Open space preservation in an urbanization context

PRELIMINARY VERSION

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Abstract

The objective of this paper is to address the question of open space preservation in an urbanization context. Should the cities grow in a compact way letting big open agricultural spaces? Or is it better to let the cities grow extensively with low density urban sprawl with small open spaces inside cities' limits? We analyze these questions into a theoretical microeconomics framework taking into account both households preferences for open space and regulator cares for ecosystem services' conservation. We derive land use patterns at private equilibrium and we study the impact of different policy instruments.

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1 Introduction

An increasing share of the world population locates in urban area. People choose to live in cities because they find jobs and commodities, but at the same time, the expansion of cities is responsible for the destruction of natural land and the loss of open space. Hence, the fast expansion of cities leads to a growing public concern regarding the environmental impacts of urbanization. A lot of public policy try to limit urban expansion, and more precisely urban sprawl, which refers to the spreading outwards of a city to its outskirts that is excessive relative to what is socially desirable. Brueckner (2000) explains that urban sprawl is the consequence of the failure to account for the social value of open space. Hence, he recommends to limit urban sprawl in order to preserve open space that are located at the outskirts of city, such as big agricultural plane or forest. However, he does not take into account the possibility of intra-urban open space. In that case, sprawl may be the consequence of households preference for small open space available just near their place of residence. Indeed, several studies show that household value open space that is located directly next to to their habitations (see Brander and Koetse (2011) for a review). In a hedonic price study, Joly et al. (2009) show that only forest and farmland in the immediate vicinity of houses have positive prices, and landscape more than 200 meters away have insignificant hedonic prices.

In a theoretical model, Turner (2005) analyzes the equilibrium and optimum city structure when households value local open space, and he shows that the optimal city is less compact than at the equilibrium. According to him, public policy such as urban growth boundaries are not fitted when households value local open space. Cavailhès et al. (2004) also demonstrate that the sprawl pattern of cities and the existence of a periurban area is the consequence of households preferences for natural amenities and thus is not necessarily a inefficient pattern of development.

So the question of open space preservation is cities is not easy to answer : is it better to preserve intra-urban open space in small patches and let the city extend more, or is it better to have a very compact city with large natural open space at its outskirts? This question fits in the recent land sharing-land sparing debate. This debate first appears in the literature of the impact of agriculture on biodiversity, and recently extends to the context of cities (Lin and Fuller, 2013; Soga et al., 2014). From an ecological perspective, the question is far to be completely answered. To broaden the debate, we propose in this paper an economic analysis of these questions, in order to understand how the behavior of economic agents influence the city's structure and the existence and preservation of different types of open space.

Several papers have already studied the effect of open space in a spatial urban context. For example, Wu (2001) and Wu and Plantinga (2003) consider city formation when people have a taste for proximity to exogenously located open space, such as a park or an ocean shore. Their analysis focus on the role of open space in city structure, but they do not consider the possibility for the available amount of open space to be modified by the choice of localisation of people, concealing the fact that people impose external costs on each other. Strange (1992) considers the question of open space in city in a model where there are housing externalities but does not model a land market. Walsh (2007) proposes a Tiebout model in which people have preferences over the characteristics of neighborhood landscape and the amount of open space in particular. The analysis is interesting but the Tiebout framework does not allow to analyse the micro-strucutre of urban development that we want to develop here.

This paper departs from the previous literature by developing a theoretical urban model which examine the interactions between agents economic behavior and the existence of different types of open space.

The objectives of this paper are : (i) to identity the effect of households preferences for local open space on the equilibrium city structure, (ii) to analyze the effects of an urban growth boundary and a development tax on the preservation of different types of open space : local intra-urban open spaces and large open space at city's outskirts.

The remainder of the paper is organized as follows. Section 2 presents the structure of the model without any functional specifications. Section 3 extends the analysis with an application with linear functional forms, and section 4 deals with policy design for open space preservation. Finally, section 5 concludes.

2 The model

2.1 Residential behavior

Consider a monocentric city in which all the firms locate at the central business district (CBD), which size is neglected. The city lies on a uni-dimensional space $Z = [0, +\infty[$. At each location $z \in Z$, the quantity of available land is equal to one. The problem is to obtain the pattern of the residential area in this city, when the number of households varies endogenously and the equilibrium utility level is fixed and equal to the world utility level at each time (i.e. it is an open city).

All households are assumed to be homogeneous, i.e. that each household's income level and utility function are identical, and they receive utility from residing in the city.

Households divide their entire income between the consumption of a composite good, a house, and transportation cost. The lot size of each house is assumed to be exogenously fixed.

The character of each house is heterogenous across the city, as households have preferences for natural amenities : we consider that households care about local open space, available directly at their place of residence. In other word, they prefer to live in a place with a low level of development.

Natural amenities are considered as spatial attributes of housing, which affect the households' utility function but not their budget constraint.

Thus, households' maximization program is the following :

$$\begin{cases} \max\limits_{m,z} & u(m, q, d(z)) \\ s.t. & R(z)q + m + t(z) \leq w \end{cases}$$

where

$u(\cdot)$: the utility function

z : the distance from the city center

m : the amount of the composite good of which price is the numéraire

q : the lot size of the house assumed to be fixed

$d(z)$: amenities related to the amount of open space directly available at location z

$R(z)$: the rent of a house at distance z

$t(z)$: the transport cost for a household at distance z

w : the income

If we call $x(z)$ the level of development at each location z (with $0 \leq x(z) \leq 1$), the level of amenities $d(z)$ provided by local open space is a decreasing function of $x(z)$.

At equilibrium, all households receive the same reservation utility level $\bar{u}$, no matter their residential location as they are identical and mobile. The household's demand function for the composite good m can be found by solving:

$$u(m, q, d(z)) = \bar{u} \tag{1}$$

We can now derive the residential bid-rent function $R_h(z)$, which indicates the maximum amount a household is willing to pay at one location relative to another while receiving the utility level $\bar{u}$:

$$R_h(z) = \frac{w - t(z) - m^*(q, d(z), \bar{u})}{q} \tag{2}$$

Where $m^*(q, d(z), \bar{u})$ is the solution to $u(m, q, d(z)) = \bar{u}$. Thus, the residential bid-rent is an implicit function of the income, the transport cost, the lot size, and the level of amenities :

$$R_h(z) \equiv R(w, t(z), q, d(z), \bar{u}) \tag{3}$$

With $\frac{\partial R}{\partial w} > 0$, $\frac{\partial R}{\partial t(z)} < 0$, $\frac{\partial R}{\partial q} > 0$, and $\frac{\partial R}{\partial d(z)} > 0$. When prices vary according to (3) across the landscape, households' utilities are identical across locations and households have no incentive to move. The bid-rent function reveals the difference between our model and the standard monocentric city model. In the standard model, natural amenities are assumed to be distributed uniformly across the landscape : residential rents always fall with the distance from the CBD, compensating suburban residents for their cost of commuting. However, with spatial variations in amenities, the spatial pattern of the rent is more complicated. A household may be willing to sacrifice proximity to the workplace for amenities, with the result that willingness to pay for housing may no longer be a monotonically decreasing function of CBD distance. These results are fully developed in section 3.

2.2 Development decision

On the supply side, housing is produced with land, labor and materials under constant returns to scale. The development cost per-acre is given by $c(x(z))$ and is a function of the level of development. The house size, q, is fixed, and outside developers choose the level of development (or development density) $x(z)$ at each location (which is equivalent to the number of houses per acre). We make the assumption that at each location, one and only one developer is the landowner of the parcel and takes the development decision.

Moreover, we suppose that the cost of development $c(x(z))$ is a linear function of the development density $x(z)$ such that $c(x(z)) = Cx(z)$ where C is a positive constant, meaning that the cost increases at the same rate as $x(z)$. At each location, the developer chooses the development density to maximize profit :

$$\max_{x} \pi(x,z) = R(z)x(z) - Cx(z)$$

Here, two possibilities arises depending on the level of information of developers.

- If developer does not know that the residential rent depend on the level of development $x(z)$, then she takes the rent as given and the first order condition is the following :

$$R(z) = C \tag{4}$$

  As the developers does not know that the residential rent depends on the level of development, the second order condition gives $\pi''(x(z)) = 0$ meaning that the profit function is a linear function of x.

- If the developers have a higher level of information, meaning that she knows that the residential rent will vary with the level of development $x(z)$, the solution of the maximization problem is the following :

$$\frac{\partial R}{\partial x(z)} x(z) + R(x(z)) = C \tag{5}$$

  The second order condition gives $\pi''(x(z)) < 0$ (as long as the rent is a decreasing and concave or decreasing and linear function of $x(z)$), thus the profit function reached its maximum when $x(z)$ is the solution of the differential equation (5).

  The development density is a function of the residential rent and, through it, the level of amenities at each location.

2.3 Equilibrium city structure

At equilibrium, housing prices are bid up until no household has any incentive to move. This condition is satisfied when housing prices are represented by (3) since the household's bid function is the maximum willingness to pay for housing. The equilibrium number of households at any location, $n^*(z)$, equals the equilibrium development density divided by floor space per household : $n^*(z) = x^*(z)/q$. Land will be developed if the developer's profit from construction exceed the rent of land in its previous state (agricultural or natural). We suppose that this rent equals zero.

2.3.1 The level of development

To make the analysis simpler, we suppose from now on that the transport cost is a linear function of distance z. The transport cost $t(z)$ increases proportionally with the distance to the city center following $t(z) = Tz$ with T a positive constant.

When developer has no information on the residential rent The first order condition of the developer's program is given by :

$$\pi'(x(z)) = 0 \Leftrightarrow R_h(w, t(z), q, d(x(z)), \bar{u}) = C \tag{6}$$

The rent function depends negatively on $x(z)$ as households prefer location with a low level of development, however recall that the developer does not have this information. Thus, the first order condition can be interpreted as follow : as long as $R(z) \geq C$, the developer's profit is positive and she can choose any level of development $x(z) \in \,]0, 1]$ to maximize profit. We suppose that she will choose $x^*(z) = 1$ and the city will be fully developed until the location $\bar{z}$ where the developer's profit becomes negative $(R(z) < C)$

then $x^*(z) = 0$ for $z \geq \bar{z}$. At the city's limit $\bar{z}$, when the profit exactly equals zero, $x(z)$ is the solution of (6).

When developer has informations about the residential rent In that case, the first order condition of the developer's program is given by :

$$\frac{\partial R_h}{\partial x(z)} x(z) + R_h(w, t(z), q, d(x(z)) = C \tag{7}$$

The second order condition gives $\pi''(x(z)) < 0$ meaning that the profit function is a concave function of x and the maximum level of profit is obtained when the first order condition is satisfied, so when :

$$x^*(z) = \frac{R_h(w, t(z), q, d(x^*(z))) - C}{K} \tag{8}$$

Where K is a constant. In that case, the level of development vary with the residential rent. Further, an increase in residential rent would increase the development density. However, the development density is a disamenity for households and an increase in development density will reduce households' willingness to pay for housing. In that case, the developer chooses the number of houses built by balancing households' taste for local open space and her own interest for high density.

Thus, an important result to note here is the following : the fact that developers have some informations about the residential rent when they make their choice of development is a sufficient condition for the existence of a periurban city where the level of development is not maximum in each point of the city.

2.3.2 The residential rent

The objective of this section is to understand how residential rent varies with distance to the city center. The equilibrium rent is found by replacing the equilibrium development level $x^*(z)$ into the residential rent $R_h(z)$, thus :

$$R^*(z) \equiv R_h(w, t(z), q, d(x^*(z))) \tag{9}$$

The first derivative of the rent function with distance z is given by :

$$\frac{dR^*}{dz} = \frac{\partial R^*}{\partial t}\frac{\partial t}{\partial z} + \frac{\partial R^*}{\partial d}\frac{\partial d}{\partial x^*}\frac{\partial x^*}{\partial z} \tag{10}$$

In the standard urban model, the second term of the right hand side of the equation is nul, and the slope of the residential rent always fall with distance to the center to compensate for higher transport costs. In our model, their is an additional term related to natural amenities existing in each location z.

When developer has no information on the residential rent We know that the level of development $x^*(z)$ is always maximum for $z < \bar{z}$, meaning that $\frac{\partial x^*}{\partial z} = 0$. So in that case, there is no difference with the standard urban model : the slope of the residential rent fall with distance to the center to compensate for higher transport costs.

When developer has informations on the residential rent In that case, the equilibrium development density $x^*(z)$ varies with distance z to the CBD such that the second term in the right-hand side of (10) does not equal zero. To know if this term is positive or negative, we need to solve equation (8) with respect to $x^*(z)$. To do so, an application with a choice of functional forms is needed. This is the object of the following section.

3 Application with linear functions

In this section, we develop the model with linear functional forms, in order to derive tractable analytical results. From now on, we focus only on the case where developers have information on the residential rent, because the results in the other case are trivial.

3.1 Households

The utility function of households takes the following form :

$$U(m, q, d(z)) = \alpha m + (1-\alpha)q + \gamma d(z) \tag{11}$$

where the amenities function $d(z)$ is decreasing with the level of development $x(z)$ in a linear fashion : $d(z) = 1 - x(z)$. Each household maximizes the utility function with respect to the budget constraint as established in section 2. We derive the bid-rent function of households by solving the maximization program, which gives :

$$R_h(z) = \frac{1}{q}(w - Tz - \frac{1}{\alpha}(\bar{u} - (1-\alpha)q) - \gamma d(z)) \tag{12}$$

The bid rent function of households has the following properties :

It is decreasing with transport cost T according to $\frac{\partial R_h}{\partial T} = \frac{-z}{q}$.

It is increasing with the level of amenities in each z according to $\frac{\partial R_h}{\partial d(z)} = \frac{\gamma}{\alpha q}$.

It is decreasing with the level of development density in each z such that : $\frac{\partial R_h}{\partial x(z)} = \frac{\partial R_h}{\partial d(z)} \frac{\partial d(z)}{\partial x(z)} = \frac{-\gamma}{\alpha q}$.

In choosing their residential location, households trade-off between the transport cost and the level of development in each z.

3.2 Developers

Recall that the objective of the developer is to choose the level of development density $x(z)$ that maximises her profits. When the developer knows that households care about open space available at their place of residence, the first order condition of her maximisation program is :

$$\frac{\partial R}{\partial x(z)} x(z) + R(w, t(z), q, d(x(z))) = C \tag{13}$$

To find the level of development $x^*(z)$ that satisfies this condition at equilibrium, we replace $R(w, t(z), q, d(x(z)))$ by the residential rent $R_h(z)$ given by (12). The equilibrium level of development is thus given by :

$$x^*(z) = \frac{\alpha}{2\gamma}\left[w - Tz - Cq + \left(\frac{1-\alpha}{\alpha}\right)q - \frac{\bar{u}}{\alpha} + \frac{\gamma}{\alpha}\right] \tag{14}$$

We see that $\frac{\partial x(z)}{\partial z} = \frac{-1}{2}\frac{\alpha T}{\gamma}$. This result means that at equilibrium, the level of development always decreases with distance to the city center. The negative slope of the development density result from a trade-off between the transport cost and the level of open space in each z. This trade-off reflects households preferences for open space, and it affects the equilibrium level of development chosen by developers because they have information on households preferences when they make their development decision. Thus, this equilibrium development density is also the result of the developers trade-off between maximizing the number of houses built and gaining the maximum possible rent from each house.

3.3 The urban-periurban-rural equilibrium

As we see previously, the fact that developers have some informations about the residential rent when they make their choice of development is a sufficient condition for the existence of a periurban city where the level of development is not maximum in each point of the city, because developers trade-off between the number of houses built and the rent earned from each house. Here we investigate in more details the possible configurations of the city at equilibrium, especially we demonstrate that a urban-periurban-rural equilibrium can arise. In this configuration, the CBD is surrounded by a pure urban area with no open space and where the density of development is maximum, which is itself followed by a periurban area where there is proximity open space available in each parcel of land, and finally by a rural area where there is no urban development.

3.3.1 Equilibrium level of development

The pure urban area At equilibrium the level of urban development in each z is given by (14), reflecting the trade off between transport cost and the amount of open space in each z. It is possible that for some z, the transport cost is so low that the level of development x reaches its maximum level, so equal to 1 :

$$x^*(z_u) = \frac{\alpha}{2\gamma}\left[w - Tz_u - Cq + \left(\frac{1-\alpha}{\alpha}\right)q - \frac{\bar{u}}{\alpha} + \frac{\gamma}{\alpha}\right] = 1 \tag{15}$$

$$\Leftrightarrow z_u = \frac{1}{T}\left(w - Cq + \frac{1-\alpha}{\alpha}q - \frac{\bar{u}}{\alpha} - \frac{\gamma}{\alpha}\right) \tag{16}$$

Thus, for every $z \leq z_u$, there is no open space left, and the level of development $x^*(z)$ is equal to 1. The parcel z_u delimitates the frontier of the pure urban area in the city. We need to check under which condition this frontier z_u is greater than zero to ensure that there exists an urban core at equilibrium :

$$z_u > 0 \tag{17}$$

$$\Leftrightarrow \gamma < \alpha(w - Cq) + (1-\alpha)q - \bar{u} \tag{18}$$

If γ is low enough, meaning that household have moderate preferences for open space available at their place of residence, there exists a pure urban area at equilibrium. Otherwise, if γ is too high, households have very strong preference for open space and there is no possibility for a pure urban area to exist at equilibrium.

The periurban area The periurban area is the zone for which the level of development $x^*(z)$ is equal to (14). In this zone, the level of urban development varies between 0 and 1. Recall that $\frac{\partial x(z)}{\partial z} = \frac{-1}{2}\frac{\alpha T}{\gamma}$, meaning that to z_u, the level of development is high and close to 1, and it decreases along the city until it equals zero at the city's limit z_m.

The rural area The city's limit z_m is reached when the level of development $x^*(z)$ is equal to zero :

$$x^*(z_m) = \frac{\alpha}{2\gamma}\left[w - Tz_m - Cq + \left(\frac{1-\alpha}{\alpha}\right)q - \frac{\bar{u}}{\alpha} + \frac{\gamma}{\alpha}\right] = 0 \tag{19}$$

$$\Leftrightarrow z_m = \frac{1}{T}\left(w - Cq + \frac{1-\alpha}{\alpha}q - \frac{\bar{u}}{\alpha} + \frac{\gamma}{\alpha}\right) \tag{20}$$

Thus, for every $z \geq z_m$, the level of urban development is null. The condition that $x^*(z) = 0$ is equivalent to the condition $\pi(z) = 0$, in other term, when $z \geq z_m$ developers have no interest to develop houses because their profit becomes negative, thus they let land in its natural state.

3.3.2 Equilibrium rent gradient

The pure urban area In the pure urban area, the level of development $x^*(z)$ is equal to one. To compute the equilibrium rent, we replace $x^*(z)$ by one in the equation of the residential rent given by (12). For $z \leq z_u$, the equilibrium rent is thus equal to :

$$R_u^*(z) = \frac{1}{q}\left[w - Tz - \frac{\bar{u}}{\alpha} + \left(\frac{1-\alpha}{\alpha}\right)q\right] \tag{21}$$

In that case, their is no difference with the classic urban economics model with no open space, and the rent is decreasing with the distance to the CBD according to the variation of transport cost :

$$\frac{\partial R_u^*(z)}{\partial z} = \frac{-T}{q} \tag{22}$$

The periurban area In the periurban area, the level of development $x^*(z)$ varies between zero and one and it affects the equilibrium rent. For $z \in [z_u, z_m]$, the equilibrium rent is given by :

$$R_p^*(z) = R_h(x^*(z)) = \frac{\alpha}{2q}\left[w - Tz - \frac{\bar{u}}{\alpha} + \left(\frac{1-\alpha}{\alpha}\right)q - \frac{\gamma}{\alpha} - Cq\right] \tag{23}$$

Here, we see that the slope of the rent is different than in the pure urban area :

$$\frac{\partial R_p^*(z)}{\partial z} = \frac{-1}{2}\frac{T}{q} \tag{24}$$

The residential rent decreases with distance to the CBD, but at a slower rate than in the pure urban area. This phenomenon is explained by households preference for open space : when households locate far away from the center, they pay high transport cost, but they trade-off with the amount of open space enjoyed. Thus, the rent is decreasing slowly because open space create a positive force on the equilibrium rent.

The rural area Finally, in the rural area, for $z \geq z_m$, the equilibrium rent is equal to the land rent in its natural state, here it is equals to zero for simplicity.

4 Implications for public policy

The objective of this section is to explore the issue of how to design appropriate policy instruments to induce private developers to make socially optimal decisions. Until now we have explored the equilibrium process when households value open space near their place of residence. Households value open space located just near their place of residence because they derive benefits from interaction with open space, rather than simply with the existence of open space (Marshall, 2004). They value open space mainly for aesthetic reasons and open space provide them cultural ecosystem services. However open space is also provider of regulation ecosystem services, for example, forest and natural land located at the outskirts of cities help to regulate water quality and climate pollution. Thus, the social planner value the sole existence of open space, and that is why cities planner concentrate their efforts to slow down urban sprawl (Brueckner, 2000). Here, we see that what we call "open space" can be split into two categories : small local open spaces available inside the city, near residences, which are directly valued by households, and large open space at the city's fringe which is valued by the social planner for environmental concern. Several studies analyse the efficiency of different public policies to stop urban sprawl and conserve open space available at cities' fringe (see for example Bento et al. (2006)), but these papers do not take into account the preference of households for local open space. Yet, there is a potential contradiction between the existence of these two types of open space : the preservation of large open space at the city's edge may induce to concentrate cities in the detriment of local open space. On the other hand, the preference of households for local open space may be responsible for too much urban sprawl.

In this section we study the efficiency of different policy instruments when both types of open space are taken into account. Specifically, we examine the efficiency impact of two policies : an urban growth boundary (UGB) and a tax per unit of residential land (a development tax).

4.1 Urban growth boundary

First, consider that the social planner decide to limit the expansion of the city with a regulatory instrument : she imposes an urban growth boundary z_m^{UGB}.

The impacts of an UGB on equilibrium

When making development decisions, developers now take into account the new constraint introduced by the urban growth boundary. Each developer solves the following program :

$$\begin{cases} \max_x \pi(x, z) = R(z)x(z) - Cx(z) \\ s.t. \quad z_m \leq z_m^{UGB} \end{cases}$$

We know that at equilibrium, the households rent is given by $R_h(z) \equiv R(w, t(z), q, x(z), \bar{u})$. At the equilibrium without UGB, the urban fringe z_m is the solution to $\pi(z, x(z)) = 0$, which is equivalent to $R(w, t(z), q, x(z), \bar{u}) - C = 0$. The urban fringe is actually a function of the level of development x and we have $z_m = z_m(x)$ with $\frac{\partial z_m}{\partial x} < 0$.

The lagragian function of the problem is :

$$\ell(x(z),\lambda) = R(z)x(z) - Cx(z) - \lambda(z_m^{UGB} - z_m(x)) \tag{25}$$

The first order conditions are given by :

$$\begin{cases} \frac{\partial l}{\partial x} = \frac{\partial R(z)}{\partial x(z)}x(z) + R(z) - C - \lambda z_m'(x) = 0 \\ \frac{\partial l}{\partial \lambda} = z_m^{UGB} - z_m(x) = 0 \end{cases}$$

The equilibrium level of development with an urban growth boundary x^*_{UGB} is the solution of the above system and is given by :

$$x^*_{UGB} \equiv x(R_h(z), z_m^{UGB}) \tag{26}$$

This result means that when there is an urban growth boundary, the equilibrium level of development depends not only on the value of the residential rent, but also on the level of the urban growth boundary with $\frac{\partial x^*_{UGB}}{\partial R_h} > 0$ and $\frac{\partial x^*_{UGB}}{\partial z_m^{UGB}} < 0$.

Thus, stricter is the urban growth boundary, greater is the level of development x^*_{UGB} and the level of development with an urban growth boundary is always larger than in the case without regulation.

So finally, at equilibrium with an urban growth boundary, the city is smaller than without regulation, and the level of development in each z in the city is larger, meaning that the city is more concentrated. An urban growth boundary is efficient to preserve large open space at the urban fringe but at the same time it as for consequence to destroy local intra-urban open space. Households residing in the city are worse-off with an urban growth boundary because they enjoy a smaller amount of local open space. Moreover, as the level of development in each z of the city increases, the equilibrium rent falls, and developers may also be worse-off than without regulation.

4.2 Tax on development

Consider now that the social planner wants to reduce urban development by taxing new construction. Let τ be the tax paid by developers per unit of residential development. Tax revenues are redistributed lump sum to all developers, and developers take this revenue g_τ as given.

The impacts of a development tax on equilibrium

Impact on the level of development When making development decisions, developers now take into account the development tax into their program :

$$\max_x \pi(x,z) = R(z)x(z) - Cx(z) - \tau x(z) + g_\tau$$

The first order condition of the following program is :

$$\frac{\partial R}{\partial x(z)}x(z) + R(w, t(z), q, d(x(z))) - C - \tau = 0 \tag{27}$$

And the equilibrium level of development with a development tax is the solution of (27), so it is given by :

$$x^*_{tax}(z) \equiv x^*(R_h(z), \tau) = \frac{R_h(w, t(z), q, d(x^*(z))) - C - \tau}{K} \tag{28}$$

Where K is the same constant as in the case without regulation. Thus, we see that the tax on development as for consequence to reduce the equilibrium level of development because $\frac{\partial x^*_{tax}(z)}{\partial \tau} < 0$. Larger is the tax paid by developers, higher is the indirect cost of development, and lower is the equilibrium level of development.

Impact on the rent The modification of the equilibrium level of development induces a change in the equilibrium rent in each location z of the city. Indeed, the equilibrium rent increases in each point z of the city with a tax on development, because the level of development decreases. The new rent equilibrium is given by :

$$R^*_{tax}(z) \equiv R_h(w, t(z), q, x^*_{tax}(\tau, z)) \tag{29}$$

With $\frac{\partial R^*tax}{\partial \tau} = \frac{\partial R^*tax}{\partial x^*_{tax}(z)} \frac{x^*_{tax}(z)}{\partial \tau} > 0$. As the rent varies negatively with the level of development, and the level of development varies negatively with the tax level, an increase in the tax level has for consequence to increase the land rent. Thus, developers choose to develop less because the indirect cost of development is higher due to the tax, but each house built yield more rent, so they may be better-off with a tax on development than with no regulation.

Impact on the city's limit The introduction of a development tax also has an impact on the equilibrium city's limit z_m. Indeed, z_m^{tax} is reached when developer's profit equals zero, so when $R^*_{tax} - C - \tau = 0$. Thus z_m^{tax} is an implicit function of the rent, the cost of development C and the tax τ :

$$z_m^{tax} \equiv z(C, \tau, R(w, t(z), q, x^*_{tax}(\tau, z)), C, \tau)$$

The equilibrium city's limit varies with the tax according to :

$$\frac{\partial z_m^{tax}}{\partial \tau} = \frac{\partial z}{\partial \tau} + \frac{\partial R}{\partial x^*_{tax}(z)} \frac{x^*_{tax}(z)}{\partial \tau} \tag{30}$$

We see that the development tax has two opposite effects on the city's limit. The first term of the right hand side of (30) the direct effect of the tax : it is negative meaning that the urban fringe is reduced because it is more expansive to develop new land. The second term of the right hand side of (30) is an indirect effect : it is positive, and it means that the introduction of the tax increases the land rent and thus gives incentives for developers to construct more land.

With a proper choice of the level of τ the direct effect may be more important than the indirect effect. In that case, the city is smaller and the level of development in each z is also smaller than the case without regulation : the development tax allows to preserve at the same time local intra-urban space and large open space at the urban fringe. However, if the objective of the planner is just to limit urban sprawl, a tax on development appears to be less efficient than an urban growth boundary because of the indirect effect of the tax on land rent.

4.3 Application with linear functions and numerical analysis

Work in progress

5 Conclusion

We developed a model in which open space can be split into two categories : local intra-urban open space that are directly valued by households as cultural ecosystem services, and large open space at city's outskirts valued by the social planner for environmental reasons. Our aim what to understand how households' preferences affect the equilibrium city structure, we show that when household value local open space, the city is first composed of a pure urban core where all the land is developed, followed by a periurban area where a part of the land is not developed forming intra-urban open spaces. Finally a rural area completes the equilibrium land-use pattern. This result entails that the city extends more when households value local open space, which is directly responsible for the loss of large open space at city's outskirt. We then study the impact of an urban growth boundary and a tax on development on the preservation of the two types of open space. An urban growth boundary is efficient to preserve large extra-urban open space, but it decreases the amount of intra-urban open space, letting households worse-off. On the other hand, a tax on development may be efficient to conserve at the same time intra-urban and extra-urban open spaces, but the effect of the preservation of extra-urban open space is smaller than with an urban growth boundary.

Our analysis is a first step in the land-sharing vs. land-sparing debate in an urban context with economic tools. However, several questions still need to be addressed, and an interesting extension would be to performed a detailed welfare analysis to be able to derive fully the optimal land use pattern and optimal policy measures.

References

Bento, A., Franco, S., and Kaffine, D. (2006). The efficiency and distributional impacts of alternative anti-sprawl policies. *Journal of Urban Economics*, 59:121–141.

Brander, L. M. and Koetse, M. J. (2011). The value of urban open space : Meta-analyses of contingent valuation and hedonic pricing results. *Journal of Environmental Management*, 92(2763-2773).

Brueckner, J. (2000). Urban sprawl: Diagnosis and Remedies. *International Regional Science Review*, 23(2):160–171.

Cavailhès, J., Peeters, D., Sékeris, E., and Thisse, J. (2004). The periurban city: Why to live between the suburbs and the countryside. *Regional Science and Urban Economics*, 34(6):681–703.

Joly, D., Brossard, T., Cavailhès, J., Hilal, M., and F.P, T. (2009). A quantitative approach to visual evaluation of landscape. *Annals of the association of american geographers*, 99(2):292–308.

Lin, B. B. and Fuller, Richard, A. (2013). Sharing or sparing? how should we grow the world's cities? *Journal of Applied Ecology*, 50:1161–1168.

Marshall, E. (2004). Open-space amenities, interacting agents, and equilibrium landscape structure. *Land Economics*, 80(2):272–293.

Soga, M., Yamaura, Y., Koike, S., and Gaston, K. J. (2014). Land sharing vs. land sparing : does the compact city reconcile urban development and biodiversity conservation? *Journal of Applied Ecology*, 51:1378–1386.

Strange, W. C. (1992). Overlapping neighborhoods and housing externalities. *Journal of Urban Economics*, 32(1):17–39.

Turner, M. A. (2005). Landscape preferences and patterns of residential development. *Journal of Urban Economics*, 57(1):19–54.

Walsh, R. (2007). Endogenous open space amenities in a locational equilibrium. *Journal of Urban Economics*, 61(2):319–344.

Wu, J. (2001). Environmental amenities and the spatial pattern of urban sprawl. *American Journal of Agricultural Economics*, 83(3):691–697.

Wu, J. and Plantinga, A. (2003). The influence of public open space on urban spatial structure. *Journal of Environmental Economics and Management*, 46(2):288–309.