: A Comparison among Alternative Approaches, Working Paper no. 105, Innocenzo Gasparin Institute for Economic Research.
- Dixit, A.K. and J.E. Stiglitz (1977): Monopolistic Competition and Optimum Product Diversity, *American Economic Review* 67(3), pp. 297-308.
- Duranton, G. and M. Storper (2005): Rising Trade Costs? Agglomeration and Trade with Endogenous Transaction Costs, *CEPR Discussion Paper* 4933.
- Forslid, R. and G.I.P. Ottaviano (2003): An Analytically Solvable Core-Periphery Model, *Journal of Economic Geography* 3, pp. 229-240.
- Fujita, M., Krugman, P. and A.J. Venables (1999): *The Spatial Economy - Cities, Regions, and International Trade*, The MIT Press, Cambridge (MA).
- Fujita, M. and J.-F. Thisse (2002): *Economics of Agglomeration*, Cambridge University Press, Cambridge (MA).
- Kilkenny, M. (1998): Transport Costs and Rural Development, *Journal of Regional Science* 38(2), pp.293-312.

- Krugman, P. (1991a): *Geography and Trade*, Leuven University Press and Cambridge University Press, Leuven, Cambridge.
- Krugman, P. (1991b): Increasing Returns and Economic Geography, *Journal of Political Economy* 99(31), pp. 483-99.
- Larch, M. (2005): The Multinationalization of the Transport Sector, Discussion Paper TI 2005-019/2, Tinbergen Institute, Rotterdam.
- Marshall, A. (1891): *Principles of Economics*, vol. 1, second edition, MacMillan, London, New York.
- Puga, D. (1999): The Rise and Fall of Regional Inequalities, *European Economic Review* 43, pp. 303-334.
- Samuelson, P.A. (1952): The Transfer Problem and Transport Costs: The Terms of Trade when Impediments are Absent, *Economic Journal* LXII, 278-304.
- Samuelson, P.A. (1954): The Transfer Problem and Transport Costs, II: Analysis of Effects of Trade Impediments, *Economic Journal* LXIV, 264-289.
- Thünen, J.H. von (1921 [1826]): *Der isolierte Staat in Beziehung auf Landwirtschaft und Nationalökonomie*, Neudruck der Ausgabe letzter Hand (2. bzw. 1. Auflage, 1842 bzw. 1850), Zweite Auflage, Verlag von Gustav Fischer, Jena.

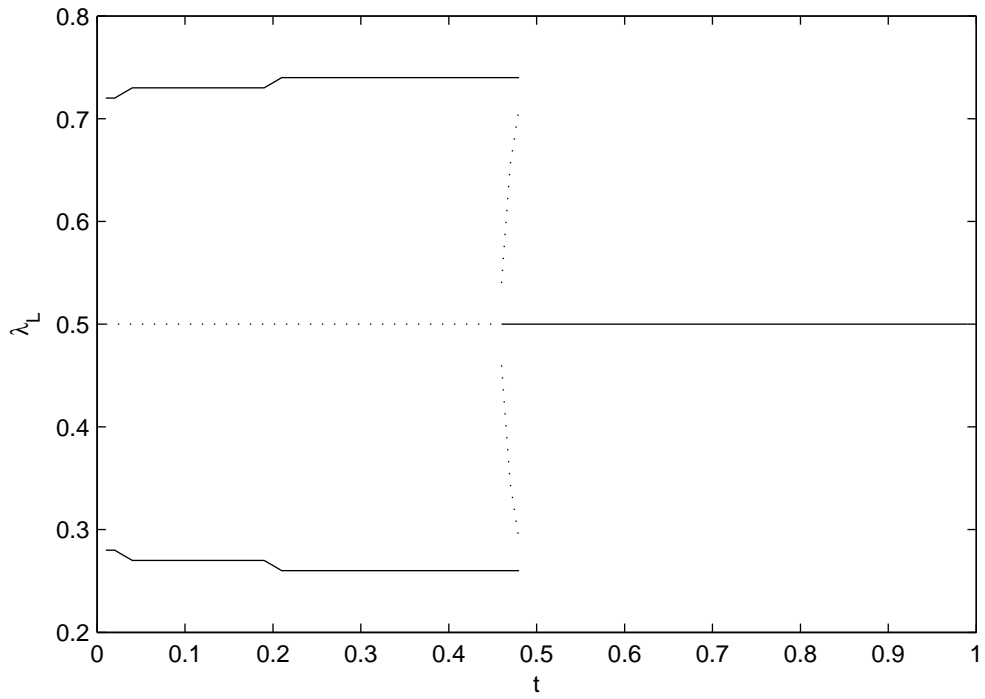


Figure 1: Core-periphery pattern with $\lambda_T = 0.5$.

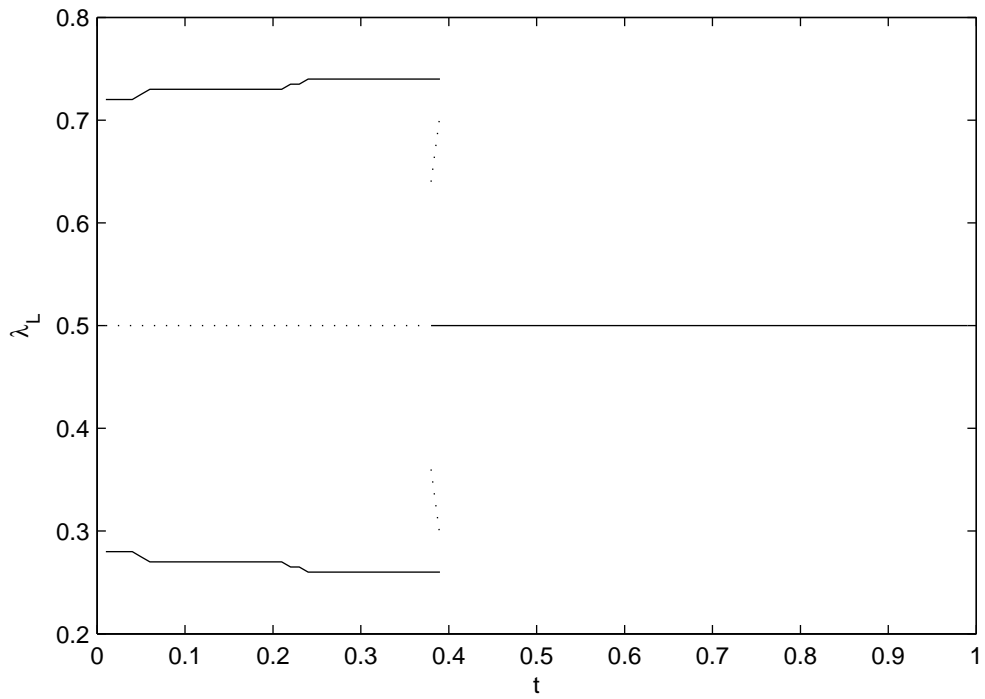


Figure 2: Core-periphery pattern without taxation, and $\lambda_T = 0.5$.

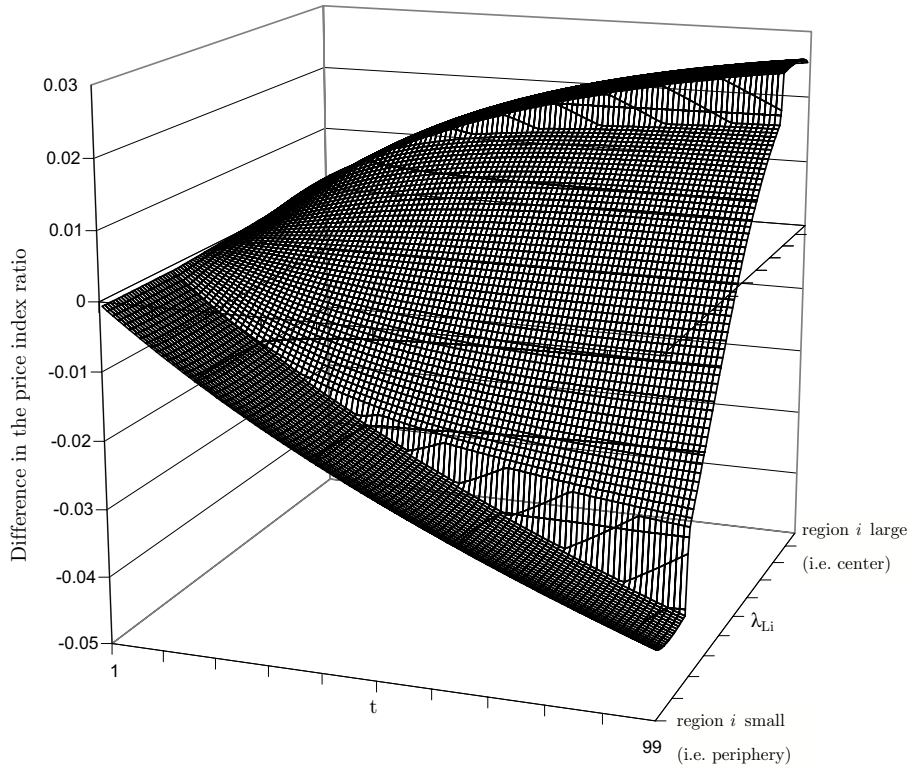


Figure 3: Difference in the price-index ratio for manufacturing goods between the scenarios of Figures 1 and 2.

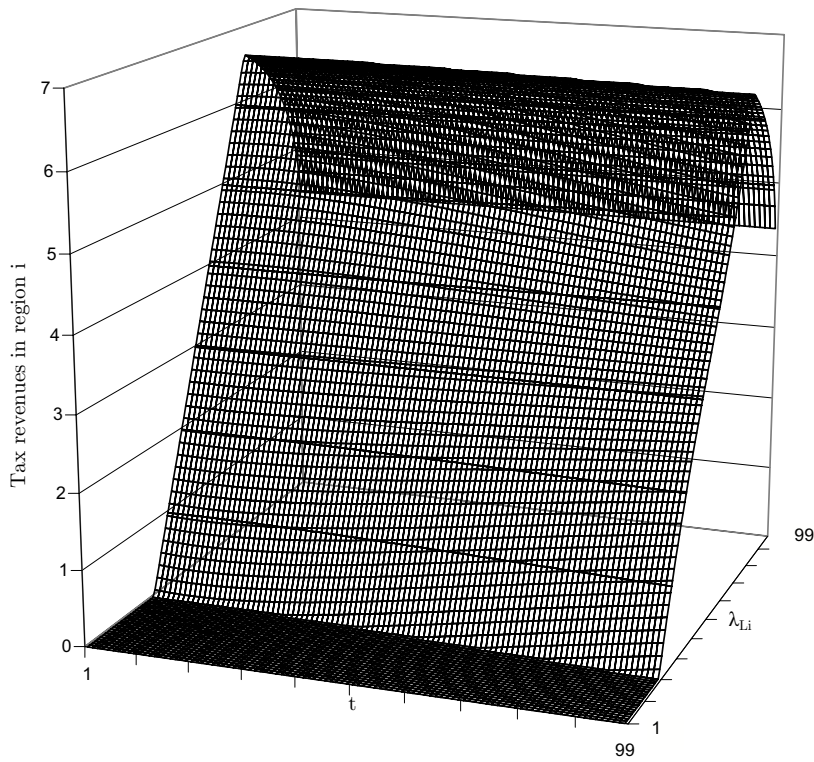


Figure 4: Tax revenues corresponding to the benchmark scenario of Figure 1.

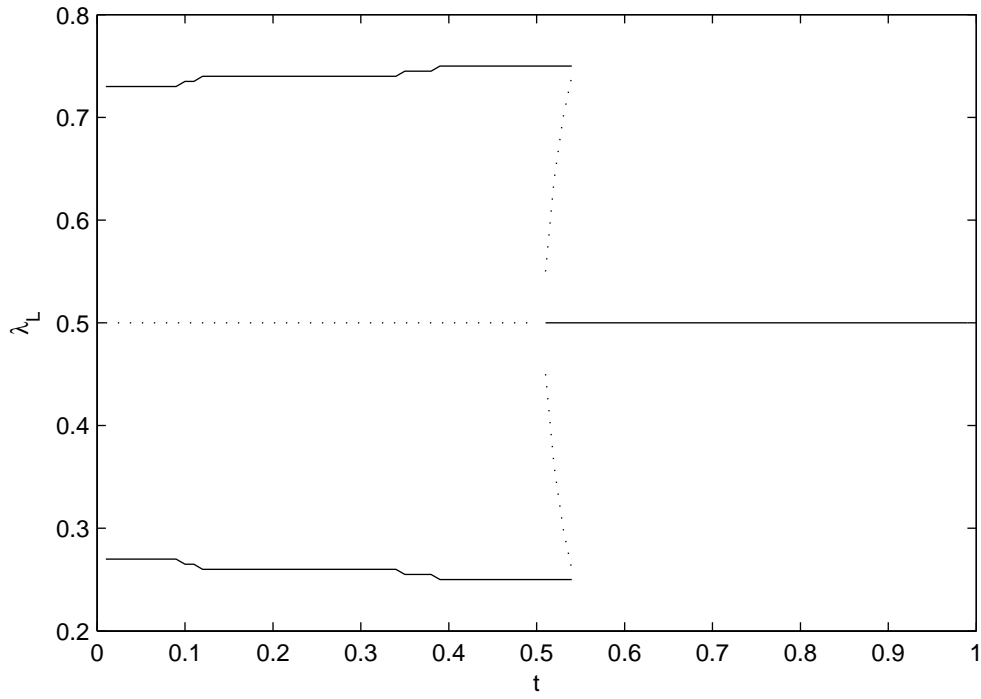


Figure 5: Core-periphery pattern with $tax_i = tax_j = 0.5$, and $\lambda_T = 0.5$.

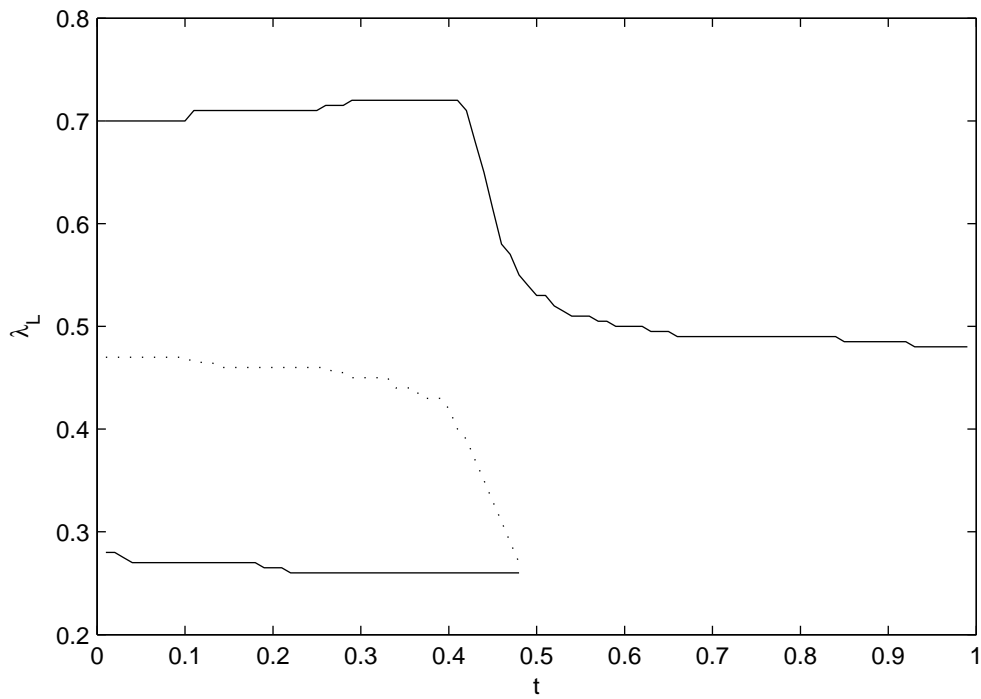


Figure 6: Core-periphery pattern with region i free riding in infrastructure provision, and $\lambda_T = 0.5$.

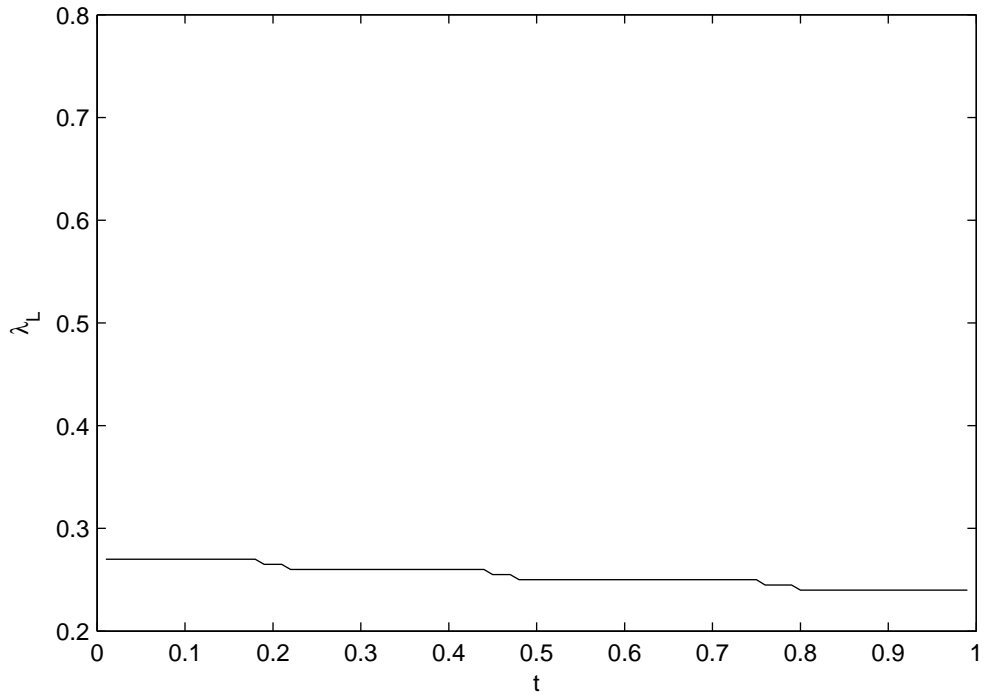


Figure 7: Core-periphery pattern with $tax_i = 0.5$, and $\lambda_T = 0.5$.

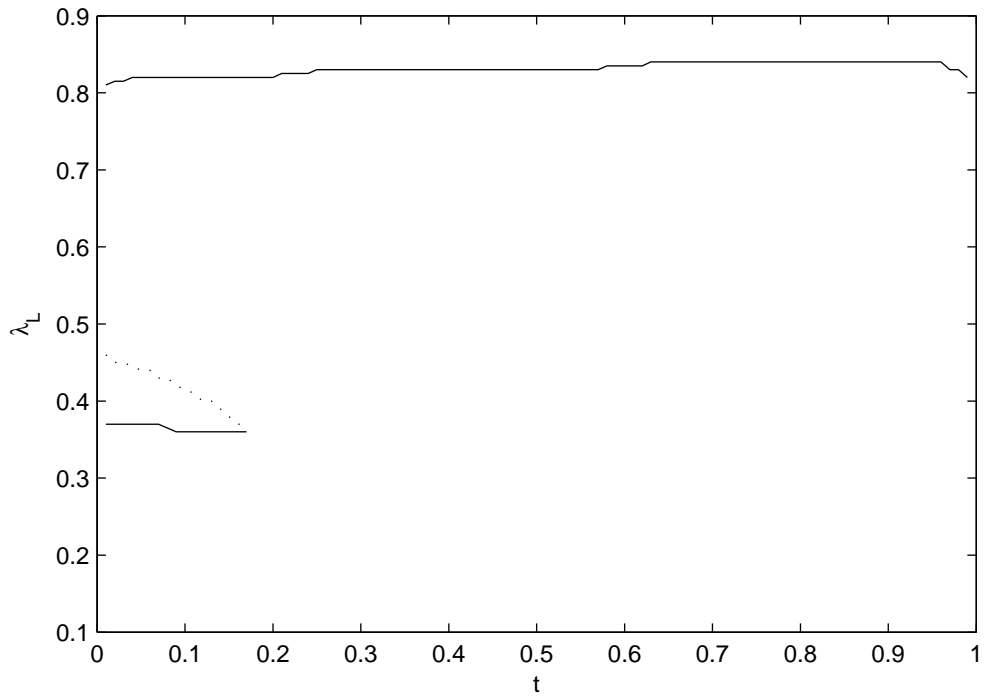


Figure 8: Core-periphery pattern with $\lambda_T = \frac{2}{3}$.

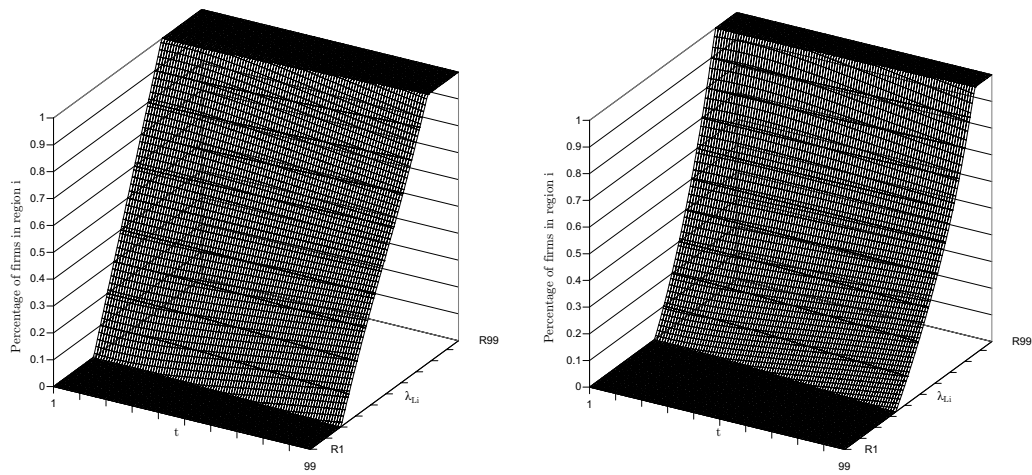


Figure 9: Share of firms in region i (left panel, benchmark case) and with $tax_i = 0.5$ and $tax_j = 0.2$ (right panel).

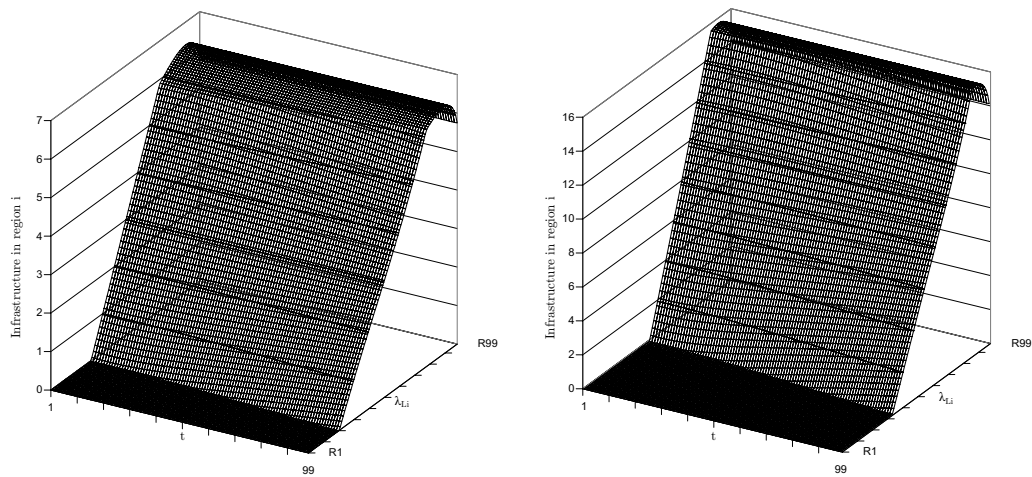


Figure 10: Infrastructure provided in region i (left panel, benchmark case) and with $tax_i = 0.5$ and $tax_j = 0.2$ (right panel).

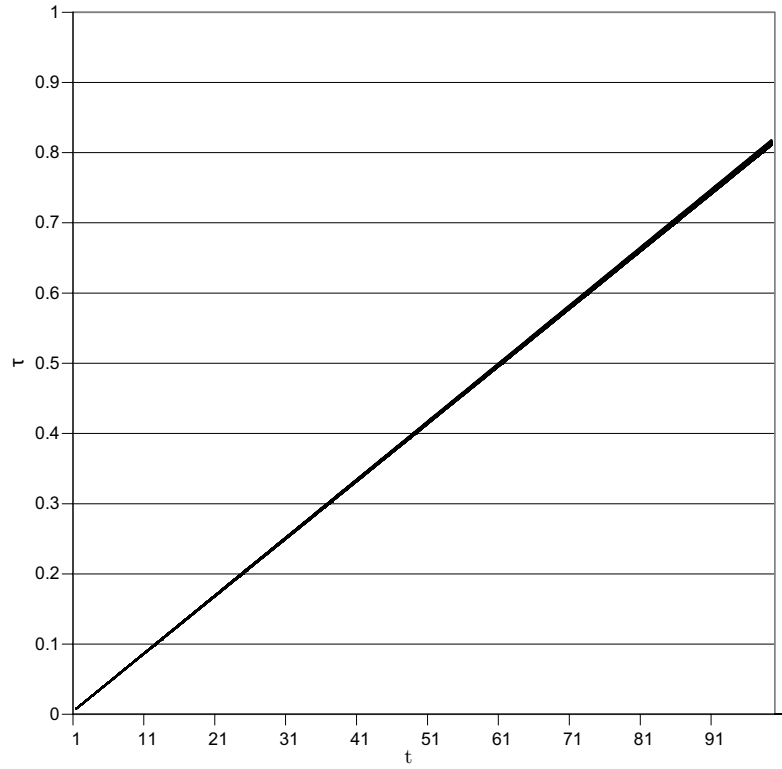


Figure 11: Actual trade costs (τ) as a function of initial impediments to trade (t).

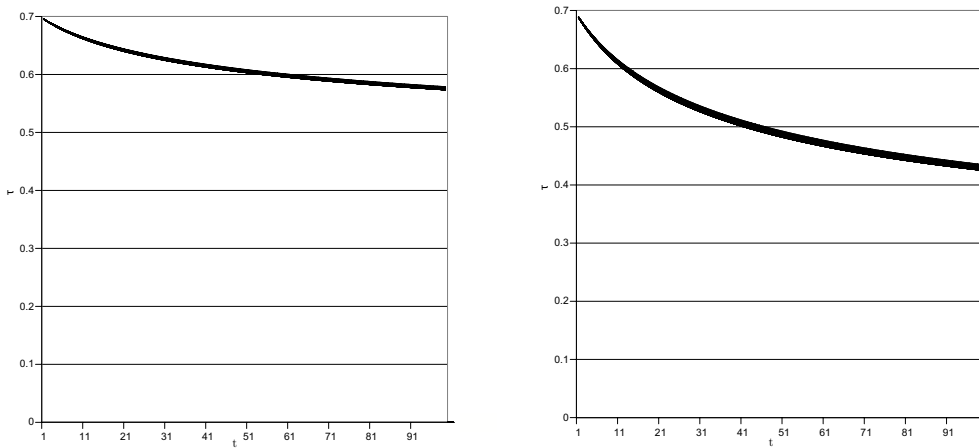


Figure 12: Trade costs as κ varies with $\beta = 0.1$ (left panel), $\beta = 0.25$ (right panel), and $t = 0.7$.

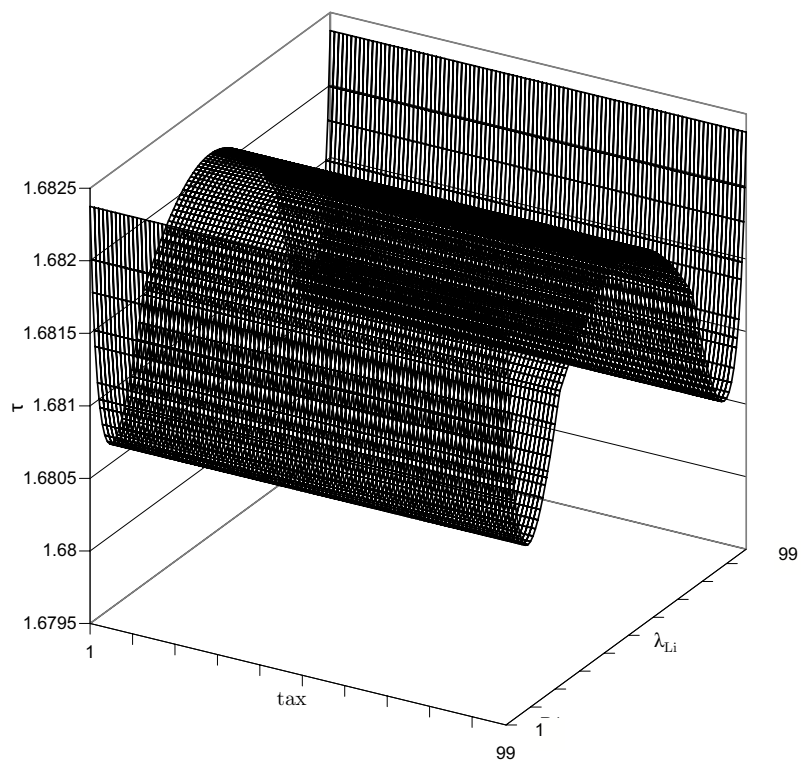


Figure 13: Trade costs as the tax rate varies.