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Trade and the structure of cities

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Abstract

Our purpose is to investigate how the interplay between trade, commuting and communication costs shapes the economy at both the interregional and intraurban levels. Specifically, we study how economic integration affects the internal structure of cities and show how decentralizing the production and consumption of goods in secondary employment centers allows firms located in a large city to maintain their predominance. Several new results in both economic geography and urban economics are established, which all agree with empirical evidence.

JEL Classification: F12, F22, R12, R14

Key-words: city structure, secondary business centers, commuting costs, trade costs, communication costs

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1 Introduction

Cities are major actors in the process of trade. It is, therefore, fundamental to understand (i) how the intensity of trade is influenced by their size and structure and, conversely, (ii) how economic integration affects the internal structure of cities. This is what we undertake in this paper by modelling the interplay between *trade costs*, *commuting costs* and *communication costs*. Our approach, which combines basic ingredients from urban economics and new economic geography, explains how decentralizing the production of goods in secondary employment centers may allow large cities to keep a large share of firms and jobs.

Our starting point is that firms' performances are affected by the level of housing and commuting costs, which we call "urban costs". This occurs through the land rent they pay to occupy central urban locations, and through the higher wages they have to pay to their workers to compensate them for their longer commutes and/or higher land rents. Hence, high urban costs render firms less competitive on local and foreign markets alike. As a result, despite scale economies arising from urban agglomeration (Duranton and Puga, 2004), increasing urban costs could shift employment from large monocentric cities either to their suburbs or to distant and smaller cities, where these costs are lower, at least once trade costs have sufficiently declined to permit large-scale exports to distant markets. In other words, economic integration could well challenge the supremacy of large cities in favor of small cities. The main point we wish to stress in this paper is that *the emergence of subcenters within cities is a powerful strategy for large cities to maintain their attractiveness.*

Despite the many advantages provided by the inner city through a good access to highly specialized services (Porter, 1995), firms or developers may choose to form secondary employment centers, enterprise zones, or edge cities (Henderson and Mitra, 1996). In this way, firms are able to pay lower wages and land rents while retaining most of the benefits generated by large urban agglomerations. And, indeed, Timothy and Wheaton (2001) report large variations in wages according to intraurban location (15% higher in central Boston than in outlying work zones, 18% between central Minneapolis and the fringe counties). As they enjoy living on larger plots and/or move along with firms, workers may also want to live in suburbia (Glaeser and Kahn, 2004). Consequently, the creation of subcenters within a city, i.e. the formation of a polycentric city, appears to be a natural way to alleviate the burden of urban costs. It is, therefore, no surprise that Anas *et al.* (1998) observe that "polycentricity is an increasingly prominent feature of the landscape".[1]

Thus, the escalation of urban costs in large cities seems to prompt a redeployment of activities in a polycentric pattern, while smaller cities retain their monocentric shape. However, for this to happen, firms set up in the secondary centers must maintain a very good access to the main urban center, which requires low communication costs. Indeed, as pointed out by Schwartz (1993), about half of the business services consumed by US firms located in suburbia are supplied in city centers. As a result, by focusing on urban and communication costs, we recognize that both

[1] To illustrate, Giuliano and Small (1991) identify 29 job centers in Los Angeles, McMillen and McDonald (1998) find 15 in Chicago, and Creveso and Wu (1997) count 22 for the San Francisco Bay Area.

agglomeration and *dispersion* may take two quite separate forms because they are now compounded by *centralization* or *decentralization* of activities within the same city. Such a distinction is crucial for understanding the interaction between cities and trade.

To achieve our goal, we develop a two-region model where regions have a spatial extension that imposes commuting and communication costs whereas interregional shipments of commodities imply trade costs. Unlike Helpman (1998), Tabuchi (1998) and others, our framework allows cities to be polycentric. Our model thus sheds light on some important concrete issues that have been pretty much overlooked until now. To show it, we organize our main conclusions around two main ideas: (i) *local factors may change the global organization of the economy*, whereas (ii) *global forces may affect the local organization of cities*. This interaction arises because the spatial organization of production and employment may take different forms as either a single polycentric city or two monocentric cities may emerge, thus yielding very contrasted economic landscapes and trade patterns. Regarding the first idea, we focus on commuting and communication costs. When these costs are high, the economic landscape is likely to be formed by several small cities trading differentiated varieties. By contrast, when commuting and/or communication costs are sufficiently low, a single and large polycentric city emerges. In particular, by facilitating the formation of secondary centers, the development of New Information and Communication Technologies (in short NICTs) may prevent the re-dispersion of activities between regions that a deep economic integration is expected to trigger (Ottaviano and Thisse, 2004).

Concerning the second idea, our thought experiment is about trade costs. When trade costs decrease steadily, agglomeration within a city emerges gradually. This is because the decentralization of jobs in a polycentric city allows firms to pay lower wages. This result agrees with the formation of megalopolises in which employment is decentralized in several centers that all belong to the same metropolitan area (MacMillen and Smith, 2003). Interestingly, such an outcome may still prevail even when trade costs decrease sufficiently for the full dispersion of activities to be again a stable equilibrium, thus showing in a very neat way the prevalence of the phenomenon of *hysteresis* in urban structures. Yet, when trade costs fall below some lower threshold, the agglomeration becomes *partial* in that it loses jobs to the benefit of smaller cities. During this process, the internal structure of the megalopolis changes gradually in that the secondary business districts (in short SBDs) first gain more jobs, whereas the central business district (in short CBD) then recovers some of its importance.

In the sections that follow, we first describe our modeling strategy (section 2). The intracity equilibrium is characterized in section 3, whereas the subsequent section analyzes the urban system when cities have given structures. In section 5, we study the impact of trade and communication costs on the size and structure of cities. Section 6 concludes.

2 The model

2.1 The spatial economy

Consider an economy with two regions, labelled $r = 1, 2$, separated by a given physical distance, one sector and two primary goods, labor and land. Each region can be urbanized by accommodating firms and workers within a city, and is formally described by a one-dimensional space X. Whenever a city exists, it has a CBD located at the origin $0 \in X$. One would expect us to explain why this CBD exist as well as why firms want to be together when they form a SBD. Doing that would make our analysis much more involved from the technical point of view, without adding much to our understanding of the space-economy. Indeed, the reasons for urban clusters to arise have been well explored in the literature and our model has nothing new to add to what is known in this domain. By contrast, we determine both the size and structure of each city.[2]

Firms are free to locate in the CBD or to set up in the suburbs of the metro where they form a SBD. Both the CBD and SBDs are assumed to be dimensionless.[3] As mentioned in the introduction, the higher-order functions (specific local public goods and nontradeable business-to-business services such as marketing, banking, insurance) are still mainly located in CBDs. Hence, when some firms set up in a SBD, they must incur a cost $K > 0$, which we call communication cost, for using such services. Because communicating mainly requires the building of facilities that have the nature of fixed costs, we may suppose that this cost is independent on the CBD-SBD distance. This assumption vastly simplifies the analysis of the land market (see Section 3.1). Further, making the communication cost dependent on the CBD-SBD distance does not affect qualitatively our results provided that this cost does not increase rapidly with distance - a very plausible assumption - but makes the analytical expressions more cumbersome. However, recognizing the fact that communication costs between the CBD and a SBD are distance-sensitive implies that the CBD and SBD residential areas are adjacent. This is why we will assume below that these two areas are adjacent, despite the fact that it does not matter whether or not they are so in the case of a constant communication cost.

In what follows, the superscript C is used to describe variables related to the CBD, whereas S describes the variables associated with a SBD. Without loss of generality, we focus on the right-hand side of the city, the left-hand side being perfectly symmetrical. Distances and locations are expressed by the same variable x measured from the CBD located at $x = 0$ in city $r = 1, 2$ whereas the SBD, if any, is established at $x_r^S > 0$, which is endogenous. Both the CBD and the SBD are surrounded by residential areas occupied by workers. Furthermore, as the distance between the CBD and SBD is small compared to the intercity distance, we disregard the intracity transport cost of goods. Finally, as creating a new subcenter requires

[2]Thus, we differ from Fujita *et al.* (1999) because cities have a spatial extension and an endogenous structure. Unlike them, however, the inter-city distance is given. We also differ from Henderson (1974) who considers monocentric cities and zero transport costs between cities.

[3]In Cavailhes *et al.* (2004), we suppose that firms consume land, thus implying that clusters have a spatial size. This makes the analytical treatment of the model more cumbersome without changing the nature of our results.

a positive fixed cost (Glaeser and Kahn, 2004), we find it convenient to restrict ourselves to the case of two SBDs. It should be clear, however, that the extension to more SBDs does not generate new major insights.

Under those various assumptions, the location and size of the SBDs as well as the size of the CBD are endogenously determined. In other words, apart from the assumed existence of the CBD, the internal structure of each city is endogenous.

2.2 Workers

The economy is endowed with L mobile workers. The welfare of a worker depends on her consumption of the following three goods. The first good is unproduced and homogenous.[4] It is assumed to be costlessly tradeable and chosen as the numéraire. The second good is produced as a continuum n of varieties of a horizontally differentiated good under monopolistic competition and increasing returns, using labor as the only input. Any variety of this good can be shipped from one city to the other at a unit cost of $\tau > 0$ units of the numéraire. The third good is land; without loss of generality, we set the opportunity cost of land to zero.

Each worker living in city r consumes a residential plot of fixed area chosen as the unit of surface.[5] The worker also chooses a quantity $q(i)$ of variety $i \in [0, n]$, and a quantity q_0 of the numéraire. She is endowed with one unit of labor and $\overline{q}_0 > 0$ units of the numéraire. The initial endowment $\overline{q}_0$ is supposed to be large enough for her consumption of the numéraire to be strictly positive at the market outcome. Each worker commutes to her employment center - without cross-commuting - and bears a unit commuting cost given by $t > 0$, so that for the worker located at x the commuting cost is either tx or $t\left|x - x_r^S\right|$ according to the employment center.

The budget constraint of an individual residing at $x \in X$ in city r and working in the corresponding CBD can then be written as follows:

$$\int_0^n p_r(i)q(i)di + q_0 + R_r^C(x) + tx = w_r^C + \overline{q}_0 \qquad (1)$$

where $R_r^C(x)$ is the land rent prevailing at a distance x from the CBD. The budget constraint of an individual working in the SBD is obtained by replacing tx by $t\left|x - x_r^S\right|$, $R_r^C(x)$ by $R_r^S(x)$, and w_r^C by w_r^S. Thus, as in Fujita and Ogawa (1980), commuting costs and wages are endogenously determined by the spatial distribution of firms and workers within the city.

Preferences over the differentiated product and the numéraire are identical across workers and represented by a quasi-linear utility encapsulating a quadratic subutility:

$$U(q_0; q(i), i \in [0, n]) = \alpha \int_0^n q(i)di - \frac{\beta - \gamma}{2} \int_0^n [q(i)]^2 di - \frac{\gamma}{2} \left[\int_0^n q(i)di\right]^2 + q_0 \qquad (2)$$

where $\alpha > 0$ and $\beta > \gamma > 0$. The condition $\beta > \gamma$ implies that workers have a preference for variety.

[4] The model can easily be extended by introducing a second sector producing the homogenous good under constant returns and perfect competition, using an immobile factor.

[5] Allowing for a variable lot size makes the analysis much more involved without affecting the nature of our results. See Tabuchi (1998) for a study of the monocentric-city case.

2.3 Firms

Technology in manufacturing is such that producing $q(i)$ units of variety i requires a given number ϕ of labor units.[6] There are no scope economies so that, due to increasing returns to scale, there is a one-to-one relationship between firms and varieties. Thus, the total number of firms is given by $n = L/\phi$. Labor market clearing implies that the number of firms located (or varieties produced) in city r is such that $n_r = \lambda_r n$, where λ_r stands for the share of workers residing in r.

Denote by Π_r^C (resp., Π_r^S) the profit of a firm set up in the CBD (resp., the SBD) of city r. Let θ_r be the share of firms located in the CBD of city r and, therefore, by $(1-\theta_r)/2$ the share of firms in its right-hand side SBD. When the firm producing variety i is located in the CBD of city r, its profit function is given by:

$$\Pi_r^C(i) = I_r(i) - \phi w_r^C \tag{3}$$

where $I_r(i)$ stands for the firm's revenue earned from local sales and from exports (see (13) below). When the firm set up in the SBD of the same city, its profit function becomes:

$$\Pi_r^S(i) = I_r(i) - \phi w_r^S - K \tag{4}$$

where the firm's revenue is the same as in the CBD because shipping varieties within the city is costless so that prices and outputs do not depend on firm's location in the city. Those two expressions encapsulate the trade-off faced by firms located in city r: by locating at the SBD, firms are able to pay a lower wage to workers, but must incur the communication cost K.

2.4 Market structure

Solving the budget constraint for the numéraire consumption, plugging the corresponding expression into (2) and taking the first order condition with respect to $q(i)$ yields

$$\alpha - (\beta-\gamma)q(i) - \gamma\int_0^n q(j)dj = p(i) \qquad i \in [0,n].$$

The demands for a variety i produced in city r by a worker living in city r and a worker living in city s can then be written, respectively, as follows:

$$q_{rr}(i) = a - (b+cn)\,p_{rr}(i) + cP_r \tag{5}$$
$$q_{rs}(i) = a - (b+cn)\,p_{rs}(i) + cP_s \tag{6}$$

where $p_{rr}(i)$ (resp., $p_{rs}(i)$) denotes the price a variety-i firm located in city r charges to consumers living in city r (resp., city $s \neq r$) and P_r the average price (up to n) of varieties in city r:

$$P_r \equiv \int_0^{n_r} p_{rr}(i)\mathrm{d}i + \int_0^{n_s} p_{sr}(i)\mathrm{d}i \qquad s \neq r. \tag{7}$$

[6]When a second sector is considered, we may assume that the production of $q(i)$ units of variety i requires $mq(i)$ units of the immobile factor. Without loss of generality, we may then set $m = 0$ (Ottaviano *et al.*, 2002).

Furthermore, we have $a \equiv \alpha b$, $b \equiv 1/[\beta+(n-1)\gamma]$ and $c \equiv [\gamma/(\beta-\gamma)]b$. Parameter a expresses the desirability of the differentiated product with respect to the numéraire and may, therefore, be viewed as a measure of the size of this market; b gives the link between individual and industry demands: when b rises, consumers become more sensitive to price differences. Finally, parameter c is an inverse measure of the degree of product differentiation between varieties; when $c \to \infty$, varieties are perfect substitutes, whereas they are independent for $c = 0$.

Firm i located in city r faces a downward sloping demand in city r and city $s \neq r$:

$$Q_{rr}(i) = \lambda_r L q_{rr}(i) \qquad Q_{rs}(i) = \lambda_s L q_{rs}(i)$$

where $q_{rr}(i)$ and $q_{rs}(i)$ are given by (5) and (6), respectively.

As empirical evidence suggests that firms practice some form of spatial price discrimination (Greenhut, 1981; Engel and Rogers, 1996; Haskel and Wolf, 2001), we assume that markets are spatially segmented, which means that each firm chooses a delivered price specific to the city in which its variety is sold. As the price of a variety does not vary within a city, the total revenue of firm i located in city r is given by

$$I_r(i) = p_{rr}(i)Q_{rr}(i) + [p_{rs}(i) - \tau]Q_{rs}(i).$$

Because there is a continuum of firms, each firm has a negligible impact on the market outcome in the sense that it may accurately ignore its influence on, and hence reactions from, other firms. However, aggregate market conditions of some kind (here the price index P_r) affects any single firm. This defines a setting in which individual firms are not competitive (in the classic economic sense of having infinite demand elasticity) but, at the same time, they have no strategic interactions with one another. Because varieties are symmetric, all firms located in the same city charge the same price. As shown by Ottaviano *et al.* (2002), the equilibrium prices are as follows:

$$p^*_{rr} = \frac{1}{2}\frac{2a + c\tau(1-\lambda_r)n}{2b + cn} \tag{8}$$

$$p^*_{rs} = p^*_{ss} + \frac{\tau}{2} \qquad s \neq r. \tag{9}$$

It thus appears that the equilibrium price prevailing in a city decreases with the number of firms located there, but increases with the level of trade costs. Finally, even though factor prices do not enter (8)-(9) because they have the nature of a fixed cost, they have a negative impact on the number of firms set up in city r, whence an indirect positive impact on equilibrium prices.

Substituting the equilibrium prices (8)-(9) into the demands (5)-(6) and using (7), the equilibrium consumption levels can be expressed as follows:

$$q^*_{rr} = a - bp^*_{rr} + cn\tau/2 \tag{10}$$

$$q^*_{rs} = q^*_{ss} - (b + cn)\tau/2. \tag{11}$$

Not surprisingly, high trade costs raise the local demand for each locally produced variety at the expense of varieties produced in the other city. This substitution effect decreases when varieties becomes more differentiated.

Hence, evaluated at the equilibrium prices (8)-(9), the consumer surplus is given by:

$$S_r^* = \frac{a^2 n}{2b} - a(n_r p_{rr}^* + n_s p_{sr}^*) + \frac{b + cn}{2}\left[n_r (p_{rr}^*)^2 + n_s (p_{sr}^*)^2\right] - \frac{c}{2}(n_r p_{rr}^* + n_s p_{sr}^*)^2 \tag{12}$$

while the equilibrium revenue of a firm located in r is may be expressed as follows:

$$I_r = \lambda_r L p_{rr}^{*2} + \lambda_s L \left(p_{rs}^* - \tau\right)^2. \tag{13}$$

Both (12) and (13) depend on the distribution of firms and workers between the two cities.

It remains to determine the conditions to be imposed on τ for trade to occur between cities at the equilibrium prices regardless of the interregional distribution of firms and workers. This is so if and only if the equilibrium demand q_{rs}^* is positive for any distribution of workers. It is readily verified that this condition is equivalent to:

$$\tau < \tau_{trade} \equiv \frac{2a\phi}{2b\phi + cL}$$

which is assumed to hold throughout the paper. This condition also guarantees that it is always profitable for a firm to export to the other city ($p_{rs}^* - \tau > 0$).

To sum-up, we consider a full-fledged general equilibrium model involving labor, land as well as a differentiated product and a homogeneous good. At the global level, increasing returns at the plant level are the agglomeration force whereas urban costs are the dispersion force. At the city level, communication costs act as agglomeration forces, whereas commuting costs act as dispersion forces. In the next section, we study the city equilibrium within one city before considering the case of an urban system in the subsequent section.

3 Decentralization within a city

A *city equilibrium* is such that each individual maximizes her utility subject to her budget constraint, each firm maximizes its profits and markets clear. Individuals choose their workplace (CBD or SBD) and their residential location with respect to given wages and land rents. Within each workplace (CBD or SBD), the equilibrium wages are determined by a bidding process in which firms compete for workers by offering them higher wages until no firm can profitably enter the market. Given such equilibrium wages and the location of workers, firms choose to locate either in the CBD or in the SBD. At the city equilibrium, no firm has an incentive to change place within the city, and no worker wants to change her working place and/or her residence. In this section, we analyze such an equilibrium, taking as fixed the number of workers as given. To ease the burden of notation, we drop the subscript r.

3.1 Land rents, wages and workplaces

Within each city, a worker chooses her location so as to maximize (2) under the constraint (1). Let $\Psi^C(x)$ and $\Psi^S(x)$ be the bid rent at $x \in X$ of an individual working respectively in the CBD and the SBD. Land is allocated to the highest bidder.[7] Because there is only one type of labor, at the city equilibrium it must be that

$$R(x) = \max\left\{\Psi^C(x), \Psi^S(x), 0\right\}.$$

Denote by y the right endpoint of the residential area formed by people working in the CBD. Let z_1 be the endpoint of the residential area on the left-hand side of the SBD, and z_2 the symmetrical residential endpoint, which is also the outer limit of the city. As discussed above, we assume that the two residential areas are adjacent, which means $y = z_1$. Therefore, the critical points are as follows:

$$y = \frac{\theta l}{2} \qquad x^S = \frac{1+\theta}{4} l \qquad z_2 = \frac{l}{2} \tag{14}$$

where l is the city size and θ the share of firms located in the CBD. Note that the bid rents at y and z_2 are equal to zero because the lot size is fixed and the communication cost K is constant. An illustration of the land rent profile is provided in Figure 1.

Figure 1

Because of the fixed lot size assumption, at the city equilibrium the value of the equilibrium consumption of the nonspatial goods

$$\mathbf{E} = \int_0^n p(i)q(i)di + q_0$$

is the same regardless of the worker's location. Then, the budget constraint of an individual residing at x and working in the CBD implies that $w^C - R(x) - tx = \mathbf{E}$, whereas the budget constraint of an individual working in the SBD is $w^S - R(x) - t\left|x - x^S\right| = \mathbf{E}$. At the city equilibrium, the worker living at the right-endpoint y of the CBD residential area (or at the left-endpoint z_1 of the SBD residential area) is indifferent between working in the CBD or in the SBD, which implies

$$w^C - R(y) - ty = w^S - R(z_1) - t(x^S - z_1).$$

Because $y = z_1$ and $R(y) = R(z_1) = 0$, this becomes

$$w^C - w^S = t(2y - x^S) = t\frac{3\theta - 1}{4} l \tag{15}$$

where we have used the expressions of x^S and z_1 in (14). Thus, *the difference in the wages paid in the CBD and in the SBD compensates exactly the worker for the difference in the corresponding commuting costs.* The wage wedge $w^C - w^S$ is positive as long as $\theta > 1/3$, that is, the size of the CBD exceeds the size of each SBD (recall that another SBD exists on the left-hand side of the CBD). Observe that a rise in the population size increases the wage wedge: as the average commuting cost rises, firms located in the CBD must pay a higher wage to their workers.

[7] Utilities being quasi-linear, the structure of land ownership across indivuals is immaterial for our analysis provided that the distribution is atomless.

3.2 Equilibrium wages and the city structure

Regarding the labor markets, the equilibrium wages of workers are determined by the zero-profit condition. In other words, operating profits are completely absorbed by the wage bill. Hence, the equilibrium wage rates in the CBD and in the SBD must satisfy the conditions $\Pi^C(w^{C*}) = 0$ and $\Pi^S(w^{S*}) = 0$, respectively. Thus, setting (3) (resp., (4)) equal to zero, solving for w^{C*} (resp., w^{S*}), we get:

$$w^{C*} = \frac{I}{\phi} \qquad w^{S*} = \frac{I-K}{\phi}. \tag{16}$$

Hence $w^{C*} - w^{S*} = K/\phi$, which means that the equilibrium wage wedge is proportional to the level of the communication cost K.

Substituting (16) into (15) and solving with respect to θ yields:

$$\theta^* = \min\left\{1, \frac{1}{3} + \frac{4K}{3t\phi}\frac{1}{l}\right\}. \tag{17}$$

Observe first that $\theta^* = 1/3$ when $K = 0$ because the city is formed by three identical employment centers. Furthermore, when $\theta^* < 1$, increasing the population size leads to a decrease in the relative size of the CBD, though its absolute size rises, whereas both the relative and absolute sizes of the SBD rises. Indeed, increasing the size of the labor force leads to a more than proportionate increase in the wage rate prevailing in the CBD. This is because of the corresponding rise in the average commuting cost. The number of firms being fixed, this in turn implies that more firms choose to set up in the SBD at the expense of the CBD. Last, as long as $\theta^* < 1$, the higher the communication costs, the larger the CBD. In the same way, the lower the commuting costs, the larger the CBD size.

It is readily verified that the city is monocentric if and only if

$$t \leq 2K/\phi l. \tag{18}$$

Hence, *a polycentric city is more likely to occur when commuting and/or communication costs are low and the population size is large.* This agrees with Anas *et al.* (1998) who observe that by the end of the 19th century telephones have made it possible for US firms to decentralize, whereas NICTs play nowadays a comparable role. By contrast, a high degree of increasing returns favors the centralization of production.

We may summarize the main results of that analysis in the following proposition.

Proposition 1 *A city is monocentric if and only if $t \leq 2K/\phi l$. Otherwise, the city is polycentric.*

Finally, it is worth noting that the equilibrium land rents are given by

$$R(x) = \Psi^C(x) = t\left(\frac{\theta^* l}{2} - x\right) \qquad \text{for } x < y \tag{19}$$

where we have used the expression of y and the condition $\Psi^C(y) = 0$ and by

$$R(x) = \Psi^S(x) = t\left(\frac{1-\theta^*}{4}l + x^S - x\right) \qquad \text{for } x > x^S. \tag{20}$$

Workers' bid rents around the SBD are maximized at x^S whereas $\Psi^S(z_1) = 0$. The gap $\Psi^C(x) - \Psi^S(|x - x^S|) > 0$ at any given x rises as the relative size of the CBD increases. Note also that the households' bid rents functions Ψ^C and Ψ^S in the CBD and the SBD are identical once the employment centers have the same size, that is, $\theta^* = 1/3$.

4 Urban system and intercity trade

Consider now our two-city setting in which workers and firms are free to choose the city in which they want to live. Let λ be the endogenous share of workers residing in city 1. A *global equilibrium* arises at $0 < \lambda^* < 1$ when the utility differential $\Delta V(\lambda^*) \equiv V_1(\lambda^*) - V_2(\lambda^*) = 0$, or at $\lambda^* = 1$ when $\Delta V(1) \geq 0$, or at $\lambda^* = 0$ when $\Delta V(0) \leq 0$. Without loss of generality, we assume that $\lambda \geq 1/2$. An interior equilibrium is stable if and only if the slope of the indirect utility differential ΔV is strictly negative in a neighborhood of the equilibrium, i.e., $\partial \Delta V(\lambda)/\partial \lambda < 0$ at λ^*, whereas an agglomerated equilibrium is stable whenever it exists. In what follows, we simplify notation by deleting the subscripts 1 and 2, unless explicitly mentioned.

The indirect utility of an individual working in the CBD is given by

$$V^C(\lambda) = S^* + w^{C*} - C^C + \overline{q}_0 \tag{21}$$

where S^* is the consumer surplus given by (12) and C^C the urban costs borne by this individual. Using (19), it is readily verified that

$$C^C \equiv R^C + tx = \frac{\theta^* \lambda L}{2} t. \tag{22}$$

If she works in the SBD, her indirect utility becomes:

$$V^S(\lambda) = S^* + w^{S*} - C^S + \overline{q}_0$$

where C^S now denotes the urban costs the individual bears. Using (20), we have

$$C^S \equiv R^S + t|x - x^S| = \frac{(1-\theta^*)\lambda L}{4} t. \tag{23}$$

Two comments are in order. First, the equilibrium allocation of workers and firms within each city depends on the spatial distribution of firms and workers between cities through the value of λ. Hence, workers are distributed at the city equilibrium in a way such that

$$V^C(\lambda) = V^S(\lambda).$$

Likewise, when λn firms are established in city 1, firms are distributed at the city equilibrium such that $\Pi^C(\lambda) = \Pi^S(\lambda) = 0$. Second, when deciding whether or not to move from one city to the other, workers know whether the cities of origin and destination are monocentric and/or polycentric; they also know the land rent that prevails in each one of them.

In order to determine the global equilibrium, we define two critical values

$$t_1 \equiv \frac{\Upsilon K}{\lambda} \qquad t_2 \equiv \frac{\Upsilon K}{1-\lambda} \tag{24}$$

where

$$\Upsilon \equiv 2/\phi L$$

and l has been replaced by λL and $(1-\lambda)L$, respectively, in (18).Because $\lambda \geq 1/2$, we have $t_1 \leq t_2$. Using Proposition 1, it is easily seen that the following three spatial patterns may emerge: (i) when $t < t_1$, both cities are monocentric, (ii) when $t_1 < t < t_2$, city 1 is polycentric and city 2 is monocentric, and (iii) when $t_2 < t$, both cities are polycentric. Hence, under dispersion ($t_1 = t_2 = 2\Upsilon K$), the two cities are monocentric if $t < 2\Upsilon K$ and polycentric if $t > 2\Upsilon K$. Similarly, under agglomeration ($\lambda = 1$), $t_1 = \Upsilon K$ and $t_2 \to \infty$; thus, agglomeration arises in a monocentric city when $t < \Upsilon K$ or in a polycentric city when $t > \Upsilon K$. The following lemma summarizes those various results.

Lemma 1 *For dispersion between two monocentric (resp., polycentric) cities to arise, it must be that $t < 2\Upsilon K$ (resp., $t > 2\Upsilon K$). For agglomeration in a monocentric (resp., polycentric) city to arise, it must be that $t < \Upsilon K$ (resp., $t > \Upsilon K$).*

Having this purpose in mind, in order to determine what a global equilibrium is, we must consider the three forms the utility differential governing migrations may take with respect to these patterns. In the following subsections, we study the global equilibria when cities are (i) monocentric, (ii) polycentric, and (iii) one city is polycentric and the other monocentric. Note that one region may be empty in each of those configurations.

4.1 Monocentric cities

Assume that $t < t_1$ so that both cities are monocentric ($\theta^* = 1$ for all $\lambda \in [1/2, 1]$). As mentioned above, the equilibrium wages are given by a bidding process in which firms compete for workers by offering them higher wages until no firm can earn positive profits, given by (3), in the CBD of either city. Using (12) and the equilibrium wages given by (29) in the appendix, it is readily verified that the utility differential with two monocentric cities (with subscript mm) is as follows:

$$\Delta_{mm} V(\lambda) \equiv \delta_{mm}(\lambda - 1/2) \tag{25}$$

where

$$\delta_{mm} \equiv -\varepsilon_1 \tau^2 + \varepsilon_2 \tau - \varepsilon_3 t$$

with

$$\begin{aligned}
\varepsilon_1 &\equiv (b\phi + cL)(6b^2\phi^2 + 6b\phi cL + c^2L^2) > 0 \\
\varepsilon_2 &\equiv 4a\phi(b\phi + cL)(3b\phi + 2cL) > 0 \\
\varepsilon_3 &\equiv 2(2b\phi + cL)^2\phi > 0.
\end{aligned}$$

Clearly, $\lambda = 1/2$ is always a global equilibrium. This equilibrium is stable if and only if $\delta_{mm} < 0$ or, equivalently, $t > t_m$ with

$$t_m \equiv \frac{(-\varepsilon_1\tau + \varepsilon_2)\tau}{\varepsilon_3}$$

which is positive for all admissible value of τ because $\tau_{trade} < \varepsilon_2/\varepsilon_1$. On the contrary, when $t < t_m$, agglomeration prevails.

Using Lemma 1, the discussion above may be summarized as follows.

Proposition 2 *If $t < t_m$ and $t < \Upsilon K$, there exists a global equilibrium in which the industry is agglomerated into a single monocentric city. If $t_m < t < 2\Upsilon K$, there exists a global equilibrium in which the industry is dispersed between two monocentric cities of equal size.*

Note, first, that communication costs have to be sufficiently large to fulfill the condition $t < 2\Upsilon K$. Agglomeration in a monocentric city may then occur provided that commuting costs are very low ($t < t_m$). Once commuting costs get larger ($t > t_m$), the industry is dispersed between two monocentric cities. In other words, a pattern involving two symmetric and monocentric cities is more likely to emerge when both commuting and communication costs are high.

However, for the dispersed pattern to arise, it must be that $t_m < 2\Upsilon K$. As ε_2 increases with a whereas ε_1, ε_3 and ΥK are independent of a, this condition is satisfied when the parameter a does not exceed the unique solution a_m to the equation

$$\varepsilon_2\tau = \varepsilon_1\tau^2 + 2\varepsilon_3\Upsilon K.$$

In other words, the size of the differentiated product market cannot be too large, $a < a_m$, for two monocentric cities to be a global equilibrium.

Otherwise, when $a > a_m$ - hence $t_m > 2\Upsilon K$ - the industry is always agglomerated in a single monocentric city: there is both *agglomeration* and *centralization.* This form of extreme agglomeration arises because the intensification of price competition that such a spatial structure brings about is itself compensated by a sufficiently large market size effect ($a > a_m$).[8]

[8]When the communication cost is arbitrarily large, cities are necessarily monocentric. Proposition 2 is then equivalent to what Ottaviano *et al.* (2002) obtain in the case where all workers are mobile.

4.2 Polycentric cities

We now assume that $t > t_2$ so that both cities are polycentric (with subscript pp). Hence, $\theta^* < 1$ for all $\lambda \in [1/2, 1]$. The expression of the equation of motion becomes:

$$\Delta_{pp} V(\lambda) = \delta_{pp}(\lambda - 1/2) \tag{26}$$

where

$$\delta_{pp} \equiv -\varepsilon_1 \tau^2 + \varepsilon_2 \tau - \frac{\varepsilon_3}{3} t. \tag{27}$$

Again, $\lambda = 1/2$ is a global equilibrium. As δ_{mm} and δ_{pp} are almost identical, the argument is similar to the one developed in the foregoing subsection. Clearly, dispersion with two symmetric and polycentric cities prevails when $\delta_{pp} < 0$ or, equivalently, $t > t_p$ where

$$t_p \equiv \frac{3(-\varepsilon_1 \tau + \varepsilon_2)\tau}{\varepsilon_3} = 3t_m > 0$$

whereas agglomeration is a spatial equilibrium when $t < t_p$. Hence, using Lemma 1, we may state:

Proposition 3 *If $t > t_p$ and $t > 2\Upsilon K$, there exists a global equilibrium in which the industry is dispersed between two polycentric cities of equal size. If $\Upsilon K < t < t_p$, there exists a global equilibrium in which the industry is agglomerated into a single polycentric city.*

In words, when commuting costs are large and communication costs low, firms and workers alleviate the burden of urban costs by having two polycentric cities: there is both *dispersion* and *decentralization*. In other words, the spatial organization of the production of the industry leads to the lowest level of urban costs in the global economy. Observe that a strong reduction in trade costs leads to low values of t_p, thus fostering the dispersion of the industry, which now takes the form of two polycentric cities. Note, however, that, because t_p exceeds t_m, agglomeration is sustainable over a larger set of t-values in the case of polycentric cities than under monocentric cities.

Agglomeration in a polycentric city may also occur when commuting costs take sufficiently low values. However, for that outcome to be possible, it must be that $\Upsilon K < t_p$. It is easy to show that this condition holds if and only if $a > a_p$, where a_p is the unique solution to the equation

$$\varepsilon_2 \tau = \varepsilon_1 \tau^2 + \frac{\varepsilon_3}{3} \Upsilon K.$$

Consequently, when the market size effect is strong ($a > a_p$), agglomeration within a polycentric city takes place. Because a_p is smaller than a_m, agglomeration is sustained for weaker market size effects in the polycentric case than under monocentric cities. This confirms the idea that dispersion is a less likely outcome when cities have SBCs.

Note, finally, that there is multiplicity of equilibria when $\Upsilon K < t < 2\Upsilon K$ and $t_m < t < t_p$ as both agglomeration within a single polycentric city (Proposition 2) and dispersion between two monocentric cities (Proposition 3) are global equilibria. This may be viewed as the counterpart of the overlapping domain in which both agglomeration and dispersion coexist in the standard core-periphery model (Krugman, 1991).

4.3 Monocentric vs polycentric cities

It remains to consider the case in which cities exhibit different spatial structures. Without loss of generality, we may assume that city 1 is polycentric whereas city 2 is monocentric ($\theta_1^* < 1$ and $\theta_2^* = 1$): $t_1 < t < t_2$. Note that this condition implies $1/2 < \lambda < 1$ so that *the polycentric city hosts the majority of firms and workers.*

The equation of motion - with subscript pm - is now given by

$$\Delta_{pm} V(\lambda) \equiv \delta_1 \lambda + \delta_2 = \delta_1 \left(\lambda - \frac{\delta_2}{-\delta_1} \right)$$

with

$$\delta_1 \equiv -\varepsilon_1 \tau^2 + \varepsilon_2 \tau - \frac{2}{3} \varepsilon_3 t \qquad \delta_2 \equiv \frac{1}{2} \left[\varepsilon_1 \tau^2 - \varepsilon_2 \tau + \varepsilon_3 \left(t - 2\Upsilon K \right) \right].$$

Since $\Delta_{pm} V(\lambda)$ is both linear and continuous, the intermediate value theorem implies that such the interval $(1/2, 1)$ contains a unique equilibrium, given by $\lambda^* = -\delta_2/\delta_1 \in (1/2, 1)$, if and only if the two inequalities $\Delta_{pm} V(1/2) > 0$ and $\Delta_{pm} V(1) < 0$ hold. Furthermore, this equilibrium is stable because $\Delta_{pm} V(\lambda)$ is monotone decreasing when these two inequalities are satisfied, which in turn implies that $\delta_1 < 0$.

Note that $\Delta_{pm} V(1/2) > 0$ is equivalent to $-\delta_2/\delta_1 > 1/2$, whereas $\Delta_{pm} V(1) < 0$ is equivalent to $\delta_1 + \delta_2 < 0$. It is then readily verified that the former inequality is itself equivalent to $t > 6\Upsilon K$, whereas the latter is equivalent to $t_p - 6\Upsilon K < t$. Hence, under these two conditions, $\lambda^* = -\delta_2/\delta_1 \in (1/2, 1)$ is a stable interior equilibrium, thus meaning that the economy involves a large polycentric, which hosts the majority of firms and workers, together with a small monocentric city.

By contrast, there is agglomeration in the polycentric city if and only if $\Delta_{pm} V(1) > 0$ because $\Delta_{pm} V(\lambda)$ is linear, which amounts to the condition $t < t_p - 6\Upsilon K$.

Thus, using Proposition 3, we have:

Proposition 4 *If $t > 6\Upsilon K$ and $t > t_p - 6\Upsilon K$, there exists a global equilibrium in which the industry is split between a large polycentric city and a small monocentric city. If $\Upsilon K < t < t_p - 6\Upsilon K$, there exists a global equilibrium in which the industry is agglomerated in a single polycentric city.*

Hence, a partial agglomeration may emerge as an equilibrium outcome once it is recognized that SBDs exist. Such a configuration never arises in the standard core-periphery model. Again, there is multiplicity of equilibria - two polycentric cities of the same size (Proposition 3) or an asymmetric configuration with a polycentric city and a monocentric city (Proposition 4) - when $t > 6\Upsilon K$ and $t > t_p - 6\Upsilon K$.

Figure 2 describes the different types of intracity and global equilibria in the (t, K)-space, as identified in Propositions 2, 3 et 4.

Figure 2

5 Interaction between local and global forces

In this section, we study the impact of changes in commuting costs, communication costs and trade costs on the location of firms within and between cities. Our results are organized around the following two ideas: (i) local factors may well change the global organization of the economy, whereas (ii) global forces may affect the local/urban organization of production and employment. We first study how a variation in commuting and/or communication costs affects the space-economy. Next, we will consider the usual thought experiment of new economic geography, namely the impact of falling trade costs on the spatial distribution of activities, except that the urban spatial structure now depends on the evolution the interregional distribution of activities.

5.1 How the local affects the global

Agglomeration seems to be the more likely outcome when commuting costs take low values. Indeed, agglomeration is always the single spatial equilibrium when commuting costs fall below t_m, but is never an equilibrium when $t > t_p$ (see Figure 2). This may be explained as follows. When cities are monocentric, it is readily verified that

$$\left.\frac{dC^C}{dt}\right|_{\theta^*=1} = \frac{L}{2} > 0$$

where C^C is given by (22). When cities are polycentric, some tedious, but standard, calculations show that

$$\left.\frac{dC^j}{dt}\right|_{\theta^*\in[1/3,1)} > 0 \qquad j = C, S$$

where C^j is given by (23). Hence, regardless of the city structure, urban costs borne by workers decrease as commuting costs fall. Consequently, net wages increase regardless of workers' residential location. This implies that more workers and firms are willing to choose to set up in a single city. This larger concentration of workers and firms then makes the agglomeration forces stronger, which in turn increases workers' utility. Eventually, all workers end up living in the same city when commuting costs are sufficiently low.

It is also worth stressing that increasing (resp., decreasing) commuting costs does not necessarily induce the decentralization (resp., centralization) of production within cities. Contrary to what a standard approach would suggest, monocentric cities may retain their spatial structure when commuting costs take high values. This is because economic agents react by getting dispersed between two cities, instead of getting re-organized within a polycentric city. For example, when $t < t_m$ and $t <$

ΥK, Figure 2 shows that the economy involves a single monocentric city. However, when commuting costs get larger than t_m while being lower than $2\Upsilon K$, the city remains monocentric while half the firms and workers leave it to form a new one (see Figure 2). Likewise, as shown by Figure 2, a polycentric city may emerge when commuting costs are sufficiently low ($t < t_m$). This is because low commuting costs foster agglomeration, thus raising, all else equal, land rents, and inducing, *in fine*, the decentralization of production within the same city.

Consider now the case of decreasing communication costs. When $t_p > t > t_m$, *falling communication costs foster agglomeration in a single city as well as dispersion within that city*. The argument goes as follows. Low values of K trigger the decentralization of production, thus increasing net wages. Indeed, it is easy to check that

$$\frac{d(w_r^S - C_r^s)}{dK} = \frac{d(w_r^C - C_r^C)}{dK} = -\frac{2}{3\phi} < 0$$

which means that agglomeration forces are strengthened when communication costs decline. Hence, the industry is concentrated because low communication costs induce decentralization within a large city - which may or may not coexist with a small city.

Finally, our setting shows how hysteresis effect may impact on the evolution of the urban landscape. To this end, consider again the case of decreasing communication costs together with $t_p > t > t_m$. A system of two monocentric cities having the same size holds as long as $t < 2\Upsilon K$. Even though agglomeration in a polycentric city is an alternative equilibrium once $2\Upsilon K > K > \Upsilon K$, urban inertia is likely to imply that the economy remains on the same path with two identical monocentric cities.[9] In this case, the hysteresis effect prevents full agglomeration within a single city. However, when communication costs reach a sufficiently low value, the economy displays agglomeration under the form of a single polycentric city or two asymmetric cities with one large polycentric city and one small monocentric city. In the latter case, the equilibrium path does not exhibit any discontinuity: *once the large city exists, its size grows and shrinks smoothly* while remaining polycentric. It should be noted that the economy may not shift to a pattern involving agglomeration in a single polycentric city, even when K is very low. For that, it suffices to have $t > t_p$ because dispersion forces then remain sufficiently strong.

5.2 How the global affects the local

In order to study the impact of falling trade costs, we re-write our main conditions in terms of t and distinguish the following three cases: (i) $t > 2\Upsilon K$; (ii) $2\Upsilon K > t > \Upsilon K$ and (iii) $\Upsilon K > t$. The most interesting situation arises when $t > \Upsilon K$ (cases (i) and (ii)) because it involves potential changes in the urban spatial structure with respect to the level of trade costs. Indeed, when $\Upsilon K > t$, no city can be polycentric. In this case, a gradual fall in trade costs generates the bell-shaped curve of spatial development - the sequence dispersion/agglomeration/re-dispersion - obtained in several models of new economic geography with urban costs (Ottaviano and Thisse,

[9]Urban inertia is strengthened by the durability of the housing stock, a variable not taken into account in the present model (Glaeser and Gyourko, 2005).

2004). When $2\Upsilon K > t > \Upsilon K$, we have at most one polycentric city whereas we have at least one polycentric city when $t > 2\Upsilon K$.

Figure 3

When commuting costs are high, Figure 3 shows that the economy may follow fairly different paths.[10] As long as $t > 2\Upsilon K$, the economy may involve one or two polycentric cities according to the trade cost value; its shifts from agglomeration (and no trade) to dispersion (and symmetric trade) when trade costs steadily decline, with a discontinuous change in the spatial pattern. Such an outcome is reminiscent of what is obtained within different frameworks of economic geography with urban costs and agrees with the bell-shaped curve of spatial development. The difference here lies in the fact that cities are polycentric instead of being monocentric. However, once $t > \max\{6\Upsilon K, t_p - 6\Upsilon K\}$ there is a second equilibrium path in which the economy displays a large polycentric city and a small monocentric city, with asymmetric trade in the differentiated product. Nevertheless, it is worth noting that the location of firms and workers smoothly reacts to a marginal change in trade costs. Indeed, the large city gets smaller as its size $\lambda^* = -\delta_2/\delta_1$ reduces when trade costs keep decreasing:

$$\frac{d(-\delta_2/\delta_1)}{d\tau} > 0 \quad \text{iff} \quad \tau < \tau_{trade} < \frac{\varepsilon_2}{2\varepsilon_1}.$$

Thus, as the global economy gets more and more integrated, less and less firms and workers are agglomerated in the large city. The partial redispersion of the economic activity is now gradual and not abrupt. Yet, $\lambda^* > 1/2$ when $\tau = 0$ because $t > 6\Upsilon K$. In other words, *the large city always hosts the majority of mobile activities when communication costs are sufficiently low for the decentralization of production within that city to arise.*

When $2\Upsilon K > t > \Upsilon K$, high trade costs are compatible with two very contrasted equilibrium paths. Along the first one, the economy involves two monocentric cities for all admissible values of the trade costs. However, when t is lower than t_p but larger than ΥK, the economy may also be agglomerated in a single polycentric city (see Figure 3). Despite the dispersion force generated by urban costs, a gradual fall in trade costs over a large interval of τ-values is consistent with agglomeration in a polycentric city. This is because commuting costs are sufficiently low with respect to trade costs for the polycentric city to guarantee urban costs that prevent the dispersion of activities. Yet, when trade costs decrease sufficiently for t to exceed t_p while being smaller than $2\Upsilon K$, two moncentric cities then emerge. This is because trade costs are now sufficiently low with respect to commuting costs.

To conclude, it appears that *the large city is often able to maintain its primacy* in the sense that dispersion does not arise once trade costs take low values - especially when commuting costs are not very low - as it does in other economic geography models with urban costs. This suffices to show that the development of urban SBDs may deeply affect the shape of the global economy.

[10]In order to avoid different subcases that do not add to our results, we assume that $t_m < 2\Upsilon K$ so that t_m does not appear in Figure 3. Such an inequality holds when $a_m > a > a_p$ (see sections 4.1 and 4.2.). We also assume that $t_p - 6\Upsilon K < 6\Upsilon K$ for all admissible trade cost values, which implies that an interior equilibrium emerges provided that $t > 6\Upsilon K$ (see Proposition 4).

6 Concluding remarks

We have presented a simple model that uncovers how the interplay between different types of spatial friction affects the location of economic activities *between* and *within* cities. Historical evidence shows that both trade and commuting costs have been decreasing since the beginning of the Industrial Revolution. Ever since the end of the 19th century, the development of the new communication technologies has allowed firms to alleviate the burden of urban costs in large metropolitan areas, through the emergence of secondary employment centers. We have shown how these various technological changes have impacted on the way firms and workers locate; our results agree with empirical evidence. Thus, we may safely conclude that what matters for the organization of the space-economy is the relative evolution of three types of costs: the commuting of workers, the transfer of information and the transport of commodities.

When cities are open to trade, *the organization of the space-economy varies with the ability of cities to accommodate a small or a large population in the monocentric arrangement*. For example, with low commuting costs and high communication costs, we obtain the bell-shaped curve of spatial development as trade costs keep decreasing. With high commuting costs and low communication costs, the picture is quite different. More precisely, when trade costs fall from high levels, the economy moves gradually from dispersion to agglomeration. Once agglomeration within a polycentric city has been achieved, the core maintains its primacy over a large range of trade cost values, thus confirming the idea that the polycentric structure fosters agglomeration. Our results also highlight the importance of local factors in the emergence of regional inequalities. For example, we have seen that global agglomeration is more likely to occur when commuting costs take very low values.

Last, note that the multiplicity of stable equilibria has an important implication that has been very much overlooked in the literature: *different types of spatial patterns may coexist under identical technological and economic conditions*. It should be no surprise, therefore, to observe a variety of urban systems in the real world.

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Appendix

In what follows, we determine the equilibrium wages when both cities are polycentric (case A) and when one city is polycentric whereas the other is monocentric (case B).

Case A. The corresponding equilibrium wages (w_r^C and w_r^S for $r = 1, 2$) are such that all firms, located either in the CBD or in the SBD of each city, earn zero profits (given, respectively, by (3) and (4)). More precisely, the equilibrium wages in city 1 are given by

$$w_1^C(\lambda) = \frac{I_1(\lambda)}{\phi} \qquad w_1^S(\lambda) = \frac{I_1(\lambda) - K}{\phi} \tag{28}$$

where

$$I_1(\lambda) = \frac{(b\phi + cL)L}{4(2b\phi + cL)^2\phi^2} \left\{ [2a\phi + \tau cL(1-\lambda)]^2\lambda + [2a\phi - 2\tau b\phi - \tau cL(1-\lambda)]^2(1-\lambda) \right\}$$

is quadratic in λ; a similar expression holds for $w_2^C(\lambda)$ and $w_2^S(\lambda)$.

Case B. When city 1 is polycentric whereas city 2 is monocentric ($\theta_1^* < 1$ and $\theta_2^* = 1$), the equilibrium wages (w_1^C, w_1^S and w_2^C) are such that no firm established in city 1 and located either in the CBD or in the SBD of this city, or established in the CBD of city 2 is able to make positive profits. More precisely, they are given by (28) for city 1 and by

$$w_2^C(\lambda) = \frac{I_2(\lambda)}{\phi} \tag{29}$$

for city 2, where

$$I_2(\lambda) = \frac{(b\phi + cL)L}{4(2b\phi + cL)^2\phi^2} \left\{ (2a\phi + \tau cL\lambda)^2(1-\lambda) + (2a\phi - 2\tau b\phi - \tau cL\lambda)^2\lambda \right\}$$

is quadratic in λ.

Figure 1. Land rents and urban structure

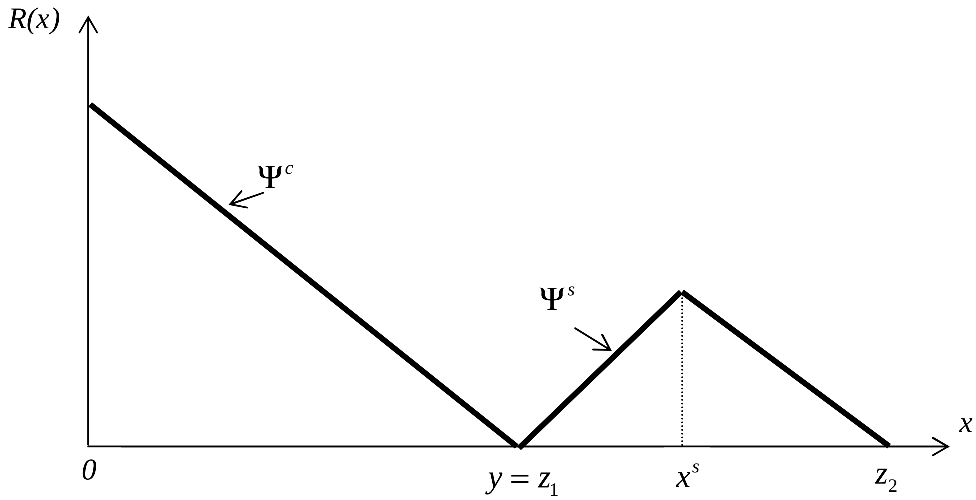

Figure 2. Spatial equilibria in (*K*, *t*)-space.

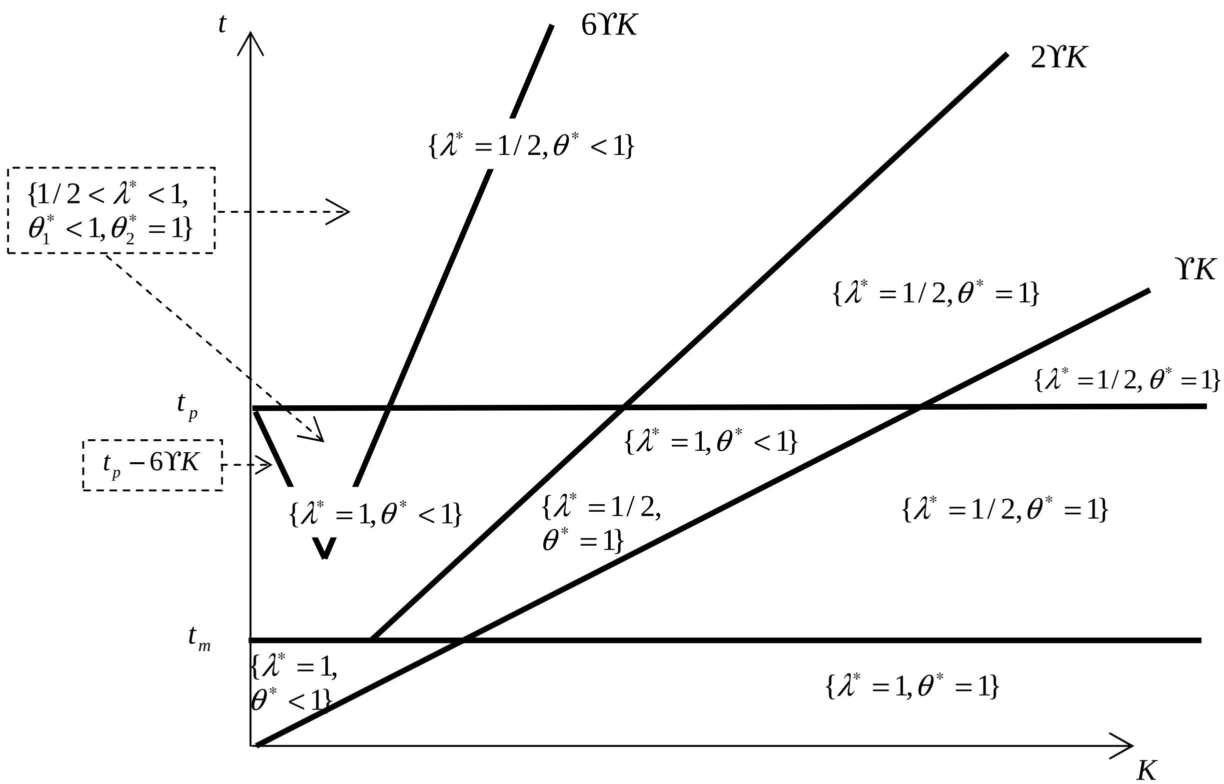

Figure 3. Spatial equilibria in (t,τ)-space