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Urban Expansion or Clustered Deconcentration? An Applied Welfare Economic Analysis of Growth Controls and the Foundation of Satellites

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Abstract: *How should urban containment and the diversion of households to nearby residential areas be evaluated from a welfare economic perspective? Assuming the existence of a negative externality of city size, we develop a concise general equilibrium model for a mother city and a satellite. This satellite should be founded if the gain in surplus exceeds the fixed costs of intercity infrastructure provision, and a Pigouvian tax on the conversion of land to urban use in both cities would then attain the first-best allocation. Rising incomes and falling transport costs enhance the surplus gain from 'clustered deconcentration', or the accommodation of growth in planned satellites, relative to expansion of the mother city. Nevertheless, plans by the Dutch government to uphold strict growth controls around Amsterdam, while fostering large-scale residential construction projects in the nearby satellite of Almere, are difficult to reconcile with the optimal policy in a calibrated version of our model.*

Keywords: land use regulation, growth controls, systems of cities, housing markets, applied general equilibrium

Classification-JEL: R52, R13, R14

1 Introduction

Greenbelts or urban growth boundaries (UGB's) are applied in cities all over the world, and their popularity appears to be on the rise both in Europe and the US.[1] The upward effect that such policies exert on house prices in restricted areas is well documented in the economic literature[2], but much less attention has been paid to their impact on surrounding regions. In locations that are sufficiently close substitutes, households that are somehow tied to the area will push up housing demand. This may give rise to scattered leapfrogging development, or boost growth in nearby communities. For example, the much debated UGB around Portland, Oregon, appears to have spurred population growth in nearby Clark County (Jun, 2004). To the extent that the jobs held by these households remain in the restricted area, growth controls will also push up intercity commuting. For instance, new jobs in the San Francisco Bay Area, where rigid land use restrictions exist, are increasingly held by people living at the outskirts of the region (cf. Ogura, 2005).

The question that concerns us in this paper is, how the diversion of households from a restricted city to a nearby satellite should be evaluated from a welfare economic perspective. This diversion may be argued to be a harmful side-effect of growth controls, because it raises the total residential land consumption in the region, as well as the number of intercity commuters and the externalities they impose. Furthermore, the costs of providing infrastructure and other local public goods and services may be higher for the resulting pattern of spatial development (cf. Cho, 1997). On the other hand, the widespread popularity of urban containment policies suggests that people attach value to living in a small city, and this idea is also reflected in a theoretical literature on growth controls.[3] Under such preferences, an equilibrium in which households are divided over a main city and one or more satellites may yield higher welfare than an equilibrium in which they all live in one big city.

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[1] While an early form of greenbelt regulation existed already in sixteenth century London (Evans, 1999), several European countries nowadays conduct policies that foster the development or preservation of compact cities. Moreover, at the EU level, the pursuit of compact cities is expressed as an explicit policy goal (European Commission, 1999). The proliferation of urban growth boundaries in the US is documented by Nelson and Duncan (1995). Amongst cities in other parts of the world that have been subject to greenbelt regulation are Moscow (Russia), New Delhi (India), Ottawa (Canada), Seoul (Korea) and Tianjin (China) (Cho, 1997).

[2] See Fischel (1990) for an early survey and Quigley and Rosenthal (2005) for an overview of more recent evidence.

[3] For instance, Engle *et al.* (1992) argue that population growth may affect welfare in a city negatively because of congestion costs, pollution externalities and rising costs of public goods provision, while Brueckner (1990) considers a direct negative impact of the number of residents in a city on their wellbeing. These type of models have become known in the theoretical growth control literature as *amenity-creation* models, see Brueckner (1999) a survey.

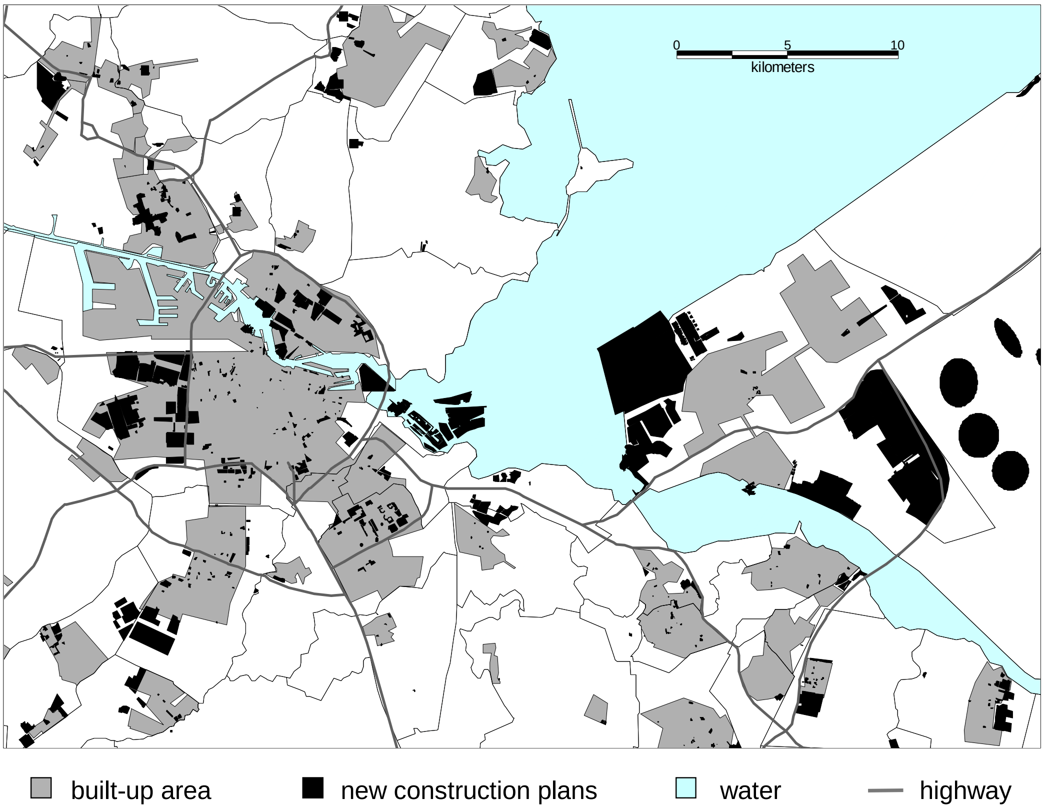
Such considerations seem to have motivated so-called *clustered* or *focussed deconcentration* policies in the 1960s and 1970s. Against a background of substantial negative externalities in large cities and rising suburbanization, governments of various European countries fostered household growth in especially designated and sometimes newly founded satellite towns. The accommodation of growth in a limited number of satellites was preferred to unregulated sprawl, because this allowed for an efficient scale in terms of the supply of local public services and infrastructure, while limiting landscape fragmentation. Typical examples are the UK *New Towns*, the French *Pôles de Croissance* and the Dutch growth centres or *Groeikernen* (cf. Anas *et al*., 1998). These policies are of interest today, because they are still reflected in land use patterns and policies in Europe – as aptly illustrated for the Netherlands in Figure 1.1, while the popularity of European style urban growth boundaries and greenbelts appears to be on the rise in the US.[4]

In order to evaluate the diversion of households from a restricted city to a nearby satellite, we develop and calibrate a concise general equilibrium model. The distortion that motivates government intervention in land markets is a negative externality of the geographical size of a city, as experienced by its residents. This assumption is similar to the negative population externality that is common in the growth controls literature, but it relates more directly to land use and the role of open space. As all jobs are located in the central business district of the main city, residents of the satellite incur higher commuting costs, but they enjoy living in a city that is smaller. Furthermore, we allow for differences in the attractiveness of both cities, reflecting the level of cultural and historical amenities. This may be particularly relevant in a European setting, in which such amenities contribute significantly to the quality of life in the major ancient cities, while they are generally absent in newly found satellites. We show that taxing the conversion of land to urban use in both cities is a first-best policy response to the city size externality. Founding a satellite is desirable if the gain in surplus exceeds fixed costs that are incurred, modelled here as the costs of intercity infrastructure provision. In an extension, the optimal foundation of multiple satellites is considered.

Our analysis is applied to the Dutch capital of Amsterdam and nearby Almere. Founded in the 1970s on land regained from the sea, this town was designated as a growth

[4] For instance, Irwin and Bockstael (2004) report on the effects of a development clustering policy in Maryland, US, which concentrates development and generates preserved open space.

Figure 1: Current and permitted future development in Amsterdam (left) and Almere (right)



centre that should accommodate population growth from the capital.[5] The restrictiveness of present land use controls is substantial in Amsterdam and negligible in Almere, which may be inferred from the gap between house prices at the urban fringe and total marginal production costs. Moreover, future plans by the national and local governments consist of strict containment of Amsterdam and a major expansion of Almere. This is illustrated in Figure 1, which indicates areas that are presently built-up in these cities by grey zones, and areas in which new construction has been approved of by the national and local governments by black zones.[6] It shows that residential construction in Amsterdam is mainly limited to infill development, whereas large plots for new construction are available in Almere.[7]

[5] An overview of land use regulation in the Netherlands is provided in Vermeulen and Rouwendal (2007). See Faludi and Van der Valk (1990) for an in depth discussion of the Dutch growth centre policy.

[6] There data were taken from the 'New map of the Netherlands' (www.nieuwekaart.nl), a collection of all national and municipal land use regulations, in the fall of 2006.

[7] This map is somewhat imprecise, though, because it does not indicate construction densities and the horizon of new plans is not always clear. Projections by provincial and municipal governments suggest that net of demolitions, the housing stock will grow with about 50,000 to 60,000 dwellings until 2030 in both Amsterdam and Almere. So in relative terms, the satellite is planned to grow at a much higher rate. About a third of all new construction in the northern part of the Randstad area ('de Noordvleugel') is planned to take place in Almere, while other towns in the region surrounding Amsterdam will expand at a significantly lower rate.

We calibrate the model in such a way that present land use restrictions are optimal by assumption. This turns out to require a city size externality that is so large that in order to internalize its effect, households in Amsterdam should spend about 10% of their income on (capitalized) development taxes, while they spend about 6% on land net of these taxes. The model may be used to evaluate plans for future residential development. For instance, its comparative static properties indicate how the optimal distribution of households over the main city and one or several satellites is affected by income and demographic growth. We also infer optimal population and city sizes in several scenario's of income and demographic growth and contrast these to the land use plans that are indicated in Figure 1. Finally, we shed light on the social costs of implementing suboptimal policies, which may result from a misperception of the type or size of externalities.

Our study adds to a small number of applied welfare economic analyses of land use regulation such as Cheshire and Sheppard (2002), Bento *et al*. (2006) and Walsh (2007), which have been surveyed in Cheshire and Vermeulen (2008). It also relates to a concise literature on the Seoul greenbelt, which is modelled in a theoretical analysis by Cho (1997) and Lee and Fujita (1999) as a (congestible) multifunctional park that provides citizens with recreational areas, environmental amenities and scenic views, while Lee and Linneman (1998) provide evidence that proximity to this greenbelt is capitalized in residential land prices. Reflecting the rise of 'periurban belts' in France, Cavailhès *et al*. (2004) develop a model in which agricultural and residential land use are mixed in a zone around the urban fringe, but they do not perform a full welfare analysis of land use policies. To our knowledge, Ogura (2005) presents the only theoretical model on growth controls that does consider the possibility of intercity commuting from a nearby satellite, but taking a political economic perspective, this paper ignores the valuation of policy-induced amenities. To some degree, our analysis of the decision to found a satellite may be understood within the wider literature on systems of cities (cf. Henderson, 1987), which considers the optimal and equilibrium number of cities in a system as a function of fixed costs and (dis)economies of scale. In dynamic models, Henderson (1986) and Anas (1992) find that it is optimal to set up a new city much earlier than the date at which it would emerge under laissez-faire.[8] Furthermore, the concept of satellites may bear some similarity to the edge cities that are analysed by Henderson and

[8] These models exhibit city-level agglomeration economies in production that are counterbalanced by congestion effects through rising costs of land and transportation.

Mitra (1996). However, land use externalities are generally absent or they remain implicit in this literature.[9]

In the next section, we propose our model for a mother city and a satellite, and we derive first-best policies. The calibration of this model is discussed in section 3, where explicit consideration is also given to validation. Comparative static properties and policy analysis are contained in section 4. We then consider an extension with multiple satellites. The final section concludes and it puts the policy implications of our model into the perspective of the range of assumptions and simplifications that have necessarily been made.

2 Theoretical framework

After outlining model preliminaries and the geographical setting, this section considers the problem of a benevolent planner who wants to maximize social surplus under the constraint that all households reach the same target utility level. It is shown that the solution to this problem may be decentralized as a free market equilibrium with costless household mobility within and between cities through the imposition of appropriate transfers and development taxes. We then consider the desirability of founding a satellite if there are fixed setup costs and discuss the extension of our framework to multiple symmetric satellites. An investigation of comparative static properties is deferred to section 4, where we make use of the calibrated model.

Preliminaries and geographical setting

Households have a well-behaved utility function $u = u(z, s, A, S)$, where s denotes the consumption of land and z is the consumption of a composite commodity that represents all other goods, including the capital component of housing. Furthermore, utility is affected by two city level variables A and S. The amenity level A reflects the inherent attractiveness of living in a city, due to for instance the presence of historical buildings or cityscapes. It also allows for a first pass on more endogenous factors, such as the variety of local services and the offer of cultural facilities, which tend to differ strongly between large cities and newly found satellites.

Fundamental to our analysis is the assumption that the utility of living in a city is decreasing in its geographical size S. The most immediate interpretation of this externality is

[9] A number of studies exist, though, that analyse optimal land use policies in a system of cities when intracity transport infrastructure is congestible. See for instance Anas and Pines (2008).

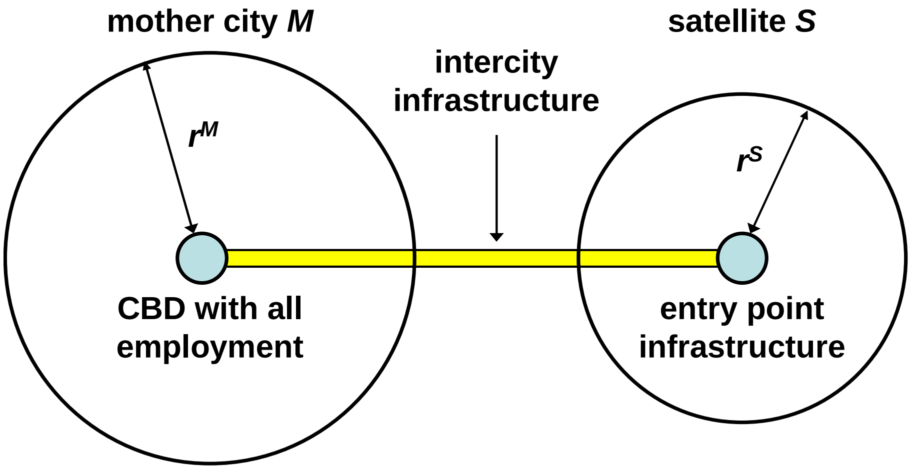
that people dislike to be surrounded by bricks and asphalt. The larger a city grows, the more they feel themselves lost in an 'urban jungle'. Some evidence supporting this view may be found in an analysis of residential transactions in an exurban region in central Maryland, USA by Irwin (2002), who reports that conversion of agricultural land to low-density residential land had a negative impact on surrounding house prices, suggesting that one of the important attractions of open space is simply that it is not developed. In line with this view, stated preference studies indicate that negative externalities of residential development are an important motivation for the preservation of open space (cf. McConnell and Walls, 2005). Another way of interpreting the city size externality is that when S increases, the total amount of space left undeveloped is reduced and the distance to open space at the fringe rises for most residents in the city, which reduces welfare if open space at the city fringe is amenable and accessible to urban residents. Interpreted this way, the externality captures that society may value not only the total supply of open space in the country, but also its accessibility.[10] However, open space in parks may substitute for proximity to a greenbelt, which would reduce the negative externality effect of city size. We get back to this point in the concluding section, see also Cheshire and Vermeulen (2008) for a discussion.

The way in which we model the open space externality may be compared to amenity creation models in the theoretical growth controls literature that exhibit a negative externality of population size (Brueckner, 1999). Under the assumption of fixed land consumption, which is generally made in such models, the two externalities are equivalent. In contrast, Brueckner (2001) and Bento *et al*. (2006) consider welfare effects of changing the total amount of undeveloped space, calculated as some given total amount of space minus city size. This approach has the somewhat unrealistic implication that a hectare of open space near the city boundary is valued in the same way by its residents as a hectare at a distance of, say, a hundred kilometres. The foundation of a satellite can not be optimal then, since it would raise the total residential land consumption.

The geographical setting of our analysis is illustrated in Figure 2. We consider a system of two monocentric cities, in which a total number of households N reside. This

[10] Since the total stock of open space in a country is typically only marginally reduced by urban expansion, its accessibility is in fact the more important aspect of this interpretation. Access to open space could be modelled more directly by assuming that in order to enjoy it, residents travel to the city fringe at a given frequency, which has to be lower than the frequency of commutes to the CBD. It may be shown that the optimal policy in this setting is a (Pigouvian) development tax, reflecting the increased travel costs that urban expansion imposes on all residents. Although this development tax does not have the same comparative static properties as the optimal development tax that we derive in this section, there is a strong similarity between the two externalities and associated optimal policies.

Figure 2: Geographical setting



number is taken to be exogenous, so the system can be interpreted as closed.[11] Each household provides one unit of labour and all jobs are located in the Central Business District (CBD) of the main or mother city *M*. Residents who live at a distance *r* from this CBD incur commuting costs *tr*, where *t* denotes commuting costs per unit of distance. Residents of the satellite city *S* travel to the CBD of their city first, where they enter the intercity infrastructure network, and then to the CBD of the mother city. Living at a distance *r* of the satellite's CBD, they incur commuting costs *tr* + *icc*, where *icc* denotes intercity commuting costs. So under these assumptions, the satellite's CBD serves as an intercity infrastructure access point only, and it does not offer any employment opportunities. Note that the intercity commuting costs per unit of distance may be smaller than *t*, depending on the quality of the intercity infrastructure network.

We rule out scattered residential development outside cities, as it would fragment open space at the city fringe and make it less valuable.[12] In the context of our application to the cities of Amsterdam and Almere, this assumption is plausible since land use is regulated directly, so residential development outside cities can simply be prohibited.[13] As a final point,

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[11] It makes little sense in this setting to assume an open system, because growth controls in the mother city would not raise housing demand in the satellite then, whereas in the applications in which we are interested it clearly does.

[12] The presence of a negative external effect of city size implies that households have an incentive to locate outside the city, if the negative effect on utility of the higher commuting cost is compensated by the avoidance of the negative external effect of city size. Hence, if we would not impose that all households reside within city boundaries, the presence of this external effect would lead to diffuse residential location patterns around main cities that are typically associated with the negative aspects of urban sprawl. See for instance Irwin and Bockstael (2004), who find that potential benefits of a development clustering policy in Maryland, US, may be offset, because protected parcels of land attract construction at neighbouring parcels.

[13] In countries in which governments have less grip on land use, such as the US, such a pattern might still be obtained by declining the provision of infrastructure and other basic public goods at locations outside cities.

we note that the mother city and the satellite have to be located sufficiently far away from each other, so that the size of one city does not affect the utility of residents in the other.

The social planner's problem

Essentially following the well-established Herbert-Stevens approach, we develop the welfare economic analysis in this paper by considering a benevolent social planner, who aims to maximize aggregate surplus under the side condition that each household has to reach a given target utility level u^* (cf. Fujita, 1989).[14] The contribution of an individual household to the aggregate surplus is defined as the income it generates, minus the costs that have to be incurred to grant it a utility of u^*. Fixing household income at the exogenous wage level w, the optimal allocation may be interpreted as the least costly way to attain the target utility level for all households in the system of cities.

It is useful to invert the utility function with respect to z for the target utility level u^*, to obtain $z = Z(u^*, s, A, S)$. The function Z identifies iso-utility curves for different levels of u^* and its partial derivatives with respect to the other variables may be interpreted in terms of the marginal willingness to pay for the goods they represent. By assumption, the signs of the partial derivatives are:

$$\frac{\partial Z}{\partial u^*} > 0, \frac{\partial Z}{\partial s} < 0, \frac{\partial Z}{\partial A} < 0, \frac{\partial Z}{\partial S} > 0 . \qquad (1)$$

The costs of granting a household the target utility level are then equal to the sum of commuting costs, opportunity costs of alternative land use and the expenditure on the composite commodity $z = Z(u^*, s, A, S)$. We assume that the alternative land use is agricultural, which yields a rent p_a, and that the price of composite commodities is normalized to unity.[15] Ignoring the costs of founding the satellite, the aggregate social surplus SS is then

[14] This approach is more convenient than the optimization of a utilitarian social welfare function, since different utility levels would have to be assigned to similar people in order to obtain the optimum, as shown by Mirrlees (1972). One unattractive feature of this *unequal treatment of equals* property is that it cannot occur in a decentralized free market setting. Surplus optimization avoids the problem by assigning the same utility level to all similar households at the outset. See Wildasin (1986) or Fujita (1989) for additional discussion.

[15] In reality, there are costs to converting land from agricultural to residential use, relating for instance to the provision of local infrastructure. The model could be extended with a local public good that is produced using a constant returns technology. Ruling out substitution on the demand side, so that it would be provided with a constant land intensity, a constant would have to be added to the price of agricultural land in Equation 2. This is the approach we follow implicitly in our calibration.

obtained by integrating the surplus for each household over the total number of households in the two cities:

$$SS = \int_0^{r^M} \frac{L_r^M}{s_r^M}\left(w - tr - p_a s_r^M - Z\left(u^*, s_r^M, A^M, S^M\right)\right)dr + \int_0^{r^S} \frac{L_r^S}{s_r^S}\left(w - tr - icc - p_a s_r^S - Z\left(u^*, s_r^S, A^S, S^S\right)\right)dr, \tag{2}$$

where r^i denotes the distance from CBD to the fringe in city i, $i \in \{M, S\}$, L_r^i denotes the total amount of developable land at a distance r from the CBD of city i, and s_r^i denotes the consumption of land assigned to households living at a distance r from the CBD of city i. Note that L_r^i / s_r^i equals the household density at a distance r from the CBD of city i.

The social planner's problem is to choose an allocation $\left(s_r^i \geq 0, r^i \geq 0, S^i \geq 0\right)$ that maximizes SS, while satisfying a number of constraints. In the first place, the household density has to integrate over the two cities to the total number of N:

$$\int_0^{r^M} \frac{L_r^M}{s_r^M} dr + \int_0^{r^S} \frac{L_r^S}{s_r^S} dr = N \; . \tag{3}$$

Secondly, the total amount of developable land in urban use has to integrate to the (endogenous) geographical size S^i for each city:[16]

$$\int_0^{r^M} L_r^M dr = S^M \text{ and } \int_0^{r^S} L_r^S dr = S^S \, . \tag{4}$$

While conditions for the desirability of founding a satellite are discussed later in this section, for now we assume that both cities have a positive size in the optimum. Ignoring the inequality constraints, the Lagrangian associated with this optimization problem may be written as:[17]

[16] This second set of constraints could be avoided by including city size as a function of r^i directly in the utility function, but we prefer the present equivalent specification because it is more insightful.
[17] The problem could be solved more formally by applying optimal control theory, but the same outcome would obtain. See Fujita (1989) for a thorough discussion.

$$\mathcal{L} = \int_0^{r^M} L_r^M \left(\frac{w - tr - Z\left(u*, s_r^M, A^M, S^M\right)}{s_r^M} - p_a \right) dr$$

$$+ \int_0^{r^S} L_r^S \left(\frac{w - tr - icc - Z\left(u*, s_r^S, A^S, S^S\right)}{s_r^S} - p_a \right) dr \qquad (5)$$

$$+ \lambda \left(N - \int_0^{r^M} \frac{L_r^M}{s_r^M} dr - \int_0^{r^S} \frac{L_r^S}{s_r^S} dr \right) + \tau^M \left(S^M - \int_0^{r^M} L_r^M dr \right) + \tau^S \left(S^S - \int_0^{r^S} L_r^S dr \right),$$

where λ, τ^M and τ^S are Lagrangian multipliers. The first order conditions associated with this problem are $\partial\mathcal{L}/\partial s_r^M = 0$ for every $r \in \langle 0, r^M \rangle$, $\partial\mathcal{L}/\partial s_r^S = 0$ for every $r \in \langle 0, r^S \rangle$, $\partial\mathcal{L}/\partial r^M = 0$, $\partial\mathcal{L}/\partial r^S = 0$, $\partial\mathcal{L}/\partial S^M = 0$ and $\partial\mathcal{L}/\partial S^S = 0$. The first two conditions for surplus maximization refer to the demand for land. They imply that for every *r* within the city boundaries we have:

$$-\frac{\partial Z\left(u*, s_r^M, A^M, S^M\right)}{\partial s_r^M} = \frac{w - tr - Z\left(u*, s_r^M, A^M, S^M\right) - \lambda}{s_r^M},$$

$$-\frac{\partial Z\left(u*, s_r^S, A^S, S^S\right)}{\partial s_r^S} = \frac{w - tr - icc - Z\left(u*, s_r^S, A^S, S^S\right) - \lambda}{s_r^S}. \qquad (6)$$

For future reference, it is useful to note that the left hand side of these expressions can be interpreted as the marginal willingness to pay for land, while the right hand side takes the form of a bid rent function. The next two conditions refer to the optimal city boundaries, and they may be written as follows:

$$\frac{w - tr^M - Z\left(u*, s_{r^M}^M, A^M, S^M\right) - \lambda}{s_{r^M}^M} = p_a + \tau^M,$$

$$\frac{w - tr^S - icc - Z\left(u*, s_{r^S}^S, A^S, S^S\right) - \lambda}{s_{r^S}^S} = p_a + \tau^S. \qquad (7)$$

Making use of Equations 6, these equations indicate that the marginal willingness to pay for land at the fringe of city *i* should be equal to the agricultural land rent plus a Lagrangian multiplier τ^i. The final two conditions refer to the optimal city size, yielding:

$$\int_0^{r^M} \frac{L_r^M}{s_r^M} \frac{\partial Z\left(u^*, s_r^M, A^M, S^M\right)}{\partial S^M} dr = \tau^M,$$

$$\int_0^{r^S} \frac{L_r^S}{s_r^S} \frac{\partial Z\left(u^*, s_r^S, A^S, S^S\right)}{\partial S^S} dr = \tau^S. \tag{8}$$

The left-hand side of these equations may be interpreted as the willingness to pay for a marginally smaller city, integrated over the total number of households in this city. From the comparative statics of $Z(u^*, s, A, S)$ in Equations 1, we know that the multipliers τ^M and τ^S are positive, as long as both cities have a positive size. Equations 7 then imply that the marginal willingness to pay for land at the fringe of city *i* should exceed the agricultural land rent, so that urban land use is restricted in the social optimum. This suggests that the optimal policy in the presence of a city size negative externality may be decentralized through the imposition of a (Pigouvian) development tax that is equal to the external effect that a marginal extension of the size of a city imposes on its residents. Equivalently, the planner may regulate land use directly in order to obtain city sizes S^M and S^S, and the multipliers should then be interpreted as regulatory taxes or shadow prices of land use restrictions.[18]

Decentralization of the social optimum

Consider now a situation in which the role of the central planner is limited to setting development taxes $\hat{\tau}^M$ and $\hat{\tau}^S$, and imposing a (possibly negative) lump sum tax $\hat{\lambda}$ on each household, while leaving the allocation of goods and land to competitive markets. Assume further that household mobility within and between cities is costless. A household that resides at location *r* in city *i* then faces the budget constraint $p_r^i s_r^i + Z\left(\hat{u}, s_r^i, A^i, S^i\right) = w - \hat{\lambda} - tr$, where p_r^i denotes the land rent and $\hat{u}$ denotes the equilibrium utility level. Under well-known conditions, a unique equilibrium exists that is fully determined by the following conditions

[18] Direct land use regulation is much more common than taxation of residential development or residential land consumption, which are equivalent in a competitive setting where builders pass the development tax on to households. Nevertheless, there is some similarity between taxation of development and the Impact Fees that are gaining widespread popularity in the USA.

(cf. Fujita, 1989). First, equilibrium on land markets requires that p_r^i within both cities equals the bid rent function, which is defined as the maximum rent per unit of land that a household is willing to pay while attaining $\hat{u}$. This condition may be written as:

$$p_r^M = \max_{s_r^M}\left\{\frac{w - tr - Z\left(\hat{u}, s_r^M, A^M, S^M\right) - \lambda}{s_r^M}\right\},$$

$$p_r^S = \max_{s_r^S}\left\{\frac{w - tr - icc - Z\left(\hat{u}, s_r^S, A^S, S^S\right) - \lambda}{s_r^S}\right\}. \tag{9}$$

The maximization problem in these equations is resolved when p_r^i equals the marginal willingness to pay for land $-\partial Z/\partial s_r^i$, which yields a condition for the consumption of land $\hat{s}_r^i$ at each location. The size of each city is determined by the condition that land rents at the city fringe should equal the sum of agricultural rents and the development tax. Finally, the equilibrium utility level $\hat{u}$ is determined by the condition that N households have to be accommodated in the system of cities, as in Equation 3.

It can now be seen that the solution to the social planner's problem satisfies the conditions that together characterise the market equilibrium, provided that the government sets $\hat{\lambda} = \lambda$, $\hat{\tau}^M = \tau^M$ and $\hat{\tau}^S = \tau^S$. Since the social optimum satisfies Equation 6, the consumption of land s_r^i solves the decentralized consumer problem, and bid rents are as in Equations 9. Furthermore, as Equation 7 is satisfied, the bid rent at the city fringe equals agricultural rent plus development tax. Finally, the social optimum satisfies Equation 3 by construction. Thus, by setting lump sum and development taxes appropriately, the planner can decentralize the social optimum and the target utility level u^* is attained in a market equilibrium. Furthermore, it should be noted that, since this result holds for any target utility, u^* may be chosen in such a way that the associated lump sum tax equals zero. Hence, a market equilibrium in which appropriate development taxes constitute the only policy intervention corresponds to a social optimum with this target utility level.

Throughout our application of the model, we prefer to consider market equilibria without lump sum taxes or transfers. However, welfare comparisons of such market equilibria are not straightforward, because they generally yield different levels of both utility and surplus. Therefore, we compare the surplus of different equilibria, while holding utility constant through appropriate transfers.[19] Social surplus then equals the sum of all lump sum taxes and the total land rent minus opportunity costs of agricultural use.

When should a satellite city be founded?

The costs of founding a satellite are not explicitly considered in our measure of social surplus in Equation 2, but they are a crucial determinant of the desirability of this policy. Ignoring the provision of other local public goods, we assume that these costs consist of the fixed costs of intercity infrastructure provision only. So in our model, in order to create a satellite, the government has to build a road that costs *FC*.[20] The desirability of this investment derives from a comparison of social surplus with and without the satellite, where characteristics of the equilibrium with one city are obtained by constraining all households to live in the main city. Under any target utility level, foundation of the satellite is then desirable if the social surplus in the two city equilibrium exceeds surplus in the equilibrium with one city by more than *FC*. In our application, we will choose the specific target utility level for which decentralization of the optimal allocation in a system consisting of both the mother city and the satellite does not require lump sum transfers (so $\lambda = 0$).

Properties of the surplus gain from founding a satellite will be explored numerically in following sections, so the discussion here is confined to some intuitive general properties. Ignoring fixed costs, when would there be a strictly positive surplus gain from founding a satellite at all? The satellite affects outcomes only if some households decide to locate there. Hence, the bid rent in the second city has to exceed the agricultural land rent plus an optimal development tax. Let us first assume that there is no difference in amenability, and that external effects of city size are absent. The satellite is then populated if transport costs to the city fringe exceed intercity commuting costs $\left(tr^M > icc\right)$. If the distance between both cities should be large enough to avoid any externalities, commuting on the intercity transport link has to be considerably less costly per unit of distance than travel within the main city. It becomes even less likely that households are willing to live in the satellite if we also take differences in the level of urban amenities into account, as these render the main city more attractive. Hence, the demand for a satellite and the surplus it generates are entirely driven by

[19] Another possible solution to this problem would be to assume public land ownership, so that land rents are distributed over all households and surplus equals zero in all market equilibria. Welfare comparisons of different equilibria could then proceed simply through the comparison of equilibrium utility levels. However, in urban economic models, there is no obvious money metric for differences in utility. Notably, compensating and equivalent variation are problematic, since the marginal utility of income varies with location (Wildasin, 1986). This issue is avoided by keeping utility constant and comparing different surplus levels.

[20] We abstract from any relationship between *FC* and the intercity commuting costs *icc*.

the negative externality of city size. This externality makes living in the main city less attractive, and its internalization in development taxes may raise the optimal population in the satellite further.[21]

If the costs of providing intercity infrastructure are not too high, it may of course be desirable to found multiple satellites. The system of two cities that we have considered throughout this section may be readily extended with an arbitrary number of satellites, as long as these satellites are assumed to be symmetric in terms of amenability and the intercity commuting cost. This requires straightforward adjustments in the expressions for social surplus (Equation 2) and the population constraint (Equation 3). The condition for social desirability of founding an additional satellite remains that the gain in social surplus should exceed fixed founding costs, which determines the optimal number of satellites.[22]

3 Application to Amsterdam and Almere

This section applies our theoretical framework to the cities of Amsterdam and Almere. While the analysis of the previous section was carried out for an arbitrary well-behaved utility function, the choice of an appropriate functional form is essential for a meaningful applied welfare analysis. Hence, this issue is dealt with at the outset of the present section. Then, a brief discussion follows of the range of data from various sources that are available for calibration and validation of the model. We describe the procedure to find values for the model parameters that are not directly observed. Finally, some properties of the calibrated model are presented, and we validate our setup by comparing model outcomes with data that are not used in the calibration procedure.

[21] While we have so far assumed that all employment remains in the mother city, the attractiveness of founding a satellite increases strongly if at least a part of the jobs follow the population. Moreover, using regional time series data for the Netherlands, Vermeulen and Van Ommeren (2006) show that in the long run, employment adjusts to the local supply of labour, but in our application. However, the consequences of assuming all jobs to be in the Amsterdam CBD are limited for our policy analysis, as long as there are no scale economies in production. For instance, we could have assumed that there is no intercity commuting and that residents in Amsterdam and Almere receive the same wage. Since in our calibration, the model outcome should still match the data on land prices and the distribution of households over these cities, the resulting rise in the attractiveness of Almere would then have to be counterbalanced by an increase in the amenity differential.

[22] It should be borne in mind, however, that our assumption that the presence and size of satellites does not affect utility in the main city may become increasingly untenable when their number rises, as they fragment the surrounding landscape.

Functional form of utility

The utility function used in our application is composed of a CES component in household consumption of land and the numeraire good, multiplied by functions of amenability and city size. In order to keep the model tractable, we set the elasticity of substitution between land and the numeraire good equal to 0.5.[23] Some evidence in support for this assumption is presented in our discussion of the model validation. In the notation of section 2, we have:

$$u(z,s,A,S)=\frac{A\left(S^{0}+S\right)^{-\gamma}}{\alpha z^{-1}+\beta s^{-1}}. \qquad (10)$$

When interpreting the elasticity of substitution, it should be borne in mind that we have not explicitly modelled the production of housing services with capital and land. Nevertheless, the capital component of housing is implicitly contained in the consumption of numeraire goods.[24]

Next to the CES component in land and numeraire goods, utility is proportional to the amenity level A and a negative function of the geographical city size S. We set $A^S = 1$, so A^M may be interpreted as the relative attractiveness of living in the mother city in terms of access to local public goods other than open space. In choosing a functional form for the city size externality, we have allowed for the possibility that urban sprawl is more of an issue in large cities than in small towns. As long as S^0 is positive, the function $\left(S^{0}+S\right)^{-\gamma}$ implies that the willingness to pay to avoid a 1% increase of S is rising with city size, while it is zero for a city of size zero.[25] In the calibration, we will set S^0 roughly equal to the size of Amsterdam, so that open space externalities are significantly more pressing in this city than in the smaller satellite. This assumption reflects the observation that land use controls are much more permissive in Almere than in Amsterdam, which was already illustrated in Figure 1 in the first section.

[23] This allows us to solve a large part of the model analytically, so that the numerical burden reduces to the search of roots in a limited number of nonlinear equations.

[24] Local governments in the Netherlands tend to impose strong restrictions on high rise residential construction. Hence, the loss of keeping substitution of capital for land implicit in our model is probably limited.

[25] Note that when we set $S^0 = 0$, the willingness to pay to avoid a 1% increase of S does not depend on city size. In this case, the optimal restriction of residential land use in the main city and the satellite will be roughly comparable.

Data

We choose the year 2002 as a base year for our calibration, considering annualized income and expenditures on land, numeraire consumption goods and transportation.[26] Our discount rate is set at 5%, which is slightly higher than the real long interest rate in this period. For a number of exogenous city variables, such as transport costs to the CBD and the share of land in residential use, we consider data for Amsterdam only. While it is possible that these are different for Almere, but we do not want to introduce additional sources of heterogeneity in our model, in order to facilitate interpretation of the results. Table 1 presents data and estimated parameters for both calibration and validation of our model. A detailed account of sources and estimation methods is given in the Appendix. In particular, we have made use of data and results in Rouwendal and Van der Straaten (2008), who perform a hedonic analysis of house prices in Amsterdam. An estimate of the shadow price of present land use restrictions in both cities is obtained by comparing the price of new houses at the city fringe with total marginal construction costs.

Table 1

Data for the cities of Amsterdam and Almere

Variable	Value	
	Amsterdam	Almere
Data used for calibration		
number of households (1000)	405	63
average disposable household income (1000 €)	24	
expenditure on land as a share of household income (%)	16	
share of total municipal land in residential use	0.4	
transport costs (€ / m)	0.34	
transport costs from Almere to Amsterdam fringe (€)	3100	
agricultural land rent plus conversion costs (€ / m^2)	2.05	
shadow price of local land use restrictions (€ / m^2)	14	-1.6
Data used for validation		
quality controlled house price (index)	144	100
median lot size (m^2)	95	144
area of municipality in land (km^2)	165	131

Notes: See appendix for a discussion of estimation procedures and data sources.

In terms of the number of households, Amsterdam is clearly a much larger city than Almere. Although households are on average smaller in Amsterdam, the number of residents still exceeds Almere by almost a factor 5. About 40% of the land in Amsterdam is in

[26] Some data sources refer to another year in the period 2000 – 2005.

residential use, while the rest is used for infrastructure, industrial production, open space, agriculture and water. In order to account for this in the model, we impose that at each location in both cities, a share of 40% is available for residential use (so L_r^i = 0.8 π r).[27] Another striking feature of Table 1 is that after controlling for characteristics of the dwelling, houses are almost 50% more expensive in Amsterdam than in Almere. Clearly, the premium paid by households that live in Amsterdam has to be compensated through either reduced commuting costs or a higher level of amenities. Presumably in response to the large price differential, median lot sizes in Amsterdam are significantly smaller than in Almere. Finally, we observe that estimates of the shadow price of land use regulation in both cities confirm that planning is much more restrictive in Amsterdam than in Almere, as was suggested by Figure 1. The data even indicate that residential land use in Almere is effectively subsidized.

Choice of parameters that are not directly observed

While N, w, t ,ω (the share of urban land in residential use) and p_A are estimated directly, other model parameters have to be inferred by comparing properties of the implied equilibrium to data. In the utility function, we may set β = 1 without loss of generality. The parameter α is then chosen in such a way that the budget share of land in Amsterdam equals the observation in Table 1. The parameter γ is set in such a way that the optimal development tax in Amsterdam equals the estimate of the shadow price of the restrictiveness of land use regulation in this city. Note that we do not use the estimated shadow price of land use controls in Almere, since it is negative and in our model, the optimal development tax is nonnegative. Instead, we set S^0 to 100 km^2, which approximately equals the amount of land in residential use in Amsterdam, so that the optimal development tax in Almere is small (in the calibrated model we have τ^S = 2.52). The amenity level A^M is set in such a way that the equilibrium number of households in Amsterdam is equal to the observed number. Finally, *icc* is set equal to the sum of the commuting costs from the Amsterdam CBD to the fringe plus the costs of commuting from the fringe of Amsterdam to the Almere CBD, as reported in Table 1. In the general equilibrium, these parameters have to be chosen simultaneously, yielding α = 479, γ = 0.272, A^M = 1.026 and *icc* = 5733. With these values, the city size externality is so important for utility that in order to internalize it properly, households Amsterdam need to spend about 10.8% of their disposable household income on development taxes.

[27] In order to maintain internal consistency in the model, we also assume that it is the total amount of land in residential use in the city creates the externality S^i, but this does not change the interpretation of the results.

Model validation

In determining the model parameters, we have not made use of the observations in the lower panel of Table 1. This information is used to assess the performance of the calibrated model, by comparing it to the model outcomes as reported in Table 2. Our model is of course a highly stylized description of the equilibrium in both cities, so it is not reasonable to expect that the data used for validation are perfectly reproduced by the calibrated model. Nevertheless, it would be reassuring to find values in the same order of magnitude.

Table 2

City characteristics as obtained in the calibrated model

Variable	Value	
	Amsterdam	Almere
average land rent (€ / m^2)	20.7	6.0
average lotsize (m^2)	186	293
area of municipality (km^2)	188	46

Notes: Output generated with the calibrated model.

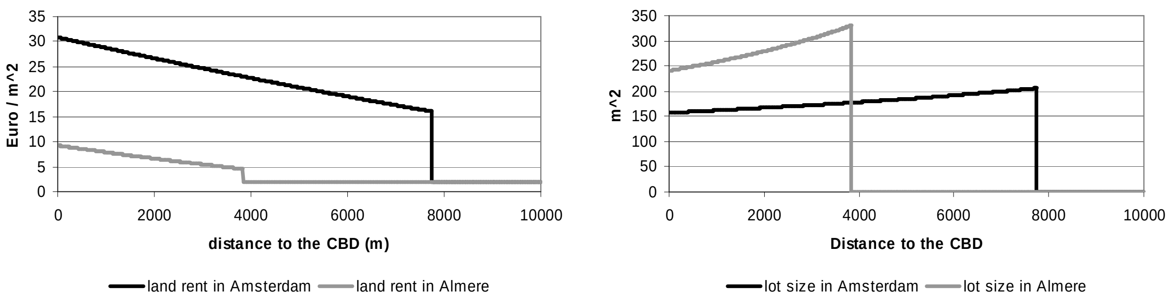
The first statistic that may be used for validation is the intercity house price differential of 44%. As shown in Table 2, land in Amsterdam is more than three times as expensive as land in Almere according to the model, which suggests that it overestimates the land price differential. However, the quality controlled house price differential is at best a very rough estimate of the land price differential. Since lots are smaller in Amsterdam, and since land expenditure is only a part of housing expenditure, the gap may be smaller than it seems at first sight. The second statistic considered is the average lot size in Amsterdam and Almere. In the model, these lot sizes are about twice as high as in the data, but their ratio is almost exactly the same.[28] Finally, the actual surface of the Amsterdam municipality is only about 10% smaller than in the calibrated model. The size of the Almere municipality is much smaller in the model than in reality, but this is due to a higher share of agricultural land within the municipal borders, and probably also a smaller share of land in residential use within this city.

Figure 3 shows land rents and lot sizes as a function of the distance to the CBD in both cities, using the calibrated model again. As expected, land rents are falling with distance, and they jump to the agricultural land rent at the city fringe, the difference being the development

[28] The difference in levels arises from the fact that in the land use statistics, local infrastructure, certain consumer services (such as shops and local bank offices) and small parks are attributed to residential use. Hence, the amount of land in residential use in our data is much larger than the medium lot size times the number of households.

tax.[29] The average slope of the land rent function in Amsterdam is -6.2% per kilometre, which compares reasonably with the -9.0% per kilometre reported in Rouwendal and Van der Straaten (2008). Given our calibration strategy, these slopes should coincide if average lot size in our model would exactly match the average lot size in the data. Lot sizes in Amsterdam rise on average with about 4.0% per kilometre, which again compares reasonably with the slope of +2.4% in the data used by these same authors.[30] In particular, this second finding gives some confidence in our choice of the elasticity of substitution between land and the composite commodity, while suggesting that if anything, this elasticity was chosen too highly.[31] Hence, the calibrated model appears to perform reasonably well, particularly in view of its highly stylized characters.

Figure 3: Land rents and lot sizes in Amsterdam and Almere



With the calibrated model, we may calculate the surplus gross of founding costs that was generated by setting up the satellite Almere. To this aim, we first derive the equilibrium that would result if all households were to reside in Amsterdam. In this equilibrium, the city size increases with about 12%, and the optimal development tax rises to almost 16 € / m^2. In order to maintain the target utility level u^*, households need to receive a lump sum transfer of 837 €. The difference between the surplus in the two city equilibrium and the surplus in this equilibrium then equals 99.7 million €, representing a present discounted value of about 2 billion €. It is this amount that may be spent at most on fixed founding costs.[32]

[29] By differentiation of the bid rent function (Equation 9) with respect to distance, it may be seen that restrictions or taxes on residential land use which reduce lot sizes lead to steeper land rent gradients. Indeed, in Figure 3, land rents fall steeper with distance to the CBD in Amsterdam than in Almere.

[30] We thank Willemijn van der Straaten for kindly providing us with this information, which is not reported in the paper.

[31] Note that with a substitution elasticity of zero, as in a Leontief utility function, lot sizes do not vary with distance to the CBD. This is the case that is often considered in the theoretical literature on growth controls.

[32] There is some reason to believe that the costs of providing intercity infrastructure are roughly in this order of magnitude. The costs of constructing the Betuwelijn, a railroad with a length of 100 kilometres, are about 6 billion €, and the distance between Amsterdam and Almere is about a third of this length.

4 Comparative statics and policy analysis

Conditional on the assumptions that underlie our model and its calibration, a welfare economic framework for the evaluation of land use policies has now been obtained. In this section, we present comparative statics of the optimal policy, as well as an indication of the social costs of implementing suboptimal policies. Furthermore, we contrast the optimal allocation of households over the system of cities with government plans, as illustrated in Figure 1, for various scenarios of income and demographic growth.

Comparative static analysis

The extent to which both the surplus of founding a satellite and the optimal development tax in both cities depend on key model parameters is reported in Table 3. As in the previous section, this surplus is calculated as the difference between the surplus in the two-city equilibrium and the surplus in the equilibrium with one city in which the same utility level is attained, and it is interpreted as the annualized amount that may be spent on fixed founding costs. In order to shed light on the underlying model mechanics, the table also reports adjustments on the extensive margin (city size) and the intensive margin (average population density) of land use in each city. These elasticities may be summed to obtain the responsiveness of the number of households in each city with respect to model parameters.

Table 3

Elasticities of model outputs with respect to key parameters

	Main city			Satellite			SS
	S^M	N^M / S^M	τ^M	S^S	N^S / S^S	τ^S	
icc	0.22	0.14	0.26	-1.88	-0.43	-2.30	-4.09
A^M	0.71	0.47	0.85	-5.32	-2.32	-6.67	-12.53
γ	-0.62	0.44	1.11	0.55	0.61	2.06	2.42
w	0.54	-0.99	0.37	3.17	-0.26	3.71	6.37
N	0.53	0.35	0.63	1.25	0.55	1.58	2.76

Notes: The variables N^M and N^S denote the population in the main city and satellite respectively. See section 2 for the interpretation of other symbols. The elasticities in this table reflect changes in variables between different equilibria, where the target utility level is adjusted in each equilibrium so that there are no lump sum transfers. They are computed numerically by evaluating the equilibrium while multiplying a specific parameter by 1.001 and then multiplying the relative change in all output variables by 1000.

Let us consider the impact of a 10% increase in intercity commuting costs (amounting to 573 €). A rise in these costs makes living in Almere less attractive. Hence, the equilibrium share of households that locate in Amsterdam expands from 87% to 90%. Increased demand for land pushes up prices here, so the average density raises by 1.4%. Households that remain in the satellite have lots that are 13 m^2 larger on average, substituting away from the consumption of numeraire goods. In response to the increased city size, the optimal development tax in the main city rises slightly, while it falls with 23% in Almere. Perhaps most significantly, the surplus of founding the satellite falls with 41% after a 10% rise in intercity commuting costs. This suggests that the surplus of founding Almere could have been much higher if it had been setup closer to Amsterdam, although negative externality effects might then have been induced that are not accounted for in our model.[33] Another interesting implication is that, with a long run decline in transportation costs, the foundation of satellites becomes increasingly attractive. On the other hand, congestion on the intercity infrastructure network, which happens to be substantial in reality, raises the social costs of this policy.

The comparative static impact of raising the amenability of Amsterdam is qualitatively similar to the effect of a rise in intercity commuting costs. The attractiveness of the main city is increased and the distribution of households over the cities and land consumption adjust accordingly. Quantitatively, however, the effects are much larger. A 1% increase in A^M already leads to a 1.2% increase the in share of households in Amsterdam, and a 13% loss in surplus. Besides the way in which amenities enter utility in our calibrated model, this is also a consequence of the fact that the amenability of Amsterdam matters directly for a much larger group of households than the intercity commuting costs. Note that while amenability is exogenous in our model, it may be regarded as a first pass on endogenous differences in attractiveness, such as the existence of agglomeration economies in production and consumption.[34] This first pass then suggests that positive agglomeration externalities reduce the social surplus of founding a satellite.

Comparative static properties of the other parameters may be interpreted along similar lines. As it is the negative externality of city size that motivates government intervention, it is not surprising that both optimal development taxes and the social surplus from founding a satellite are elastic with respect to the parameter γ. In response to higher development taxes, households reduce their consumption of land and the population density in both cities increases. The distribution of households shifts towards the satellite, as the externality renders

[33] Ignoring intercity externalities, the optimal distance between Amsterdam and Almere would be zero in our model, but this is not consistent with our interpretation of the city size externality. At least, if residents of Amsterdam would want to enjoy true open space at the urban fringe, the satellite should be so far away that it is not visible from there. However, one would think that a 10 kilometres distance would suffice for this, rather then the 30 kilometres that separate these cities presently.

[34] As long as satellites are small relative to the main city, scale effects in this city are only marginally affected by their foundation.

the main city less attractive. An increase in *w* raises the demand for land, which is obviously a normal good. The income elasticity of average lot sizes in Amsterdam is approximately equal to unity, which is also the income elasticity of the demand for land that is implied by our utility function. The size of Almere is much more sensitive with respect to this variable than Amsterdam, the income elasticity of the number of households in Almere being equal to 2.9. Hence, the social surplus from founding the satellite is also highly elastic with respect to household income, and under a long-run upward trend in incomes, this policy becomes increasingly attractive. Finally, an increase in *N* pushes up the demand for land as well, and as prices rise, land use in both cities adjusts accordingly along the intensive and the extensive margin. Hence, the average consumption of land falls in both cities, and the distribution of households shifts towards the satellite. The social surplus of founding Almere is also highly elastic with respect to the total number of households that are accommodated in the system.

Social costs of suboptimal policies

While for the calibration of our model, it was assumed that negative externalities of city size were large enough to justify the observed shadow prices of land use restrictions, it is also possible that land use regulation is set too restrictively. Table 4 explores the welfare economic consequences of setting a suboptimal policy. The three columns refer to different true values of the externality parameter γ and the rows contain policy scenario's whose optimality is conditional on a perceived value of this parameter. For each column, we report social surplus for a target utility that obtains under the optimal land use policy without lump sum transfers. So throughout the first column for instance, in which there is no negative externality of city size at all, the target utility level is chosen such that the optimal allocation is obtained in a free market equilibrium in which there are neither development taxes nor lump sum transfers, and there is only one city. Note that surplus values cannot be compared across columns, because they refer to different utility functions and target utility levels.[35]

For a meaningful comparison, it is perhaps most useful to consider the second column of Table 4, in which the true city size externality parameter equals 0.136. For sufficiently large fixed costs of founding the satellite, it is optimal to accommodate all households in a single city. The first best development tax is then equal to 6.58 € / m^2. If the government fails to levy a development tax in response to the externality, social surplus is reduced by about

[35] See our discussion in section 2.

17%, or almost 2% of disposable household income.[36] If the government sets land use regulation at a level that is too restrictive, as it mistakenly perceives a value γ = 0.272, 7% of the social surplus is lost. Under a true externality parameter of 0.136, the social surplus of founding a satellite gross of fixed founding costs is positive if development taxes are set either optimally or too restrictively. However, under optimal development taxes, only 9 million € would be left annually for fixed founding costs.

Table 4

Annual social surplus (in 10^9 €) under various externalities and policy scenarios

	$\gamma = 0$	$\gamma = 0.136$	$\gamma = 0.272$
One city, $\tau^M = 0$	0.595 (*first best*)	0.962	0.630 + *FC*
One city, $\tau^M = 6.58$	0.439	1.164 (*first best*)	1.267 + *FC*
One city, $\tau^M = 15.88$	0.157	1.079	1.375 + *FC*
Two cities, $\tau^M = 6.40$, $\tau^S = 0.39$	-	1.173 - *FC*	1.395
Two cities, $\tau^M = 14.00$, $\tau^S = 2.52$	0.211 - *FC*	1.104 - *FC*	1.475 (*first best*)

Notes: The table shows welfare effects of land use policies under various scenarios of true and perceived city size externality parameters. True values of this parameter are in columns, and policy scenarios in rows. In each column, target utility is the utility level obtained in the first best equilibrium, in which there are no lump sum transfers and development taxes are set as in the baseline calibration. The term *FC* refers to the annual fixed costs of founding the satellite. Surplus values cannot be compared across columns, as they refer to different target utility levels.

Obviously, if no negative externality of city size exists, all households should be accommodated in one city, and no development taxes should be levied. If the government does levy a development tax, misperceiving the externality parameter to be 0.272, social surplus is reduced by 74%. In this scenario, the benefits of founding a satellite gross of fixed costs are positive. So, even if there is no land use externality, suboptimal land use restrictions may render the foundation of a satellite socially desirable. The last column of Table 4 indicates that the foundation of a satellite is socially desirable as long as annualized fixed costs do not exceed 100 million €, if γ equals its calibrated value. Failing to implement land use restrictions costs 57% of the social surplus, gross of fixed founding costs.

Optimal planning in scenarios for demographic and income growth

Although we have so far analysed optimal development taxation, direct land use regulation is the more common way to steer land use patterns. In the Netherlands, national and local governments plan both the amount of land for residential development and the number of

[36] This number is smaller but in the same order of magnitude as the net social costs of growth boundaries in the case of Reading, UK, as estimated by Cheshire and Sheppard (2002). These authors found that relaxing it substantially would lead to a welfare gain of almost 4% of household income.

houses to be built in a municipality, and any mismatch between regulated supply and market demand is consequently reflected in shadow rents on residential land use. As indicated by Figure 1, the majority of new houses in the system Amsterdam-Almere is to be realised in the satellite. It makes sense to contrast these plans to the optimal distribution of additional households over these cities in our model. Table 5 indicates the number of new households that should optimally be accommodated in Almere under various scenarios. The dimensions of these scenarios are the number of new households to be accommodated in the system and disposable household income.

Table 5

Optimal number of households in Almere under various scenarios

	ΔN = 0	ΔN = 1000	ΔN = 10,000	ΔN = 100,000
Y = 24000 €	63000	63243	65432	87902
Y = 32000 €	110145	110463	113325	142301
Y = 40000 €	137999	138356	141575	174008

Notes: The table shows the optimal number of households for various values of the disposable household income and the number of additional households to be accommodated in the system.

If we keep disposable household income at the level at which the model is calibrated, about 75% of all households should be accommodated in the main city, virtually irrespective of their number. This proportion contrasts starkly with planned construction in Figure 1, casting doubt on the social desirability of these plans. However, we have seen that the optimal proportion of households in Amsterdam is fairly sensitive to income. With a real income growth rate of 1 - 2% per year over a horizon of 30 years, which is roughly the horizon of planning documents, this effect is therefore considerable. If no new households were to be accommodated in the system, a real income increase of 33% would shift the optimal proportion of households in Almere from 13.5% to 23.5%, and a 67% increase would raise it to almost 30%. So if the costs of demolishing and reconstructing dwellings could be ignored, houses should be destroyed in Amsterdam and rebuilt in Almere, while all lot sizes should be increased. Since this is a very costly thing to do in reality, it may be sensible to anticipate the demand effects of future income growth in present land use plans. If for instance, 100,000 new additional households are to be accommodated in the system and a 33% real income increase is projected, only about 20,000 new houses should be built in Amsterdam, and the rest in Almere. All other scenarios in Table 5 in which disposable household income exceeds the calibrated value involve a reduction of the number of households in Amsterdam.

One should realize, however, that adjustments in the land consumption of individual households are ignored in this table, although our comparative static results indicate that these are significant as well. Through this channel, the optimal size of Amsterdam is increasing in both income and the total number of households.[37] Hence, the findings in this table do certainly not imply that, in the face of income and demographic growth, geographical growth boundaries around this city should remain as they are currently drawn.[38] Another caveat is that transport costs within and between cities are assumed to remain constant in these scenarios, although in reality, the time costs of travel are likely to increase with income. As we have seen, higher transport costs make Amsterdam a more attractive location, thus counteracting the income effect. Finally, with rising surplus of founding a satellite, it may become preferable to accommodate households in a third new city. This possibility is further explored in the next section.

5 Extension with multiple satellites

At the end of section 2, we have briefly indicated how our theoretical framework could be extended with multiple symmetric satellites. Maintaining parameter values that were obtained in the calibration, we now explore the consequences of this extension for our policy analysis. Table 6 shows social surplus gross of founding costs as a function of the number of satellites, as well as the optimal distribution of households over the resulting system of cities. In order to enable the comparison of surplus in different equilibria, the target utility is held constant at the equilibrium level in a system with one satellite and no lump sum transfers. The policy setting to which this corresponds is a government that decides to found a certain number of satellites in addition to the one that exists already. Development taxes are chosen optimally in all equilibria considered.

When founding costs are ignored, social surplus is increasing in the number of satellites, but the associated surplus gain falls with each additional satellite. Hence, the optimal number of satellites may be determined if founding costs are known. For instance, it is not optimal to found a second satellite as long as these costs exceed 59 million € per year,

[37] With a 67% income increase and no additional households, the optimal size of Amsterdam increases with 32%, with 100,000 additional households and no income growth, it increases with 11%, and with both income and demographic growth, it increases with 47%.

[38] The elasticity of optimal total residential land consumption with respect to income equals about 1.0. However, the evidence in Vermeulen and Rouwendal (2007) suggests that income induced demand shifts are not accommodated at all by the supply of residential land, as a consequence of government interventions in land and housing markets. If our assumptions about the land use externality are valid, it follows that this extent of restrictiveness cannot be socially optimal.

and with annualized fixed founding costs of about 25 million €, the government should set up three satellites in addition to the one that is already in place. As the third and fourth columns in Table 6 indicate, the number of households in the main city and a typical satellite are both decreasing in the number of satellites. Nevertheless, given the calibrated parameters in our model, even in a system with 7 satellites, the main city should still contain about two thirds of the population.

Table 6

The foundation of multiple satellites

#(satellites)	*SS* (10^9 €)	*ΔSS* (10^6 €)	N^M / N	N^S / N
1	1.48	99.7	0.865	0.135
2	1.53	58.6	0.794	0.103
3	1.57	40.0	0.748	0.084
4	1.60	29.6	0.716	0.071
5	1.63	23.0	0.691	0.062
6	1.64	18.6	0.672	0.055
7	1.66	15.4	0.656	0.049

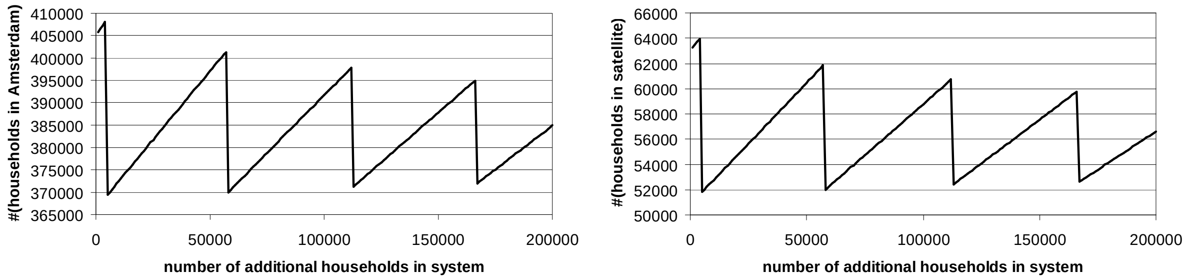
Notes: The table indicates the social surplus associated with an increasing number of satellites, as well as the distribution of households over the system of cities. The second column derives from the first one, indicating the surplus gain from founding the marginal satellite. Target utility is the utility level that is obtained in the equilibrium with one satellite without lump sum transfers. In each equilibrium, development taxes are assumed to be set optimally.

As we have seen, the surplus of founding a satellite is elastic with respect to model parameters and as a consequence, the optimal number of satellites must be sensitive to these parameters as well. Again, given the institutional context in which housing supply in the Netherlands takes place, it is interesting to see how the optimal number of satellites alters with the number of households that are to be accommodated in the system. Hence, Figure 4 shows the number of households in the main city and a representative satellite as a function of the number of new households, when an optimal policy with respect to the foundation of satellites is conducted. We assume annualized fixed founding costs of 60 million €, so that foundation of a second satellite is just not desirable in the calibrated equilibrium.

Given these fixed founding costs, the foundation of a satellite becomes optimal with 5,000 additional households already. At this point, the optimal number of households in the main city drops to 370,000, whereas the optimal number of households in both satellites drops to 52,000. Foundation of the third satellite becomes desirable when 58,000 new households are to be accommodated in the system, and the number of households in the main city and all satellites then drops to a slightly higher value than with 5,000 additional households.

Interestingly, the peaks in the number of households in each city become lower, when the total number of households in the system increases, so demographic growth does not appear to call for major expansions of the main city or the first satellite in this model.

Figure 4: Number of households in main city and a representative satellites under demographic growth



With annual fixed founding costs of 60 million € and an income elasticity of the surplus of 6.4 (see Table 3), the equilibrium number of satellites is particularly sensitive to household income. If this rises to 32,000 €, it is already optimal for the government to found 5 additional satellites in our model. In the resulting system of cities, almost half of all households remain in the main city and each satellite contains less than 10% of the total population. So, although our analysis in the previous section suggested that when expected real income growth is taken into account, new households should be predominantly accommodated in Almere, it now appears that, as long as founding costs are not too high, they should rather be accommodated in new satellites in these scenarios.

6 Conclusions

We have shown that the existence of a negative externality of city size may, from a welfare economic perspective, justify the imposition of growth controls and the foundation of satellites. With rising incomes and declining transport costs, the foundation of satellites becomes increasingly attractive. This suggests that clustered deconcentration, a policy that is or has been conducted in various European countries, may be a socially preferable alternative to unregulated urban sprawl. Even so, growth controls should be less restrictive in satellites only to the extent that the externality is less relevant for people in small towns than for inhabitants of a big city. In particular, it is never optimal to subsidize land use in a satellite with this type of externality.

The widespread popularity of urban containment policies renders the existence of a negative externality of city size plausible *a priori*, and it is commonly assumed in a class of theoretical growth control models (cf. Brueckner, 1999). It should be borne in mind, however, that the welfare economic motivation for a clustered deconcentration policy depends crucially on the precise specification of this externality. For instance, if the relevant externality relates to the total stock of open space, as in Brueckner (2001) and Bento *et al*. (2006), it is never optimal to found a satellite, as this increases residential land use at the regional level. If on the other hand, people value proximity to public parks much more than access to open space outside cities, as suggested by Cheshire and Sheppard (2001), neither the imposition of growth controls nor the foundation of satellites are called for. And to the extent that traffic congestion externalities are relevant, congestion tolls are preferable to growth controls in a first-best environment. Making use of a calibrated model, we find that the optimal land use policy is also highly sensitive to the quantitative significance of the city size externality. Moreover, the social costs of implementing a suboptimal policy appear to be substantial. Hence, policymakers should acquire a thorough understanding of the type and size of land use externalities before embarking on clustered deconcentration.

Our analysis is applied to the cities of Amsterdam and Almere. In the model calibration, parameters for the negative externality of city size are chosen that render the observed shadow price of land use restrictions optimal. It is implied that households in Amsterdam should spend about 10% of their income on a development tax, or alternatively, on the increase in prices that is caused by land use restrictions. While this extent of restrictiveness is optimal in our analysis by assumption, the calibrated model may be used to shed light on plans to accommodate new housing demand in the region predominantly in Almere. In a comparative static analysis, we find that *ceteris paribus*, about 75% of new households should be located in Amsterdam. If expected income growth is taken into account, it makes sense to concentrate household growth in Almere, but Amsterdam should be allowed to expand nevertheless, because household demand for land is pushed up. Furthermore, both demographic and income growth make it increasingly attractive to divert new households to new satellites, if we allow for them. Hence, it seems difficult to reconcile present plans for restrictions around Amsterdam and growth in Almere with the optimal policy that is dictated by a negative externality of city size.

A number of caveats apply to these policy recommendations. Land use restrictions in Amsterdam exist partly because of its proximity to an airport and some areas near this city do arguably have special environmental or historical value. We abstract from such considerations in our model. Interpretation of the income growth scenarios is somewhat troubled by the fact that housing and urban structure are not malleable in practice, while our analysis assumes that they are. A large share of the housing stock in Amsterdam is allocated to the social rental sector, so our assumption of market based housing supply is not fully appropriate. Furthermore, labour markets and economies of agglomeration have been dealt with in a very stylized manner. Finally, heterogeneity and distributional aspects are ignored in this paper, even if various studies indicate the relevance of such issues (cf. Cheshire and Sheppard, 2002, Bento *et al*., 2006). In particular, even if we abstract from any rent seeking behaviour that it might induce, benefits from the direct regulation of land use that is common in the Netherlands accrue to a significant extent to the owners of land, and a full analysis of welfare effects should therefore take account of their proper weight in aggregate social welfare.

Appendix: Data used for the model calibration

This appendix accounts for the data sources and estimation procedures used to obtain the figures in Table 1.

- The number of households in Amsterdam and Almere in the year 2002 is reported by Statistics Netherlands.
- The median lot size is computed from transaction records by the Dutch Association of Realtors (NVM) in the years 1999 and 2000. As a measure for lotsize, we have used the total surface for condominiums, and the lotsize as recorded by the land registry for single family dwellings. The amount of land used by condominiums is smaller than the total surface in the case of high-rise buildings, but land use was not observed in our data for many apartments. As the share of condominiums is significantly larger in Amsterdam, this implies that we may overestimate the land use per household in this city in particular. On the other hand, the amount of high-rise residential buildings is limited by regulation, so that this bias may be limited as well. Furthermore, it should be borne in mind that these figures refer to the owner-occupier sector, whereas the social rental sector is particularly large in Amsterdam. Since social housing construction is rather insensitive to market signals, this implies that we may underestimate the average lotsize for the total housing stock in this city.
- Rouwendal and Van der Straaten (2008) estimate the average price of residential land in Amsterdam in a hedonic analysis of house prices as 806 € per m^2. We have estimated the average lot size in Amsterdam as 95 m^2, so the value of land in an

average house amounts to about 77,000 €. Discounting with a rate of 5%, this yields an annual expenditure on land of 3,800 €. The average disposable household income in Amsterdam is 24,000 €, using data from a Dutch housing demand survey (WBO) for the year 2002. Hence, we estimate the average expenditure share of land in the household budget to be about 16% in Amsterdam.

- At the municipal level, 37% of the non-agricultural land is allocated to residential use (data for 2005, provided by the municipal government of Amsterdam). This figure may underestimate the share of space in residential use within the urban area, given the way municipal borders are drawn. Using the same data as in Rouwendal and Van der Straaten (2008), the share of land in residential use has been estimated to be 53% in the centre of Amsterdam, and 36% in a more peripheral neighbourhood (*Zuider Amstel*). For the calibration, we use a share of 40%. Note that this is also in accordance with the share of land in residential use within urban areas in Reading (38%) and Darlington (43%), as reported by Cheshire and Sheppard (2002).
- As jobs in Amsterdam are scattered over the entire city, it seems problematic to calibrate annual transport costs to the CBD by estimating travel times and inferring costs and the valuation of time. Instead, we calibrate the parameter *t* on the slope of the bid rent curve. In a hedonic analysis of house prices in Amsterdam, Rouwendal and Van der Straaten (2008) report that a 1 kilometre increase in the distance to the city centre decreases the value of a house by 9%, conditional on a range of control variables. We use this coefficient to estimate the transport costs per unit of distance from the CBD. By use of the envelope theorem, the derivative of the bid rent function with respect to transport costs equals $\partial p_r^i / \partial r = -t / s_r^i *$, where $s_r^i *$ follows from solving the consumer problem. We rewrite this to $t = -p_r^i s_r^i * \partial \log\left(p_r^i\right) / \partial r$. From the estimates in Rouwendal and Van der Straaten (2008), it follows that $\partial \log\left(p_r^i\right) / \partial r$ is equal to -0.00009. For $p_r^i s_r^i *$ we substitute the average annual expenditure on land, which equals 3,800 € (see our discussion of the expenditure share of land in the disposable household income). This yields an estimate of the annual travel costs per meter of distance from the CBD of 0.34 €.
- In an analysis of possibilities for new construction in North Holland, SEO(2003) estimates the price of agricultural land at 4 € / m^2, and the costs of conversion to residential land at 37 € / m^2. It is assumed here that the share of conversion in the total construction costs is in accordance with the share of land conversion in the total

production by building contractors in national accounts, and the estimate of the conversion costs obtains by multiplying this share with the average construction costs per square meter in North Holland.

- The shadow price of land use regulation is estimated by subtracting the price of agricultural land and conversion costs from the price of residential land at the city fringe. The Amsterdam city fringe is represented by the *Bovenkerkerpolder* in the south of this city. Ecorys-NEI (2004) estimates the value of a newly constructed house in this area to be 344,000 €. Subtracting land, conversion and construction costs, they estimate the shadow price of land use regulation to be 42,000 € per house. These calculations assume a density of construction of 26 houses per hectare. Assuming that 40% of the land is used for housing, this yields an average housing size of 154 m^2. Hence, the shadow price is 273 € per meter, which amounts to 14 €/m^2 per year.[39] The same study estimates the shadow price of land use regulation in Almere to be - 5,000 € per house, which amounts to -1.6 €/m^2 per year. This estimate suggests that the price of new housing in this city is not sufficient to cover all costs associated with its land use and construction, so that residential land use in Almere is effectively subsidized.
- The quality controlled house price differential is obtained by regressing the logarithm of house prices on housing characteristics and dummies for Amsterdam and Almere, using the WBO data again. The characteristics used are the type of house (detached, semi-detached, terraced corner, terraced non-corner, apartment), the number of rooms, the size of the living room and the kitchen, availability of an elevator, garage, garden, balcony, central heating, double glazing and the period of construction. Controlled for these characteristics, housing in Amsterdam is 35% more expensive than the national average, and in Almere it is 6% less expensive.
- The area of the municipalities refers too land only, so it ignores cannels, lakes and other water. It should be noted that the municipal borders are drawn quite widely around the built up area. For instance, the municipal share of land in agriculture was 18% in Amsterdam and 33% in Almere (Bodemstatistiek 2000). Hence, this is likely to be a poor proxy for the size of the two cities, although it still gives some rough idea of their order of magnitude.

[39] SEO (2003) estimates the shadow price of land use regulation in Amsterdam to be 550 €/m^2, which is almost twice as high as our estimate. However, local conversion and construction costs are estimated more roughly in this study, and it considers average house prices in Amsterdam, rather than prices at the city fringe. Nevertheless, this suggests that our estimate of the shadow price of land use regional in this area is conservative.

- Theoretically, we have modelled the intercity infrastructure as a direct link between the CBD's of the main city and the satellite. In reality, residents of Almere have to travel to the Amsterdam fringe (*knooppunt Watergraafsmeer*). From that point onwards, they face about the same travel costs as people who live near the fringe of Amsterdam. Hence, we proxy the transport costs faced by a resident of Almere by the sum of the transport costs from Almere to the fringe of Amsterdam and the transport costs from the fringe of Amsterdam to the CBD. The transport costs from the fringe of Amsterdam to the CBD follow from our estimate of t and the size of Amsterdam. The distance from Almere to the fringe of Amsterdam is 25 kilometres, and the average velocity during rush hours is about 60 kilometres per hour. The Dutch Transport Research Centre (AVV) estimates the valuation of travel time in 2005 to be 8.43 € per hour, and the variable costs of car use are estimated to be 0.101 € per kilometre. This results in daily commuting costs between Almere and the Amsterdam city fringe of about 12 €. With 260 working days a year, the annual costs are then about 3100 €.

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