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Developers' choices under varying characteristic time and competition among municipalities

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Abstract In a previous paper (Czamanski and Roth in Ann Reg Sci 46(1):101–118, 2011), we demonstrated that spatial variation in characteristic time can lead to leapfrogging and scattered development, especially in times when interest rates are low or negligible. We explained this result by modeling the simple behavior of developers in the context of a single city within a linear space. In this paper, we consider the case of two municipalities that leads to development policies that are reflected in different characteristic time functions in each territory. Myopic assumptions, in the sense that each city is interested only in what happens on its side of the border, can easily lead to unintended leapfrogging. Whereas competition between the cities, including in the case that each city takes into consideration processes in the entire region, can result in intentional leapfrogging or in spatially concentrated development, depending on the policy objectives of the authorities.

JEL Classification R11 · R12

1 Introduction

Much of the literature concerned with the spatial structure of cities analyzed patterns in the context of Alonso type models (Alonso 1964; Mills 1967; Muth 1969; Wheaton 1982). In contradistinction, high-rise buildings display a peculiar non-continuous spatial pattern along various rays emanating from urban centers outwards. In a recent work, we studied these patterns in the case of Tel Aviv (Roth 2009). In another recent paper (Czamanski and Roth 2011), we suggested a plausible explanation for evolution and the resulting pattern.

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In particular, our model suggests that the effort of municipalities and that of various NGO's to prevent sprawl may be counterproductive and that under some circumstances, it may contribute to the creation of edge cities (Czamanski and Roth 2011). We introduced the concept of characteristic time, the time between acquisition of property rights and the realization of returns, as a fundamental factor in a model of developers' behavior. According to our model, the evolution of urban spatial patterns is the result of developers' search process for parcels of land that can yield the highest returns. One of the critical variables in the decision making of developers is time. Despite the obvious differences in land prices within a particular real estate market, differences in costs and prices are relatively small in comparison with differences in their value due to their time incidence.

In our previous paper, we considered the presence of a single municipal authority and one set of stable rules that determined the spatial incidence of characteristic time. In this paper, we extend the analysis to the case of two cities. Here, the spatial incidence of characteristic time is determined by a municipality within its own boundary, independently of its neighbors. The characteristic time in each authority is an outcome of the behavior of several interacting actors and agendas, including the municipality's planning authorities, neighbors' idiosyncrasies, NGOs' agenda, and others. For example, in a city where the municipality leads an anti-sprawl policy and residents and environmental groups are active in efforts to preserve open spaces, the characteristic time will presumably rise from the center outwards. In a city where the CBD lacks sufficient infrastructure to support urban growth, as may the case in an historical city center, both the municipality and neighbor associations may support spreading development, and therefore, the characteristic time will be high near the center and decrease with the distance from it. We then study the repercussions of various models of rivalry and cooperation of the municipal authorities and the resulting implications for the behavior of developers and for the spatial structure of cities.

2 One city case

In a context of a linear city and in the presence of a single municipality, the phenomenon of leapfrogging varies in relation to changes in characteristic time over space. Figure 1 presents the stylized facts in the case of a simplified linear economy. The central business district (CBD) is at X_A. The city extends to a boundary at X_L. The developer chooses to build at location D at a distance X from the CBD. For the present, we ignore the presence of another municipality with a CBD at X_B.

The developers' problem is to find an optimal location $x*$ and optimal height $h*$ that leads to profit maximization. The developer's objective function (Czamanski and Roth 2011) is:

$$\begin{aligned}&\underset{x,h}{\mathrm{Max}} FV(t=\tau) = -I(x,h)(1+r)^{\tau} - C(h) + P(x)h \\ &s.t. \tau = \tau(x,h).\end{aligned} \tag{1}$$

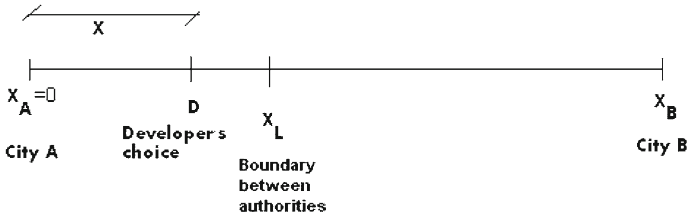

Fig. 1 The spatial structure of linear cities

where $I(x, h)$ represents that land price as a function of location x and building rights expressed as height of buildings. The discount rate is r. The overnight building cost is a function of building height and is expressed as C. Finally, $P(x)$ is the willingness to pay of buyers at location x.

Analyzing the first-order conditions for identifying the optimal location and height Czamanski & Roth arrived at the following conclusions:

1. Leapfrogging of heights occurs when

$$\frac{\partial h^*}{\partial \tau} > 0 \text{ and } \frac{\partial \tau}{\partial x^*} > 0 \text{ therefore } \frac{\partial h^*}{\partial x^*} = \frac{\partial h^*}{\partial \tau} \cdot \frac{\partial \tau}{\partial x^*} > 0. \tag{2}$$

2. There are three distinct possibilities for the sign of $\frac{\partial \tau}{\partial x^*}$:

$$\frac{\partial \tau}{\partial x^*} = 0, \quad \frac{\partial \tau}{\partial x^*} > 0 \text{ or } \frac{\partial \tau}{\partial x^*} < 0.$$

3. If $\frac{\partial \tau}{\partial x^*} = 0$, then in (2) $\frac{\partial h^*}{\partial x^*} = \frac{\partial h^*}{\partial \tau} \cdot 0 = 0$. In this case, the optimal height does not depend on the distance from the CBD.
4. If $\frac{\partial \tau}{\partial x^*} > 0$, then the sign of $\frac{\partial h^*}{\partial \tau}$ in (2) is not clear and the condition for a positive derivative that can lead to leapfrogging is a very low interest rate, such as may occur during periods of recession.
5. If $\frac{\partial \tau}{\partial x^*} < 0$, it can be shown that $\frac{\partial h^*}{\partial \tau} > 0$, and therefore, $\frac{\partial h^*}{\partial x^*} = \frac{\partial h^*}{\partial \tau} \cdot \frac{\partial \tau}{\partial x^*} < 0$. In this case, h^* is a decreasing function of the distance from the CBD. As in the previous case, only when the interest rate is negligible, leapfrogging is possible.

The above-mentioned results are suggestive of the importance of planning decisions that result from the behavior of urban actors and their implications for the spatial structure of an isolated city. Now, we turn to the more realistic situation of non-isolated urban context.

3 The case of two cities

Most cities, at least in the Western world, are segmented into many municipalities. In our linear world, X_L (see Fig. 1 above) is the administrative boundary between the two municipal administrative areas A and B. For our present purpose, the location of this boundary is insignificant. It is assumed that it was defined as part of an historical, political process. The segment $(X_L - X_A)$ and the segment $(X_B - X_L)$ are not necessarily equal.

The planning authorities' decisions are influenced by policies, regulations and not the least by the intervention of NGOs and the public in the decision-making process, and therefore, in each municipality, the characteristic time is determined by the interaction of an independent planning authority and of others involved in the planning process. We presume that in a Tiebout (1956) style world, each planning authority reflects the preferences of its self-selected residents. The characteristic time in each municipality pertains to its own territory only. As in the single municipality case, τ is function of distance from the respective central business district. It is also a function of the intensity of the proposed development. Thus, it is an increasing function of building height. In other words:

$$\tau = \tau(x, h) \begin{cases} \tau^A(x, h) \text{ If } x \in [x_A, x_L] \\ \tau^B(x, h) \text{ If } x \in (x_L, x_B] \end{cases} \tag{3}$$

As in our previous study, it is assumed that the developers have precise information about the characteristic time at each location over the segment $[x_A, x_B]$.

Since the present analysis is concerned with two neighboring municipalities, each of which defines the characteristic time in its respective area of influence, various possible situations occur and should be examined. First, we assume myopic actors in each municipality. Myopic behavior means that each actor (planners, NGO's, citizens) acts as if what happens beyond his municipal boundary is not of his concern. All the possible combinations of characteristic time functions need to be analyzed. The following table lists the various possibilities.

Relaxing the myopic behavior assumption, all the actors in both municipalities are aware of the prevailing characteristic time throughout the entire $[x_A, x_B]$ segment, irrespective of the jurisdiction that determines τ. Two possible situations arise. The situations depend on each municipality's planning goals and policies regarding the desired behavior by developers. Should their policies differ, such as for example as one city aims to spread its development and the other attempts to concentrate building areas and maximizing open areas, each of the cases included in Table 1 should be reexamined. If the policy outcomes of the municipalities are similar, they will compete in order to maximize their objectives, either by attracting developers or by imposing stricter restrictions. In this case, it is expected that their τ functions will reach an equilibrium where

$$\lim_{x \to x_l} \tau^A(x, h) = \lim_{x \to x_l} \tau^B(x, h)$$

In such a case, the characteristics of the equilibrium function should be analyzed regarding the position of the boundary limit (x_L) too. It is possible that one of the cities

Table 1 Characteristic time scenarios in the case of two cites and myopic planners

Municipality A	Municipality B
$\tau_x^A = 0$	$\tau_x^B = 0$
$\tau_x^A > 0$	$\tau_x^B = 0$
$\tau_x^A < 0$	$\tau_x^B = 0$
$\tau_x^A > 0$	$\tau_x^B > 0$
$\tau_x^A < 0$	$\tau_x^B > 0$
$\tau_x^A < 0$	$\tau_x^B < 0$

will suffer disadvantaged position due to the location of the boundary and regardless of the equilibrium that can be achieved theoretically.

So far, we considered cities A and B that were implicitly assumed to be of equal size. If their size differs and this element is included in the analysis, gravitation considerations arise that can influence developers' decisions. For example, consumers demand characteristics and willingness to pay for a house at the same distance from the CBD of a large city or the CBD of a smaller one will differ.

4 Myopic behavior

The trivial assumption that $\tau_x^A = 0$ and $\tau_x^B = 0$ means that planning policies and urban actors' behavior are place independent in the case of both cities. In other words, in each city, characteristic time does not depend on location, nor dependent on the optimal height of proposed building projects. The developer's decision concerning where and at what intensity to build is not influenced by the location on the segment $[x_A, x_B]$, but by other parameters, not considered in this model.

Similar result holds in the cases where $\tau_x^A > 0$ and $\tau_x^B = 0$ or $\tau_x^A < 0$ and $\tau_x^B = 0$. In such a case in one of the cities location-specific planning policies arise, while the other is insensitive to location in planning policy making. In this case, the model is capable of incorporating the characteristic time laws only in $[x_A, x_L]$ segment of the market, whereas in $[x_L, x_B]$, the characteristic time does not depend on location. It may well be that some non-location-related features in city B will make development there much more profitable than in $[x_A, x_L]$. However, nothing can be said about this possibility within this model framework.

Now, we consider the case that $\tau_x^A > 0$ and $\tau_x^B > 0$. This means that the characteristic time increases with the distance from the CBD in both cities. This indicates that planning policies in both cities aim to concentrate urban development near the CDB and to prevent sprawl. The further away from the CBD the proposed project is located, the more cumbersome is the approval process, due to bureaucratic impediments or legal objections, and the more time it will take to realize a return on the developer's investment. It seems reasonable to suppose that the characteristic time increases at a decreased rate (therefore, $\tau_{xx}^A < 0$ and $\tau_{xx}^B < 0$). Figure 2 below describes the general resulting scenario.

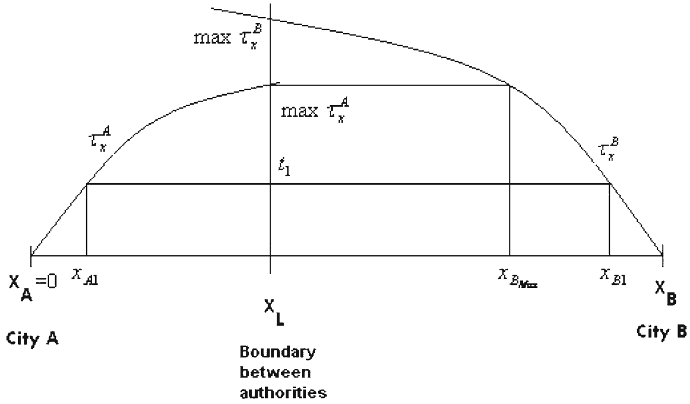

Fig. 2 Two cities case with $\tau_x^A > 0$ and $\tau_x^B > 0$

A developer ready to wait for the realization of the project until time t_1 will be indifferent between locations x_{A1} and x_{B1}. This conclusion requires the assumption that land and overnight construction costs are similar. The resulting situation holds for any location within the segment $[x_A, x_L]$ and the segment $[x_{B_{\text{Max}}}, x_B]$. The developer will choose a site within those segments, as close as possible to each of the CBDs. The possibility of leapfrogging in each city is present in the case that interest rates are low enough to lead to $I \cdot \ln(1 + r) \cong 0$.

Within the segment $[x_{B_{\text{Max}}}, x_L]$, the outcomes of this scenario depend on the initial investment required in this area. If it is low enough to overcome the longer characteristic time, the developer is expected to choose a site in $[x_{B_{\text{Max}}}, x_L]$, even at the expense of options sited in $[x_A, x_L]$ or $[x_{B_{\text{Max}}}, x_B]$. Otherwise, if the initial investment is comparable with the investment required in $[x_A, x_L]$ and $[x_{B_{\text{Max}}}, x_B]$, given the different behavior of both τ_x^A and τ_x^B curves none of the available sites in the whole segment $[x_{B_{\text{Max}}}, x_B]$ will be chosen (at least as long as there is available land on $[x_A, x_L]$ or on $[x_{B_{\text{Max}}}, x_B]$). This is because the characteristic time imposed in it by municipality B is too high.

If $\tau_x^A < 0$ and $\tau_x^B > 0$, the characteristic time decreases with the distance from the center of A, but the opposite is true starting from B's center and moving away from it. This situation may suggest that for some reason, city A is willing to spread its development far from its own CBD, while city B takes the opposite approach, trying to concentrate the urban development near its CBD. A schematic depiction of this scenario is presented in Fig. 3.

In this case, assuming interest rates far from zero ($r \gg 0$) and similar initial investments in $[x_A, x_B]$, the developer will always choose locations sited in $[x_{B_{\text{Max}}}, x_B]$, since here the characteristic time is lowest. Development asymmetries between cities A and B can be created, and following the myopic assumption, city A is expected to lower significantly its characteristic time in order to attract developers. Under the scenario assumptions, this policy is prone to failure. Reducing the length of $[x_{B_{\text{Max}}}, x_B]$ is the only expected result, but our developer will not be attracted to city A boundary, unless there is no available land on $[x_{B_{\text{Max}}}, x_B]$.

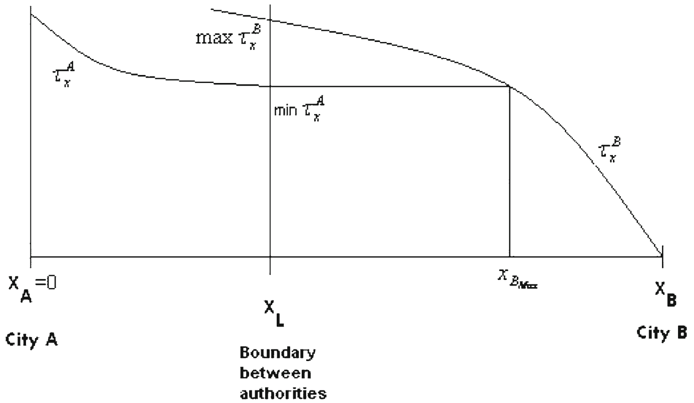

Fig. 3 Two cities case with $\tau_x^A < 0$ and $\tau_x^B > 0$

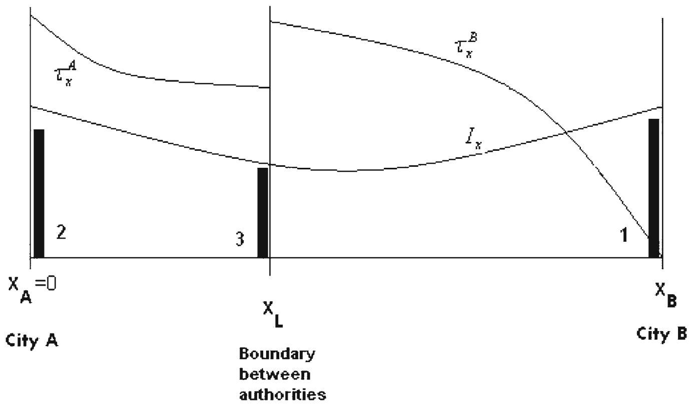

Fig. 4 Two cities case with $\tau_x^A < 0$ and $\tau_x^B > 0$ and $I_x < 0$

Still under the same assumptions, if the initial investment is assumed to be a decreasing function of the distance from the CBD ($I_x < 0$), another outcome can result. The developer should maximize profits performing higher investments and selling high-price houses near the CBD (in this case, B is the best option due to its low characteristic time) or performing lower investments and selling at a lower price in other locations. In this last case, the gap in the characteristic time in the limit x_L may determine that the developer willing to build near the border zone will search for a location closer to the city A side of the limit, leading to leapfrogging as is indicated in Fig. 4 that includes three superposed graphs as functions of x: τ_x in time units, I_x in land price units, and a sketch of the three preferable locations from the developer's point of view.

If interest rates are negligible, leapfrogging conditions may appear along the entire segment $[x_A, x_B]$, since if both $\tau_x^A < 0$ and $\tau_x^B > 0$, the low interest rates can lead to developments far from both CBDs.

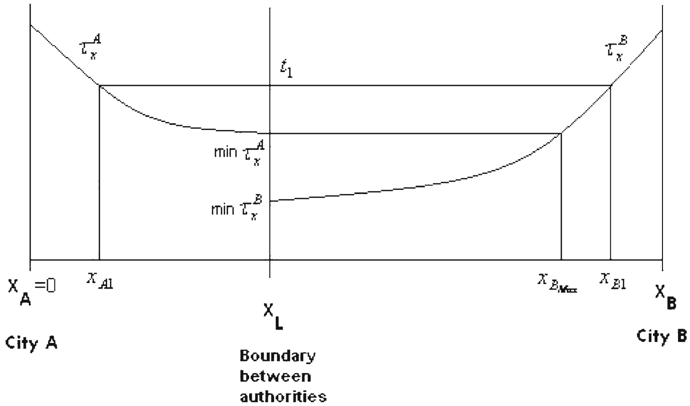

Fig. 5 Two cities case with to $\tau_x^A < 0$ and $\tau_x^B < 0$

The last case pertains to $\tau_x^A < 0$ and $\tau_x^B < 0$. This scenario suggests that both cities are encouraging developers to find locations far from the CBD. A schema of τ_x is included in the next figure.

A developer, who is ready to wait until t_1, will be indifferent between locations x_{A1} and x_{B1} if land and overnight costs are similar. This situation holds for any location between $[x_A, x_L]$ and between $[x_{B_{\text{Max}}}, x_B]$. However, the lowest characteristic times can be found within segment $[x_{B_{\text{Max}}}, x_L]$. Assuming a normal situation that includes positive interest rates and land prices that are a decreasing function of the distance from the CBD, $I_x < 0$, the result should be similar to those depicted in Fig. 4, but in this scenario with the development will occur on the city B side of the border, where $\min \tau_x^B < \min \tau_x^A$. Leapfrogging of high buildings can occur as in the previous scenarios, if interest rates are very low, and in this case, because the gap in the characteristic time near the boundary x_L, high buildings are expected to be built on the city B side of the border (Fig. 5).

5 Full awareness: competition

Assuming that both municipalities are aware of the tendencies and processes occurring in the entire $[x_A, x_B]$ segment and given that their outcome development policies are similar, they will compete in order to pursue their similar goals. In this case, not only the shape of the characteristic time (τ_x^A and τ_x^B) is important but also is their behavior near the boundary x_L.

If τ_x^A and τ_x^B have significantly different values in $x_L(\tau_x^A(x_L) \gg \tau_x^B(x_L)$ or $\tau_x^A(x_L) \ll \tau_x^B(x_L))$, developers behavior around the boundary will be heavily influenced by the difference, seeking development sites on one side of the border, presumably the side with lower characteristic time. Competition between the municipalities will lead to characteristic times that ensure that developers will be indifferent between both sides of the boundary. In other words, that

$$\lim_{x \to x_l} \tau^A(x, h) = \lim_{x \to x_l} \tau^B(x, h)$$

Again, let us look at the case when $\tau_x^A > 0$ and $\tau_x^B > 0$, as depicted in Fig. 6.

Given that land and overnight costs are similar, a developer ready to wait until time t_1 will be indifferent between locations x_{A1} and x_{B1}. In this case, assuming normal market conditions, leapfrogging conditions can arise depending on τ_x^A and τ_x^B concavity and x_L position. The behavior of the functions at x_L boundary and the assumption that $\tau_x^A > 0$ and $\tau_x^B > 0$ do not assure similar growth rates as τ_x^A moves away from x_A and τ_x^B moves away from x_B. For example, in Fig. 6, decision to develop at x_{B1} could cause leapfrogging in city B, whereas a similar decision at x_{A1} may not. This is despite the fact that from the developer's point of view, the decisions are equivalent.

If it is assumed that $\tau_x^A < 0$ and $\tau_x^B < 0$, and a similar relationship between τ^A and τ^B second derivatives and x_L location can be defined. It is related to the functions' concavity.

In Fig. 7, development in locations x_{A1} or x_{B1}, both with the same characteristic time t_1, can lead to leapfrogging in city B if x_{B1} is chosen, but probably not in city A if site x_{A1} is developed instead.

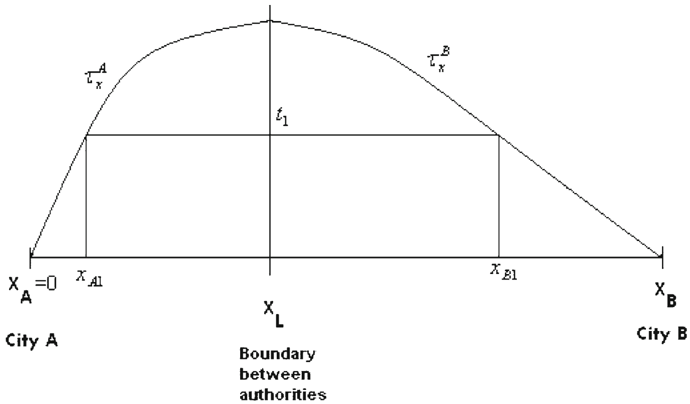

Fig. 6 Two cities case with $\tau_x^A > 0$ and $\tau_x^B > 0$

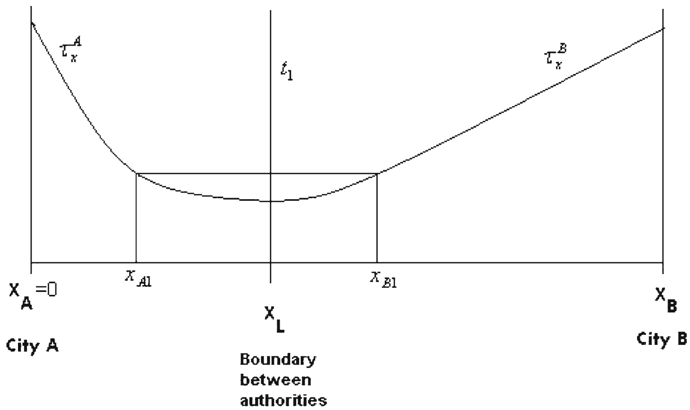

Fig. 7 Two cities case with $\tau_x^A < 0$ and $\tau_x^B < 0$

The basic assumption in this section is that the development policies in city A and city B are similar. Suppose that unwanted leapfrogging conditions are created on one side of the administrative boundary. This means that the municipality or other urban actors will provoke a change in the characteristic time function in order to encourage developers to search for developable land in other parts of its segment. It implies, in turn, that the other municipality and the agents acting in it will be forced to change their own characteristic time function, in order to avoid the creation of leapfrogging conditions in their segment. The same interactions hold if the leapfrogging is a positive outcome from the municipalities' point of view, but in this case, they will compete giving the best possible conditions to develop land far from the CBDs.

It follows that in the long run, it is expected that both τ^A and τ^B will converge to an equilibrium characterized by the rule that for every characteristic time t_n, there are $x_{A_n} = \tau_x^A(t_n)$ and $x_{B_n} = \tau_x^B(t_n)$ such that

$$\frac{x_{A_n} - x_A}{x_L - x_A} = \frac{x_B - x_{B_n}}{x_B - x_L}$$

In other words, the optimal location for each characteristic time at both sides of the administrative boundary will be proportional to the municipality's segment length. The previous condition holds both for the case when both $\tau_x^A > 0$ and $\tau_x^B > 0$ and opposite ($\tau_x^A < 0$ and $\tau_x^B < 0$).

Irrespectively of policies and shape of the characteristic time functions, negligible interest rates could provoke leapfrogging along the entire $[x_A, x_B]$ segment, as stated in (3).

Situations where $\tau_x^A < 0$ and $\tau_x^B > 0$, or where $\tau_x^A < 0$ and $\tau_x^B > 0$, are not relevant under the assumption that the resulting development policies of both municipalities are similar. This is because they define different management approaches at each side of the border.

6 Full awareness: different policies

An additional plausible assumption is that both municipalities are aware of the tendencies and processes occurring in the entire $[x_A, x_B]$ segment, but that their resulting development policies are different. For example, if city A is willing to develop low-density sprawling neighborhoods and city B wants to maintain a highly concentrated business district with plenty of open space in its periphery, a situation as depicted in Fig. 3 could arise. Since the boundary between A and B is irrelevant for the people living in segment $[x_A, x_B]$, such an arrangement could be mutually beneficial, from a regional point of view, offering simultaneously dense urban environment, low-density neighborhoods and open spaces, and for both cities, one attracting dwellers and the other attracting business and offering recreational services.

7 Conclusions

We have demonstrated that spatial variation in characteristic time can lead to leapfrogging and scattered development, especially in times when interest rates are low or negligible. This phenomenon can be explained by modeling the simple behavior of developers in the context of a single city within a linear space (Czamanski and Roth 2011).

The same situation can arise if the model includes two cities with linear edges. But in this case, additional factors play an important role and need to be considered. The main difference from the single city case is that in each city, different development policies can arise, which are reflected in different characteristic time functions in each territory. Myopic assumptions, in the sense that the urban actors in each city are interested only in what happens on their side of the border, can easily lead to unintended leapfrogging. Whereas competition between the cities, including in the case that all the factors involved in planning processes in each city take into consideration processes in the entire region, can result in intentional leapfrogging or in spatially concentrated development, depending on the outcoming policy objectives of the authorities. Additional scenarios of collaboration between authorities with different goals are also feasible.

In this paper and in all the scenarios discussed, the core cities A and B were assumed to be equivalent in each relevant parameter, such as population, size, purchase power. The only element that caused asymmetries between the cities was the location of the administrative boundary. Besides its simplicity, there is no reason to assume that this is the case. Both cities can be different, even qualitatively, such as for example, a developed city in A and a small town in B. This and other cases will be considered elsewhere.

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