Urban Growth Controls and Intercity Commuting*

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February 23, 2005

Abstract

This paper incorporates the possibility of intercity commuting (IC) in a growth control model. As controls restrict the labor supply, the wage rate increases in the city. Land rents capitalize the wage differential, but when this differential reaches the IC cost, IC starts to occur, keeping wages constant. Thus, if controls are adopted in the benefit of landowners, IC weakens the incentive for tighter controls compared to case where IC is not possible. However, if firms' profits (which decrease with higher wages) are also taken into consideration in the choice of controls, then the possibility of IC may induce tighter controls.

Keywords: Urban growth controls; intercity commuting; population mobility; labor mobility; land rents.

JEL Classification Numbers: R14, R21, R31, R52.

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*Forthcoming in the Journal of Urban Economics, 2005 - available online (as article in press) at http://www.sciencedirect.com/science/journal/00941190.

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1 Introduction

Many jurisdictions in the US have adopted controls to slow population growth and urban sprawl. Growth controls take the form of zoning restrictions that regulate the type of land use, urban growth boundaries, development fees, limits on building permits, etc. An extensive literature has studied this issue, with Brueckner [5] providing a survey of the theoretical models and Fischel [8] surveying the empirical evidence. The theories predict that, by restricting supply, growth controls raise the price of housing, and this prediction is confirmed by empirical work.

Another impact of this supply restriction is a diversion of households away from the communities imposing growth controls. One response to such residential relocation may be intercity commuting, with the displaced households traveling daily from their new location to a job site in the community where controls are in place. For example, Aivalotis et al. [1] report a significant jobs-housing mismatch in the San Francisco Bay Area, and Cervero [6] argues that land use regulation is one of the main reasons for this imbalance. In effect, economic prosperity has created many new Bay Area jobs, but workers arriving for these jobs must live in the outskirts of the region, making intercity commute trips, due to a control-induced housing shortage near the new worksites.

Despite the potential importance of intercity commuting as a response to growth controls, the theoretical literature has not considered this phenomenon. The present paper is designed to fill this gap in the literature. In a model of growth controls, intercity commuting (IC) may emerge because labor supply is restricted when population growth is restrained, creating a wage differential between cities. Assuming that aggregate production in each community exhibits decreasing returns to scale in labor use, the city with controls experiences an increase in the wage rate relative to other cities. If the difference in wages becomes high enough to compensate the IC cost, workers from neighbor cities will be attracted, so that IC occurs. The paper then studies how this potential inflow of workers affects the decision to impose growth controls.

Regarding the literature on growth controls, there are two main streams of models.[1] In both of them, controls emerge because of the political influence of landowners on local public policies. Landowners benefit from controls because land rents increase and living conditions in the city are improved. In the so-called *amenity-creation* model (Brueckner [2]; Engle, Navarro, and Carlson [7]), controls reduce negative population externalities like congestion in the use of public goods or pollution. As a result, the demand for land increases in the city with controls, leading to higher land rents there. In contrast, regardless of population externalities, the *supply-restriction* model (Brueckner [2]; Helsley and Strange [9]; Brueckner and Lai [4]) focuses on the increase of land rents due to restricted land availability in the city with controls. When controls are adopted in one city, population is diverted to other communities, increasing demand for land there. In consequence, assuming that the size of the controlling city is non-negligible relative to the urban system, land rents increase everywhere. A hybrid model, with both amenity-creation and supply-restriction, was developed by Brueckner [5]. By also taking into consideration immobile resident landowners, his model generates more realistic results: controls are adopted not only to increase land rents, but also to increase the utility of landowners by the reduction of negative population externalities.

The present paper follows the supply-restriction model, assuming an economy with a mobile population of renters, inelastic individual consumption of land, and two cities, one of which is active in the adoption of controls, while the other is passive, not imposing controls.[2] Additionally, all other agents in the economy (landowners and firm-owners) are considered to be absentee. In deriving the results, the critical assumption is that production exhibits decreasing returns to scale in the labor input,[3] which implies that wages increase when

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[1] See Brueckner [5] for other references. Models in this literature are usually static, with the city size being limited instead of actually restricting its intertemporal growth.

[2] While one justification for this difference could be that landowners are not politically influential in all cities, Brueckner [3] argued that, when individual land consumption is fixed, all cities cannot impose controls since the population could not then be housed. In contrast, if land consumption is flexible, all cities can impose controls, but the analysis becomes more complicated.

[3] This case was considered before in a model of growth controls by Sasaki [10].

labor supply is restricted by growth controls. Since land rent extracts utility differentials between locations, the increased wages inflate rents in the city with controls. Thus, when this labor supply restriction effect exists, there is an extra incentive to impose growth controls. However, when IC is possible, fewer residents do not always imply fewer workers: if the population is restricted to the point that the wage differential reaches the IC cost, any further restriction induces residents of the neighboring city to engage in IC, which keeps the wage differential constant.[4] From this point, controls do not further restrict the labor supply. Hence, one of the gains from the adoption of controls (the increase in rents due to the widened intercity wage differential) vanishes at a certain point (i.e., when IC starts). Thus, the presence of a close neighbor city that can also supply workers leads the equilibrium city size to be bigger and renters to be less hurt by controls. The neighbor city must be close because otherwise the wage differential resulting from controls may not become attractive enough to induce IC.

The basic model is presented in the next Section. In Section 3, the conflict of interests between groups of agents in the economy is discussed. Then, the basic model is extended to allow landowners to also own the firms (this can also be interpreted as the case where firm-owners share political influence). As the result, the intensity of desired controls is reduced because controls restrict labor supply, and thus lower firms' profits. However, the way IC affects the adoption of controls remains qualitatively the same, except that, because IC eliminates the profit loss (by keeping the labor supply constant), there may be tighter controls with IC than without it. In Section 4, other extensions of the basic model are discussed. First, resident landowners are considered instead of absentee ones. Second, the addition of amenities related to population size or labor force size is analyzed. Section 5 concludes.

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[4] Suh [11] analyzed the possibility of IC in a model of population allocation between cities. However, growth controls were not considered, with intercity differences in individual income being exogenous.

2 The model

2.1 Setup

Consider a closed economy with two regions indexed by $i = 0, 1$. Each region contains a linear city with width of one unit of distance and length $\bar{x}_i$. The length corresponds to the distance between the boundary of the urban area and the central business district (CBD), where production takes place, located at one of the extremes of the city area. The distance between the CBDs of the two cities is $D \geq 0$. Figure 1 depicts the geographical assumptions of the model.

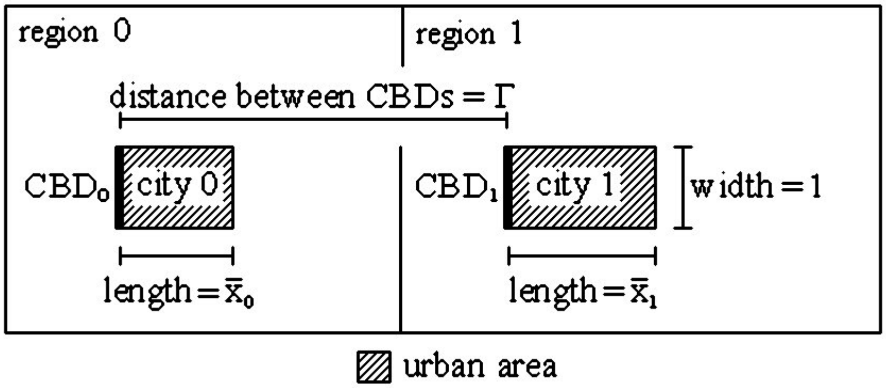

Figure 1 - Geography

Land inside each city is occupied by mobile renters, with individual land demand being unitary. Thus, $\bar{x}_i$ equals the city population, denoted P_i. Consequently, $\bar{x}_0 + \bar{x}_1 = P_0 + P_1 = P$, where P is the total population of renters in this economy. Each region can be home to the whole population of renters if necessary, so that renters can reside wherever they get the highest utility. In addition to land, renters also consume a numeraire private good. To obtain income, renters supply labor to firms. Each renter is endowed with one unit of labor, which is exchanged for a wage w_j, where j denotes the city of work.

In order to work in the CBD of her own city, a renter residing at a distance x_i from the CBD incurs a commuting cost of tx_i, where $t > 0$ represents the unit cost per distance. But if she works in the CBD of the other city, she incurs an additional IC cost equal to $T \equiv \gamma t D$, where $\gamma > 0$ is a scaling parameter relative to the intracity per unit cost (for example, if $\gamma = 1$ then the intercity and the intracity per unit costs are the same). Thus, $\Gamma \equiv \gamma D$ can be interpreted as the relative IC distance. Note that this setting implies that individuals are homogeneous in the cost of commuting between cities, since it requires any worker to go first to the CBD of the city where she resides in order to commute to the other CBD. This assumption is adopted to make the analysis tractable by ensuring that the labor-exporting city is monocentric in equilibrium, with its area being contiguous.[5]

Besides commuting costs, each renter pays land rent, denoted $r_i(x_i)$, which is a decreasing function of x_i because individuals are willing to bid more to live closer to their work place in order to avoid commuting costs. In equilibrium, land rents extract all utility differentials related to where individuals live, equalizing renters' utilities everywhere.

Assuming that utility is given by the consumption of the non-land good, the indirect utility function of a renter who lives in i and works in j can be written as

$$u_{i,j}(x_i) = \begin{cases} w_i - tx_i - r_i(x_i) & \text{if } j = i \\ w_j - T - tx_i - r_i(x_i) & \text{otherwise.} \end{cases} \tag{1}$$

To simplify the analysis, the ownership of land in and around each city is shared among absentee landowners. Moreover, each landowner receives rents from only one of the regions. Normalizing the opportunity cost of land (which equals the rent for non-urban use) to zero, total land rent in each city (denoted R_i) can be represented as a function of the city size:

$$R_i\left(\bar{x}_i\right) = \int_0^{\bar{x}_i} r_i(x_i)dx_i. \tag{2}$$

Cities are symmetric in all aspects, except that city 0 may adopt urban growth controls,

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[5] Realistically, this assumption can be interpreted as the need to take a train or bus in a central station, or a highway entry in the central region of the city. The assumption is automatically satisfied when the cities grow in opposite directions.

restricting $\bar{x}_0$ to maximize land rents there.

Finally, production in each city is carried out by competitive firms. The individual firm's production function is $f(L)$, which is strictly concave in L, the number of workers employed by the firm. With k symmetric firms in each city, $L = N_i/k$, where N_i is the number of workers in city i. Accordingly, the aggregate production function is $F(N_i) \equiv kf(N_i/k)$, with $F'(N_i) > 0$ and $F''(N_i) < 0$. It is also assumed that $F(0) = 0$ and $F'(0) = +\infty$. Hence, the aggregate production in each city also exhibits decreasing returns to scale. In equilibrium, profit maximization implies

$$w_i = F'(N_i), \tag{3}$$

yielding a positive total profit given by

$$\Pi_i = F(N_i) - N_i F'(N_i) > 0. \tag{4}$$

These profits are shared among absentee firm-owners, who are neither workers nor landowners (the pattern of ownership of firms is altered below as one extension of the model).

2.2 Growth controls in city 0

Consider first the case with no growth control. Then, land rent at the boundary of each city must be zero to equal the opportunity cost of land outside the city: $r_i(\bar{x}_i) = 0$. Rents at other places in the city are determined by utility equalization within each city, i.e., by $u_{i,i}(x_i) = u_{i,i}(\bar{x}_i)$ for all x_i. Thus,

$$r_i(x_i) = t\left(\bar{x}_i - x_i\right). \tag{5}$$

In the market equilibrium, utility is equalized between cities. Thus, it must be true that $u_{0,0}(\bar{x}_0) = u_{1,1}(\bar{x}_1)$. Substituting (3), (5), and the population constraint $\bar{x}_1 = (P - \bar{x}_0)$ in (1), this equality becomes $F'(N_0) - t\bar{x}_0 = F'(P - N_0) - t(P - \bar{x}_0)$, which is clearly satisfied when $\bar{x}_0 = \frac{1}{2}P$, with no IC occurring. The symmetric population allocation is also the social optimal outcome because the social surplus in this economy is total production minus total commuting cost, which are both optimized at the symmetric outcome.

Now, suppose that the owners of land in city 0 can force the adoption of growth controls, restricting $\bar{x}_0$ to below $\frac{1}{2}P$ in order to increase total land rents. Thus, (5) gives the land rent function only in city 1, where there is no control. To derive the land rent function in city 0, the key observation is that residents must be equally well-off in the two cities. If this equality did not hold, residents of one city would be able to outbid the other city's residents for their land. Now, suppose for the moment that IC does not occur, which means that the first of the utility expressions in (1) is relevant. Evaluating city 1 utility at $x_1 = \bar{x}_1$ yields $u_{1,1}(\bar{x}_1) = w_1 - t\bar{x}_1$. Setting this expression equal to $u_{0,0}(x_0) = w_0 - tx_0 - r_0(x_0)$ yields

$$\begin{aligned} r_0(x_0) &= t\,(\bar{x}_1 - x_0) + w_0 - w_1 \\ &= t\,(P - \bar{x}_0 - x_0) + F'(N_0) - F'(P - N_0), \end{aligned} \tag{6}$$

where the second equality results from the use of the population constraint $\bar{x}_1 = P - \bar{x}_0$ and the equilibrium wages given by (3). In words, land rents in city 0 extract two utility differential components: the commuting cost differential with respect to the boundary resident in city 1 (represented by $t\,(\bar{x}_1 - x_0)$), and the wage differential between cities $(w_0 - w_1)$. Thus, when $\bar{x}_0$ is reduced, land rent at any interior location in city 0 increases for two reasons. First, residents must relocate to city 1, increasing demand for land there. Thus, the commuting cost differential widens (because $\bar{x}_1$ increases). Second, labor supply is restricted in city 0, increasing wage w_0, while the opposite happens in city 1. Thus, the intercity wage differential widens. Analytically, as N_0 (which equals $\bar{x}_0$ in the absence of IC) falls below $\frac{1}{2}P$, $F'(N_0) - F'(P - N_0)$ rises above zero given $F'' < 0$.

Figure 2 illustrates the effects of controls on land rents in each city. First, note that initially $r_0(0) = t\bar{x}_1 + w_0 - w_1$ and $r_1(0) = t\bar{x}_1$, with the slopes of the land rent curves being

$-t$ (from equations (5) and (6)). As city 0's size is restricted from $\bar{x}_0$ to $\bar{x}_0'$, rents in city 0 increases for the two reasons mentioned: while the increase in the demand for land in city 1 from $\bar{x}_1$ to $\bar{x}_1'$ raises land rents in both cities, the increase in the wage differential (to $w_0' - w_1'$) further raises land rents in city 0.

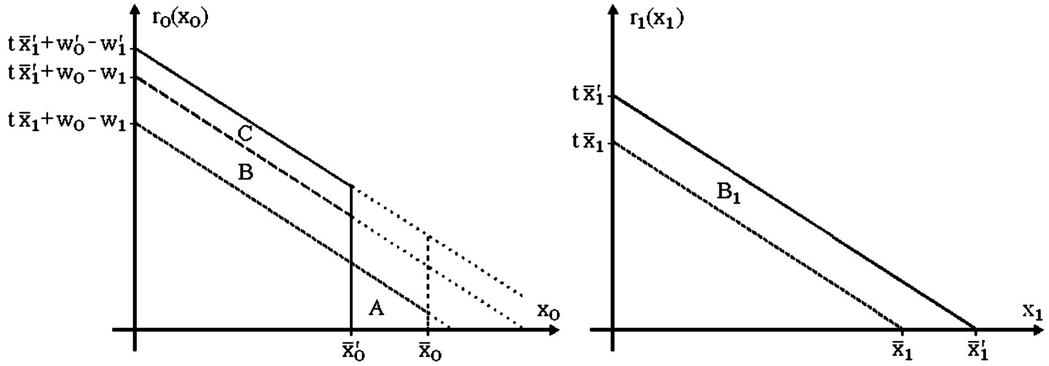


Figure 2 - Effects of controls on rents

However, under the possibility of IC, the wage differential between cities cannot grow indefinitely because labor from city 1 will flow in if the differential exceeds the IC cost T. Thus, once it reaches T, the wage differential does not increase further, being constrained by a perfectly elastic supply of intercity commuters from city 1. Once IC occurs, the size of city 0's work force, denoted $\hat{N}_0$, is determined by the following condition, which equates the intercity wage differential to the IC cost:

$$F'(\hat{N}_0) - F'(P - \hat{N}_0) = T. \tag{7}$$

Several conclusions are evident from (7). First, recall that $N_0 = \bar{x}_0$ in the absence of IC, and suppose that $\bar{x}_0 \geq \hat{N}_0$ holds. Then, the intercity wage differential in the absence of IC equals $F'(\bar{x}_0) - F'(P - \bar{x}_0) < T$, given $F'' < 0$, so that no incentive for IC exists. On the other hand, if $\bar{x}_0 < \hat{N}_0$ holds, the intercity wage differential would tend to exceed T, but IC occurs instead, that is, the local work force of $\bar{x}_0$ individuals will be supplemented by $\hat{N}_0 - \bar{x}_0$ intercity commuters to achieve total employment of $\hat{N}_0$. Note that the $\hat{N}_0$ that satisfies (7) must itself satisfies $0 < \hat{N}_0 \le \frac{1}{2}P$, given $F'' < 0$. Thus, the equilibrium size of the labor force in city 0 is

$$N_0 = \begin{cases} \bar{x}_0 & \text{if } \hat{N}_0 \le \bar{x}_0 \le \frac{1}{2}P \\ \hat{N}_0 & \text{if } 0 \le \bar{x}_0 < \hat{N}_0. \end{cases} \tag{8}$$

Furthermore, note that $\hat{N}_0$ is solely determined by T. In particular,

$$\frac{d\hat{N}_0}{d\Gamma} = t\frac{d\hat{N}_0}{dT} = t\frac{1}{F''(\hat{N}_0) + F''(P - \hat{N}_0)} < 0, \tag{9}$$

meaning that the shorter is the relative IC distance, the larger is the size of the labor force of city 0 at which IC commences.

Now, turn back to the landowners' problem in city 0. Their objective is to maximize total land rent (2) subject to the rent function (6), which depends on the labor supply function (8). Thus, the problem can be written as

$$\underset{0 \le \bar{x}_0 \le \frac{1}{2}P}{Max} \; R_0(\bar{x}_0) = \int_0^{\bar{x}_0} \left[t\left(P - \bar{x}_0 - x_0\right) + F'(N_0) - F'(P - N_0)\right] dx_0$$

$$s.t. \; (8) \tag{10}$$

or, substituting (8) in the objective function,

$$\underset{0 \le \bar{x}_0 \le \frac{1}{2}P}{Max} \; R_0(\bar{x}_0) =$$

$$\begin{cases} \int_0^{\bar{x}_0} \left[t\left(P - \bar{x}_0 - x_0\right) + F'(\bar{x}_0) - F'(P - \bar{x}_0)\right] dx_0 & \text{if } \hat{N}_0 \le \bar{x}_0 \le \frac{1}{2}P \\ \int_0^{\bar{x}_0} \left[t\left(P - \bar{x}_0 - x_0\right) + T\right] dx_0 & \text{if } 0 \le \bar{x}_0 < \hat{N}_0, \end{cases} \tag{11}$$

with condition (7) being used in the second expression to replace the intercity wage differential by the IC cost.

Note that if IC were not possible, then $N_0 = \bar{x}_0$ for all $\bar{x}_0$, implying that the first expression of $R_0(\bar{x}_0)$ in (11) would be valid in the entire range $[0, \frac{1}{2}P]$. Comparing the two expressions in (11), the first is always larger in value for $\bar{x}_0 < \hat{N}_0$ because $F'(\bar{x}_0) - F'(P - \bar{x}_0) > T$ in this range of $\bar{x}_0$, as argued before. Therefore, when IC occurs (for $\bar{x}_0 < \hat{N}_0$), a lower valued function $R_0(\bar{x}_0)$ arises compared to the case where IC is not possible.

To characterize the solution of problem (11), denoted $\bar{x}_0^*$, first notice that the objective function is not differentiable at $\bar{x}_0 = \hat{N}_0$ even though it is continuous there. The total derivative of the objective function with respect to $\bar{x}_0$ is then

$$\frac{dR_0(\bar{x}_0)}{d\bar{x}_0} = \begin{cases} \underbrace{t\,(P - 2\bar{x}_0) + F'(\bar{x}_0) - F'(P - \bar{x}_0)}_{A} \underbrace{-t\bar{x}_0}_{B} & \\ \qquad\qquad + \underbrace{\bar{x}_0\,[F''(\bar{x}_0) + F''(P - \bar{x}_0)]}_{C} & \text{if } \hat{N}_0 < \bar{x}_0 < \frac{1}{2}P \\ \underbrace{t\,(P - 2\bar{x}_0) + T}_{A} \underbrace{-t\bar{x}_0}_{B} & \text{if } 0 < \bar{x}_0 < \hat{N}_0, \end{cases} \tag{12}$$

where $A \equiv \frac{\partial R_0(\bar{x}_0)}{\partial \bar{x}_0}$ is the boundary rent effect (the loss of boundary rent when the city size is reduced), $B \equiv \frac{\partial R_0(\bar{x}_0)}{\partial r_0(x_0)} \frac{\partial r_0(x_0)}{\partial \bar{x}_0}$ is the land supply restriction effect (the escalation of interior rents due to the increase in the demand for land in city 1 as the result of lesser land availability in city 0), and $C \equiv \frac{\partial R_0(\bar{x}_0)}{\partial r_0(x_0)} \frac{\partial r_0(x_0)}{\partial N_0} \frac{dN_0}{d\bar{x}_0}$ is the labor supply restriction effect (the escalation of interior rents due to the increase in the intercity wage differential). Note that C is not present when IC occurs. The three effects can be seen in Figure 2, where they are indicated by the respective letters (A, B, and C) for a restriction of city 0's size from $\bar{x}_0$ to $\bar{x}_0'$. In the Figure, note that B comes from the change in $\bar{x}_1$, while C comes from the increase of the wage differential from $(w_0 - w_1)$ to $(w_0' - w_1')$. In city 1, the only effect is B_1, which comes from the change in $\bar{x}_1$.

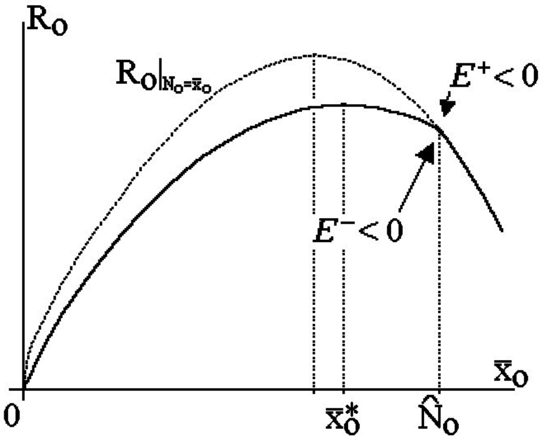
The analysis below assumes that the two expressions in the objective function in (11) are strictly concave in the entire relevant range of $\bar{x}_0$. While the second expression automatically satisfies this condition, the first expression is strictly concave only if

$$3t - 2\left[F''(\bar{x}_0) + F''(P - \bar{x}_0)\right] - \bar{x}_0\left[F'''(\bar{x}_0) - F'''(P - \bar{x}_0)\right] > 0. \tag{13}$$

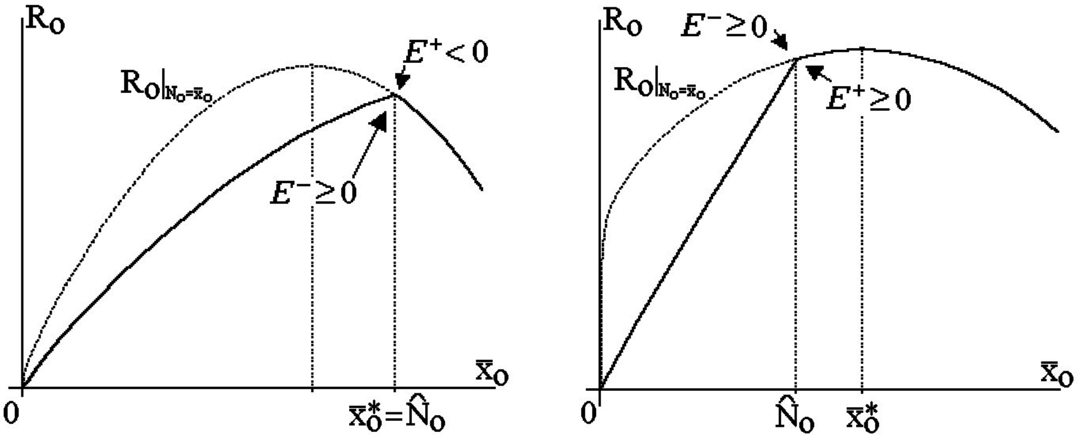
This requirement is satisfied, for instance, when the production function is quadratic ($F(N_i) \equiv \phi N_i - \beta N_i^2$, with $\phi, \beta > 0$) or exponential ($F(N_i) \equiv \psi N_i^{\alpha}$, with $\psi > 0$ and $\alpha \in (0, 1)$).

The concavity assumption allows $R_0(\bar{x}_0)$ to be depicted as one of the three cases in Figure 3. The cases are distinguished by the signs of the slopes of the R_0 curve to the right and to the left of $\hat{N}_0$ (denoted E^- and E^+, respectively). The combination of $E^- < 0$ and $E^+ \geq 0$ is not depicted because it cannot occur in this model, as verified later in the analysis. To show the effect of incorporating IC in the analysis, the Figure also depicts the total land rent that would be reached if IC were not possible (i.e., if $N_0 = \bar{x}_0$ for all $\bar{x}_0$). This is seen as the dotted curve over the range $\bar{x}_0 < \hat{N}_0$. For the range $\bar{x}_0 \geq \hat{N}_0$, IC would not happen anyway, but when $\bar{x}_0 < \hat{N}_0$, the labor supply would equal the population instead of $\hat{N}_0$. Thus, R_0 would be given by the same expression in (11) that applies for $\bar{x}_0 \geq \hat{N}_0$. As mentioned before, IC reduces $R_0(\bar{x}_0)$ when it happens, i.e., the dotted curve lies above the land rent curve that takes IC into consideration.

In terms of equilibrium outcomes, the classification into three cases presented in the Figure reflects two criteria: whether IC happens and whether the incorporation of IC in the analysis affects the adoption of controls. As can be seen in Figure 3.a, IC only occurs (i.e., $\bar{x}_0^* < \hat{N}_0$) when $E^- < 0$. Otherwise, a bigger R_0 can be achieved at a city of size $\hat{N}_0$ or larger. Figure 3.a also shows that the adoption of controls is restrained when IC occurs because the maximum R_0 achievable if IC were not possible (represented by the maximum of the dotted curve) occurs at a value smaller than $\bar{x}_0^*$ (this is formally verified later in the analysis). Restrained controls are also seen in Figure 3.b, even though IC does not happen in equilibrium. In this case, because $E^- \geq 0$ and $E^+ < 0$, controls are restrained to $\bar{x}_0^* = \hat{N}_0$. Note that further restricting the city size is not worthwhile only because IC would occur, keeping the intercity wage differential constant, which eliminates one of the marginal gains from tighter controls. If this gain were still existent, the maximum R_0 (indicated by the maximum of the dotted curve) would be achieved to the left of $\hat{N}_0$. Finally, in case 3.c, where $E^- \geq 0$ and $E^+ \geq 0$, the optimum $\bar{x}_0^*$ is to the right of $\hat{N}_0$, but this is true regardless of the possibility of IC. Therefore, IC has no effect on the adoption of controls in this case.



3.a) IC restrains controls



3.b) No IC, but controls are restrained

3.c) No IC and no effect on controls

Figure 3: Equilibrium city size

The following characterization summarizes what Figure 3 suggests about the equilibrium city size:

$$\begin{cases} \bar{x}_0^* < \hat{N}_0 & \text{if } E^- < 0 \\ \bar{x}_0^* = \hat{N}_0 & \text{if } E^- \geq 0 \text{ and } E^+ < 0 \\ \bar{x}_0^* \geq \hat{N}_0 & \text{if } E^- \geq 0 \text{ and } E^+ \geq 0. \end{cases} \tag{14}$$

Next, the paper answers which of the three cases prevails in equilibrium.

2.3 Characterization of the equilibrium

Recalling that $T = t\Gamma$, the slopes E^- and E^+ derived from (12) can be written as

$$E^- \equiv \frac{dR_0(\hat{N}_0^-)}{d\bar{x}_0} = t\left(P - 3\hat{N}_0 + \Gamma\right) \tag{15}$$

and

$$\begin{aligned} E^+ \equiv \frac{dR_0(\hat{N}_0^+)}{d\bar{x}_0} &= tP - 3t\hat{N}_0 + F'(\hat{N}_0) - F'(P - \hat{N}_0) + \hat{N}_0\left[F''(\hat{N}_0) + F''(P - \hat{N}_0)\right] \\ &= t\left(P - 3\hat{N}_0 + \Gamma\right) + \hat{N}_0\left[F''(\hat{N}_0) + F''(P - \hat{N}_0)\right], \end{aligned} \tag{16}$$

where the second equality in (16) is obtained using condition (7). Because (7) defines $\hat{N}_0$ as an implicit function of the relative IC distance Γ, the signs of E^- and E^+ depend on Γ. Consequently, the equilibrium can be characterized according to the value of Γ.

To see how E^- is related to Γ, first note that (7) implies $\hat{N}_0\Big|_{\Gamma=0} = \frac{1}{2}P$. Thus, (15) yields

$$E^-\big|_{\Gamma=0} = -\frac{1}{2}tP < 0. \tag{17}$$

On the other hand,

$$\frac{dE^-}{d\Gamma} = \frac{\partial E^-}{\partial \Gamma} + \frac{\partial E^-}{\partial \hat{N}_0}\frac{d\hat{N}_0}{d\Gamma} = t - 3t\frac{d\hat{N}_0}{d\Gamma} > 0. \tag{18}$$

Moreover, using the fact that $\hat{N}_0\Big|_{\Gamma\to+\infty} = 0$,

$$E^-\big|_{\Gamma\to+\infty} = +\infty > 0. \tag{19}$$

Hence, (17), (18), and (19) imply that there exists a threshold $\hat{\Gamma} > 0$ such that $E^- < 0$ for $\Gamma < \hat{\Gamma}$ and $E^- \geq 0$ otherwise. This threshold is the implicit solution of $E^- = 0$, i.e.,

$$P - 3\,\hat{N}_0\Big|_{\Gamma=\hat{\Gamma}} + \hat{\Gamma} = 0. \tag{20}$$

Now, turn to E^+. Note that (20) and the second line of (16) imply

$$E^+\big|_{\Gamma=\hat{\Gamma}} = \hat{N}_0\Big|_{\Gamma=\hat{\Gamma}} \left[F''(\hat{N}_0\Big|_{\Gamma=\hat{\Gamma}}) + F''(P - \hat{N}_0\Big|_{\Gamma=\hat{\Gamma}})\right] < 0. \tag{21}$$

On the other hand, using the first line of (16),

$$\frac{dE^+}{d\Gamma} = -\left\{3t - 2\left[F''(\hat{N}_0) + F''(P - \hat{N}_0)\right] - \hat{N}_0\left[F'''(\hat{N}_0) - F'''(P - \hat{N}_0)\right]\right\}\frac{d\hat{N}_0}{d\Gamma} > 0, \tag{22}$$

where the positive sign results from the fact that the term inside the braces is positive due to the strict concavity assumption (13). In addition, (16) implies that

$$E^+\big|_{\Gamma\to+\infty} = +\infty > 0. \tag{23}$$

Hence, together, (21), (22), and (23) imply that there exists a $\bar{\Gamma}$ such that $E^+ < 0$ for $\Gamma < \bar{\Gamma}$ and $E^+ \geq 0$ otherwise. $\bar{\Gamma}$ can be found by setting $E^+ = 0$:

$$t\left(P - 3\,\hat{N}_0\Big|_{\Gamma=\bar{\Gamma}} + \bar{\Gamma}\right) + \hat{N}_0\Big|_{\Gamma=\bar{\Gamma}}\left[F''(\hat{N}_0\Big|_{\Gamma=\bar{\Gamma}}) + F''(P - \hat{N}_0\Big|_{\Gamma=\bar{\Gamma}})\right] = 0. \tag{24}$$

Note that (21) and (22) ensure that $\bar{\Gamma} > \hat{\Gamma}$.

Taken together, (21) and (22) also imply that $E^+ < 0$ for $\Gamma < \hat{\Gamma}$. Since it was established that $E^- < 0$ for such Γs, the combination of $E^- < 0$ and $E^+ \geq 0$ cannot occur in this model, as claimed before.

Next, the equilibrium city size is characterized for each value of Γ.

2.3.1 Choice of controls when $\Gamma < \hat{\Gamma}$

The analysis above showed that $E^- < 0$ when $\Gamma < \hat{\Gamma}$, implying that $\bar{x}_0^* < \hat{N}_0$. Hence, the optimal city size is necessarily an interior solution of the maximization of the second expression of $R_0(\bar{x}_0)$ in (11). Thus, the optimum can be found by setting the corresponding derivative in (12) equal to zero, implying that this optimum balances out the boundary rent loss (A) against only the marginal gain from land supply restriction (B), since the gain from labor supply restriction (C) has vanished in the presence of IC. Solving for the optimum yields

$$\bar{x}_0^* = \frac{1}{3}\left(P + \Gamma\right) = \frac{1}{3}\left(P + \gamma D\right). \tag{25}$$

This optimum implies that controls are restrained (i.e., tighter controls would be adopted if IC were not possible). To verify, it is sufficient to show that $\frac{dR_0(\bar{x}_0^*)\big|_{N_0=\bar{x}_0}}{d\bar{x}_0} < 0$, i.e., the slope of the R_0 curve for the case where IC is not possible is negative at $\bar{x}_0^*$, meaning that the maximum of that curve is achieved at a value below $\bar{x}_0^*$. The Appendix presents the verification of this inequality, assuming that $F''(N_i)$ is a monotone function. The proof also uses the fact that (25) implies $\bar{x}_0^* \geq \frac{1}{3}P$ for all Γ.

There are interesting conclusions that follow from the result in (25). First, $\frac{d\bar{x}_0^*}{d\Gamma} = \frac{1}{3} > 0$, i.e., the bigger the relative IC distance, the larger is the city population. This may not seem intuitive at first, but note that the intercity wage differential equals $T = t\Gamma$ when IC happens and the wage differential is one of the components of rents. Thus, the higher is Γ, the bigger is the boundary rent loss of tightening controls, resulting in looser controls (and thus larger city size) in equilibrium. Second, because $\frac{d\hat{N}_0}{d\Gamma} < 0$, the first conclusion implies that $\frac{d(\hat{N}_0 - \bar{x}_0^*)}{d\Gamma} < 0$, i.e., the bigger is the relative IC distance, the smaller is the number of intercity commuters. Third, when $\Gamma = 0$, the optimum becomes $\bar{x}_0^* = \frac{1}{3}P$, mimicking the result of the case where production exhibits constant returns to scale.[6] This happens because when the IC distance (or cost) is zero, the supply of labor becomes constant (condition (7) implies that $N_0 = \frac{1}{2}P$ regardless of the size of the population), keeping $F'(N_i)$ constant.

2.3.2 Choice of controls when $\Gamma \geq \hat{\Gamma}$

As argued before, $E^- \geq 0$ when $\Gamma \geq \hat{\Gamma}$, implying that $\bar{x}_0^* \geq \hat{N}_0$.

Consider first the subcase where $\hat{\Gamma} \leq \Gamma < \bar{\Gamma}$. Since then $E^+ < 0$, the optimum is $\bar{x}_0^* = \hat{N}_0$. Because $\frac{d\hat{N}_0}{d\Gamma} < 0$, the equilibrium city size decreases with the relative IC distance in this range of Γ. Intuitively, the bigger is Γ, the tighter are the controls that can be adopted without making IC attractive, i.e., without making the intercity wage differential large enough to cover the IC cost.

Now, consider the other subcase, where $\Gamma \geq \bar{\Gamma}$. Here, $E^+ \geq 0$, meaning that the optimum is an interior solution to problem (11), with the first expression of $R_0(\bar{x}_0)$ being relevant. Therefore, the optimum can be found by setting the corresponding derivative in (12) equal to zero:

$$tP - 3t\bar{x}_0^* + F'(\bar{x}_0^*) - F'(P - \bar{x}_0^*) + \bar{x}_0^* \left[F''(\bar{x}_0^*) + F''(P - \bar{x}_0^*)\right] = 0. \tag{26}$$

Note that in this case the optimum balances out the boundary rent loss (A) against the sum of the two marginal gains ($B + C$) of tightening controls. Moreover, since C continues to exist at the equilibrium, IC has no effect on the choice of controls. Another way to reach this conclusion is to note that $\bar{x}_0^*$ does not depend on Γ (but only on the intracity commuting cost t). Thus, $\bar{x}_0^*$ is constant for $\Gamma \geq \bar{\Gamma}$ at the same value that would be chosen if IC were not possible. In addition, it can be shown that this value is smaller than $\frac{1}{3}P$ (the demonstration is a special case of the proof in the Appendix), proving that IC restrains controls because, according to (25), when IC occurs, $\bar{x}_0^* \geq \frac{1}{3}P$.

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[6] This is the usual case studied in the literature. To verify that the solution in this case is $(1/3)P$, set $F'' = 0$ in the maximization problem (10).

2.3.3 Summary of results

According to the analysis above, the equilibrium in terms of the city size is characterized as

$$\bar{x}_0^* = \begin{cases} \frac{1}{3}(P+\Gamma) & \text{if } \Gamma < \hat{\Gamma} \\ \hat{N}_0 & \text{if } \hat{\Gamma} \leq \Gamma < \bar{\Gamma} \\ \text{the implicit solution of (26)} & \text{if } \Gamma \geq \bar{\Gamma}. \end{cases} \tag{27}$$

This and the other results of the model can be summarized in the following proposition.

Proposition 1 *(i) Intercity commuting (IC) only emerges when the relative IC distance* Γ *is such that* $\Gamma < \hat{\Gamma}$. *In this case, IC restrains the adoption of controls to* $\bar{x}_0^* = \frac{1}{3}(P+\Gamma)$. *Moreover, the number of workers commuting from city* 1 $(\hat{N}_0 - \bar{x}_0^*)$ *decreases with* Γ.
(ii) When Γ *satisfies* $\hat{\Gamma} \leq \Gamma < \bar{\Gamma}$, *IC does not occur, but the adoption of controls is restrained to* $\hat{N}_0$.
(iii) When $\Gamma \geq \bar{\Gamma}$, *the possibility of IC does not affect the adoption of controls. The equilibrium city size is the* $\bar{x}_0^*$ *that solves equation (26), being smaller than* $\frac{1}{3}P$.

To illustrate the results, Figure 4 graphs the equilibrium city size for each Γ, keeping other parameters of the economy fixed. For $\Gamma < \hat{\Gamma}$, IC occurs and $\bar{x}_0^*$ is increasing in Γ. For $\hat{\Gamma} \leq \Gamma < \bar{\Gamma}$, $\bar{x}_0^*$ equals $\hat{N}_0$ and is decreasing in Γ. Finally, for $\Gamma \geq \bar{\Gamma}$, $\bar{x}_0^*$ is not affected by IC, becoming constant at the value that would be chosen if IC were not possible. Note that the horizontal line drawn at this $\bar{x}_0^*$ value lies below the solid curve in the Figure, showing that the possibility of IC restrains the adoption of controls when $\Gamma < \bar{\Gamma}$.

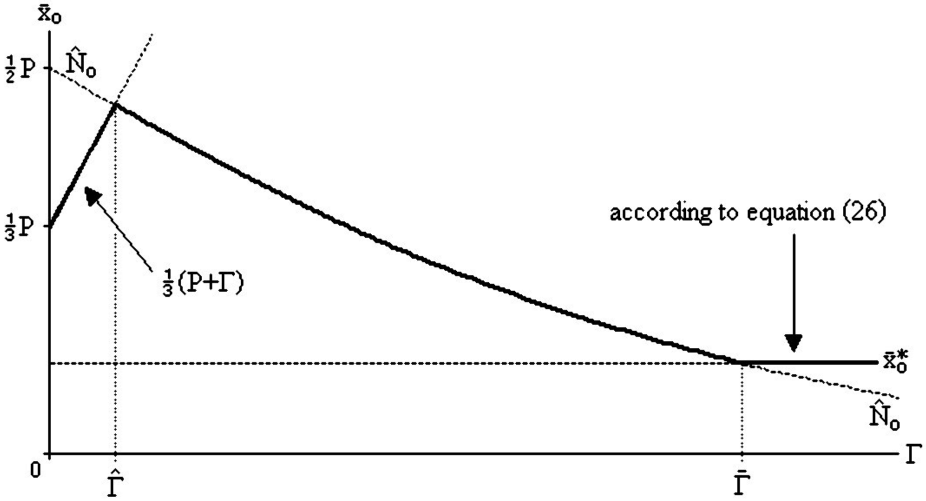

Figure 4 - Equilibrium city size $\bar{x}_0^*$ as a function of the relative IC distance Γ

2.4 Example: a quadratic production function

To make the analysis clearer, this example assumes a quadratic production function, which allows an explicit characterization of the equilibrium. As mentioned before, the quadratic function also guarantees that the concavity condition (13) is satisfied.

Assume $F(N_i) = \phi N_i - \beta N_i^2$, $i = 0, 1$, with ϕ, $\beta > 0$, and $\phi > 2\beta P$. Also, normalize $t = 1$, to simplify. Since $F'(N_i) = \phi - 2\beta N_i$, the rent function in city 0, given by (6), becomes

$$r_0(x_0) = P - \bar{x}_0 - x_0 + 2\beta\left(P - 2N_0\right). \tag{28}$$

Then, using the labor supply function (8),

$$\frac{dR(\bar{x}_0)}{d\bar{x}_0} = \begin{cases} \underbrace{P - 2\bar{x}_0 + 2\beta\left(P - 2\bar{x}_0\right)}_{A}\underbrace{-\bar{x}_0}_{B}\underbrace{-4\beta\bar{x}_0}_{C} & \text{if } \hat{N}_0 < \bar{x}_0 < \frac{1}{2}P \\ \underbrace{P - 2\bar{x}_0 + \Gamma}_{A}\underbrace{-\bar{x}_0}_{B} & \text{if } 0 < \bar{x}_0 < \hat{N}_0, \end{cases} \tag{29}$$

where $\hat{N}_0$ is obtained from the indifference condition (7):

$$\hat{N}_0 = \frac{1}{2}P - \frac{1}{4\beta}\Gamma. \tag{30}$$

Whether IC occurs in equilibrium depends on the sign of E^-. From (15),

$$E^- = -\frac{1}{2}P + \frac{3+4\beta}{4\beta}\Gamma. \tag{31}$$

If $E^- < 0$, then $\bar{x}_0^* < \hat{N}_0$. In terms of Γ, a negative E^- is equivalent to

$$\Gamma < \frac{2\beta}{3+4\beta}P. \tag{32}$$

Thus, in this range of Γ, the equilibrium city size, from (25), equals

$$\bar{x}_0^* = \frac{1}{3}\left(P + \Gamma\right), \tag{33}$$

which is increasing in Γ. Now, consider the case where $E^- \geq 0$. If in addition $E^+ < 0$, then the solution of the problem is the corner $\hat{N}_0$. From (16),

$$E^+ = -\frac{1+4\beta}{2}P + \frac{3+8\beta}{4\beta}\Gamma. \tag{34}$$

Thus, in terms of Γ, the condition $E^+ < 0$ is equivalent to

$$\Gamma < 2\beta\left(\frac{1+4\beta}{3+8\beta}\right)P. \tag{35}$$

Hence, if $\frac{2\beta}{3+4\beta}P \leq \Gamma < 2\beta\left(\frac{1+4\beta}{3+8\beta}\right)P$, the optimum is $\bar{x}_0^* = \hat{N}_0$, which is decreasing in Γ. On the contrary, if $\Gamma \geq 2\beta\left(\frac{1+4\beta}{3+8\beta}\right)P$, the solution is interior, satisfying equation (26), i.e.,

$$\bar{x}_0^* = \frac{1+2\beta}{3+8\beta}P. \tag{36}$$

Because this optimum is derived using the expression of $R_0(\bar{x}_0)$ that does not consider IC, this $\bar{x}_0^*$ would also be the solution if IC were not possible. Indeed, $\bar{x}_0^*$ does not depend on Γ, suggesting that IC has no effect on controls.

Summarizing the results, the equilibrium city size is characterized as

$$\bar{x}_0^* = \begin{cases} \frac{1}{3}(P+\Gamma) & \text{if } \Gamma < \frac{2\beta}{3+4\beta}P \\ \hat{N}_0 = \frac{1}{2}P - \frac{1}{4\beta}\Gamma & \text{if } \frac{2\beta}{3+4\beta}P \leq \Gamma < 2\beta\left(\frac{1+4\beta}{3+8\beta}\right)P \\ \frac{1+2\beta}{3+8\beta}P & \text{if } \Gamma \geq 2\beta\left(\frac{1+4\beta}{3+8\beta}\right)P. \end{cases} \tag{37}$$

Since $\frac{1+2\beta}{3+8\beta}P < \frac{1}{3}P$ and $\hat{N}_0$ is decreasing in Γ, $\bar{x}_0^*$ is bigger when IC affects controls (for $\Gamma < 2\beta\left(\frac{1+4\beta}{3+8\beta}\right)P$) than when it has no effect.

3 Effects of controls on each class of agents

In the model presented above, growth controls were adopted to benefit landowners in city 0. How are the other agents affected?

Owners of firms in city 0 will oppose growth controls for $\bar{x}_0 > \hat{N}_0$ (where labor supply is $N_0 = \bar{x}_0$) because equilibrium profits given by (4) decrease:

$$\frac{d\Pi_0}{d\bar{x}_0} = -\bar{x}_0 F''(\bar{x}_0) > 0. \tag{38}$$

Controls also hurt workers because their utilities decrease. Since utility is equalized everywhere, it is easier to study the effect of controls on the sum of renters' utilities. Then, using (1), total utility, $U \equiv \sum_{i=0}^{1}\int_0^{\bar{x}_i} u_{i,j}(x_i)dx_i$, can be written as total wage minus total commuting cost minus total rent:

$$U = \sum_{i=0}^{1} N_i F'(N_i) - \left[\sum_{i=0}^{1}\frac{1}{2}t\bar{x}_i^2 + \left(\hat{N}_0 - \bar{x}_0\right)T\left(1 - \frac{dN_0}{d\bar{x}_0}\right)\right] - \sum_{i=0}^{1} R_i(\bar{x}_i), \tag{39}$$

where N_i is given by (8) and, accordingly, $\frac{dN_0}{d\bar{x}_0} = 1$ if $\bar{x}_0 \geq \hat{N}_0$ (no IC), but 0 otherwise.

Thus,

$$\frac{dU}{d\bar{x}_0} = -PF''(P-\bar{x}_0)\frac{dN_0}{d\bar{x}_0} + tP > 0 \quad \text{for } 0 < \bar{x}_0 < \frac{1}{2}P, \tag{40}$$

implying that utility is maximized at $\bar{x}_i = N_i = \frac{1}{2}P$. Hence, any change away from the symmetric outcome reduces workers' utility.

Therefore, only landowners gain with controls,[7] implying that there is a conflict of interests between agents in city 0.

The conflict is, however, reduced if some of the classes of agents are merged. For example, it may be plausible to assume that landowners also own the firms in the same city. In that case, their objective function must incorporate firms' profits, becoming $H_0(\bar{x}_0) \equiv R_0(\bar{x}_0) + \Pi_0(N_0)$, where the second term represents the equilibrium profits as a function of N_0 according to (4), and N_0 is given by (8).[8]

Thus, the derivative of the objective function with respect to the city size is

$$\frac{dH_0(\bar{x}_0)}{d\bar{x}_0} = \begin{cases} \frac{dR_0(\bar{x}_0)}{d\bar{x}_0} - \bar{x}_0 F''(\bar{x}_0) & \text{if } \hat{N}_0 < \bar{x}_0 < \frac{1}{2}P \\ \frac{dR_0(\bar{x}_0)}{d\bar{x}_0} & \text{if } 0 < \bar{x}_0 < \hat{N}_0, \end{cases} \tag{41}$$

where $\frac{dR_0(\bar{x}_0)}{d\bar{x}_0}$ is given by (12).

Since the second expression of the derivative in (41) is the same as in the basic model, there is no change in the analysis when IC occurs. Even the value of the threshold $\hat{\Gamma}$ is not affected, with IC occurring in equilibrium when $\Gamma < \hat{\Gamma}$.

However, when IC does not occur, there is a new term in the derivative of the objective function: $-\bar{x}_0 F''(\bar{x}_0)$, which represents the negative effect of controls on profits. Thus, the intensity of desired controls is reduced[9] when profits are also considered in the objective

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[7] In city 1, landowners benefit from controls in city 0 because rents are increased in the whole economy (total land rent in city 1 is $R_1(\bar{x}_1) = \int_0^{\bar{x}_1} t(\bar{x}_1 - x_1)\,dx_1$, implying $dR_1(\bar{x}_1)/d\bar{x}_0 = -t\bar{x}_1 < 0$). Owners of firms in city 1 also benefit because labor supply expands there when $\bar{x}_0 > \hat{N}_0$, increasing profits ($d\Pi_1/d\bar{x}_0 = \bar{x}_1 F''(\bar{x}_1) < 0$).

[8] Alternatively, such objective function can represent the case where firm-owners form a separate group, but also have political influence along with landowners. A growth control model with such objective function was studied by Sasaki [10].

[9] This conclusion is true if $H_0(\bar{x}_0)|_{N_0=\bar{x}_0}$ is strictly concave for all relevant values of $\bar{x}_0$. This requires

function. Intuitively, there is less incentive to reduce $\bar{x}_0$ because of the concern that profits are reduced. In consequence, a smaller threshold $\bar{\Gamma}'$ replaces $\bar{\Gamma}$ compared to the basic model. To verify this implication, note that the new $\bar{\Gamma}'$ is the implicit solution of

$$\left.\frac{dH_0(\hat{N}_0^+)}{d\bar{x}_0}\right|_{\Gamma=\bar{\Gamma}'} = \left.\frac{dR_0(\hat{N}_0^+)}{d\bar{x}_0}\right|_{\Gamma=\bar{\Gamma}'} - \left.\hat{N}_0^+\right|_{\Gamma=\bar{\Gamma}'} F''(\left.\hat{N}_0^+\right|_{\Gamma=\bar{\Gamma}'}) = 0. \tag{42}$$

Then, evaluate this derivative at $\bar{\Gamma}$ instead of at $\bar{\Gamma}'$, recalling that $\left.\frac{dR_0(\hat{N}_0^+)}{d\bar{x}_0}\right|_{\Gamma=\bar{\Gamma}} = 0$ from (24). Thus, because $-N_0F''(N_0) > 0$ for all N_0, it can be concluded that $\left.\frac{dH_0(\hat{N}_0^+)}{d\bar{x}_0}\right|_{\Gamma=\bar{\Gamma}} > 0$. Since $\frac{d}{d\Gamma}\left[\frac{dH_0(\hat{N}_0^+)}{d\bar{x}_0}\right] > 0$,[10] $\bar{\Gamma}'$ must be smaller than $\bar{\Gamma}$. In addition, the inequality between thresholds, $\bar{\Gamma}' > \hat{\Gamma}$, can be verified in the same way used to show that $\bar{\Gamma} > \hat{\Gamma}$ in the basic model.

Therefore, if $\hat{\Gamma} \leq \Gamma < \bar{\Gamma}'$, then $\bar{x}_0^* = \hat{N}_0$. But if $\Gamma \geq \bar{\Gamma}'$, the optimum is the interior solution to the maximization of $H_0(\bar{x}_0)|_{N_0=\bar{x}_0}$, which can be obtained by setting the first expression of the derivative in (41) equal to zero. As anticipated, this optimum will be larger than in the basic model because of the negative effect of controls on profits. Indeed, it can be shown that the new optimum is greater than $\frac{1}{3}P$ if $F'''(N_i) > 0$ (the demonstration uses an argument analogous to the proof in the Appendix), which agrees with the result found by Sasaki [10] in a similar model without intercity commuting.

The results of this extension are depicted in Figure 5. Compared to the basic model, controls are looser for $\Gamma \geq \bar{\Gamma}'$. Note that now, when Γ is very small, the bold curve (representing the equilibrium city size) lies below the horizontal line (which is the desired extent of controls when IC is not possible), meaning that controls are more stringent than in the case where IC does not occur. This happens because, at a small Γ, the occurrence of IC keeps the labor supply constant. Consequently, the concern that controls reduce profits disappears, inducing tighter controls.

$F''' > 0$ or, more generally, $3t - F''(\bar{x}_0) - 2F''(P - \bar{x}_0) + F'''(P - \bar{x}_0)\bar{x}_0 > 0$.

[10] Note that $d\left[dH_0(\hat{N}_0^+)/d\bar{x}_0\right]/d\Gamma = 3t - F''(\hat{N}_0^+) - 2F''(P - \hat{N}_0^+) + F'''(P - \hat{N}_0^+)\hat{N}_0^+$, which is positive as the result of the concavity of $H_0(\bar{x}_0)|_{N_0=\bar{x}_0}$.

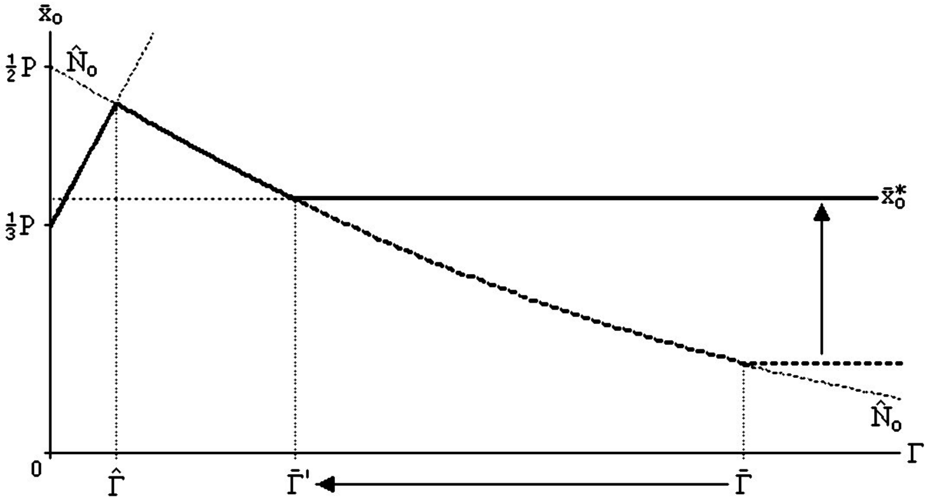

Figure 5 - Change in $\bar{x}_0$ when profits are also taken into consideration

4 Other extensions

Two additional extensions are considered. First, the assumption of absentee landowners is replaced by resident landowners. Second, the case where population or labor force size generates negative externalities (e.g., congestion) is considered.

4.1 Resident landowners

It may seem unrealistic to have absentee individuals influencing public policy. Instead, resident landowners can be incorporated to the population of the cities (as in Brueckner and Lai [4]).

To carry out this modification, the basic model is changed by adding a new population of immobile landowners. Assume that landowners live in the suburbs while renters live closer to the CBD in accordance with the location pattern of rich and poor families in the US. Moreover, landowners share the profits of the firms (it could be because they are the owners or, alternatively, because they are high skilled workers – e.g., managers – who share the profits). Even though landowners also pay rents, the total amount is shared among themselves. Thus, the adoption of controls takes into consideration only rents paid by renters in addition to profits and commuting costs incurred by landowners (assuming that they also need to commute to the CBD). Notice that, because landowners reside in the suburbs, the larger is the population of renters, the greater are the commuting costs incurred by landowners. This gives an additional incentive to restrict the renter population. Therefore, in comparison to the model in Section 3, tighter controls are desirable. Qualitatively, the effects of IC are still the same, i.e., on the one hand IC eliminates the wage differential gain in rents due to controls, restraining controls, but on the other, IC eliminates the loss of profits, stimulating controls.

4.2 Amenity-creation

The basic model did not consider the congestion (or amenity-creation) effects of controls. A simple way to add such effects is to have the consumption of the numeraire good being reduced by a term related to the size of the population. It can be shown that, in the most plausible cases, controls become more desirable because the congestion reduction makes the city more attractive, generating further rent gains and, if landowners are residents, direct benefits for landowners. Hence, the equilibrium city size tends to be smaller, but IC still has the same type of effects on controls.

In contrast, if congestion is generated by the presence of workers, rather than residents, then the restraining effects of IC on controls become stronger. The reason is that, when the labor force size becomes constant in the presence of IC, both the gain from the widening wage differential and the gain from congestion reduction vanish. However, the boundary rent loss of tightening controls is now larger because previous gains from amenity creation have been already capitalized in land rents. Thus, looser controls are preferred compared to the case where labor force size externalities do not exist.

5 Conclusion

The paper shows that the possibility of intercity commuting (IC) affects the intensity of urban growth controls. If only land rents are taken into consideration by the policymaker, growth controls are looser with IC than when IC is not possible. This difference arises because controls reduce labor supply, generating a wage increase that is capitalized in land rents. However, if cities are not too far apart, the resulting intercity wage differential will attract workers from neighboring cities. In this way, IC keeps the city's labor supply constant. With wages no longer affected, the incentive to tighten controls is reduced after IC starts. Consequently, the equilibrium city size is bigger and renters are less hurt by controls.

Section 3, however, analyzed an extension of the model where the choice of controls also considers the effects on firms' profits. Since profits are negatively affected by a labor supply restriction, there is less incentive to adopt controls. However, when IC occurs, profits become unaffected because the labor supply is then kept constant. Thus, the optimal city size in the presence of IC may be smaller than when IC does not occur. Intuitively, after IC starts, policymakers do not have to worry about loss of profits. Thus, they may choose a more stringent control than if IC were not possible.

Two other extensions were considered. First, absentee landowners were replaced by resident landowners (who also share the profits of the firms), but the conclusions are not qualitatively changed. The second extension considered the presence of negative externalities from population or labor force size. Qualitatively, the effects in the basic model remain the same when externalities come from population size. However, the restraining effects of IC on controls are reinforced when externalities are related to the labor force size because the occurrence of IC keeps that size constant, eliminating the amenity gain of tightening controls that existed until then.

Finally, in future work, it may be interesting to study the case where production benefits from agglomeration economies. In this case, production would occur with firm-level constant returns but external increasing returns, making the aggregate production function convex instead of concave. Thus, a reduction in a city's work force due to growth controls would reduce, rather than increase, the wage. Preliminary investigation of this case suggests that new types of equilibria may exist, complicating the analysis. One case with a conclusive solution is when $\Gamma = 0$. Then, since IC is costless, labor supply is concentrated in one of the cities, but population is symmetrically distributed in a market equilibrium. Consequently, the wage in the economy is fixed, regardless of controls. The model thus reduces to the typical case studied in the literature, where income is exogenously given and the only result of controls is the restriction of land supply, with the chosen city size being $\bar{x}_0^* = \frac{1}{3}P$. All cases with positive IC cost have multiple market equilibria, so that the equilibrium with controls depends on the initial population and labor allocations.

Acknowledgement

The author is grateful to Jan K. Brueckner for advice and suggestions, to Jose M. Prado Jr. and Carlos E. Lobo e Silva for discussions, and to seminar participants at the University of Illinois and two anonymous referees for helpful comments. Usual disclaimers apply.

Appendix

This Appendix shows that $\frac{d\,R_0(\bar{x}_0^*)|_{N_0=\bar{x}_0}}{d\bar{x}_0} < 0$ if $F''(N_i)$ is monotone and $\bar{x}_0^* \geq \frac{1}{3}P$.

Proof. From the first expression in (12),

$$\frac{d\,R_0(\bar{x}_0^*)|_{N_0=\bar{x}_0}}{d\bar{x}_0} = t\,(P - 2\bar{x}_0^*) + F'(\bar{x}_0^*) - F'(P - \bar{x}_0^*) - t\bar{x}_0^* + \bar{x}_0^*\left[F''(\bar{x}_0^*) + F''(P - \bar{x}_0^*)\right]. \quad (43)$$

Since the second expression in (12) is zero at $\bar{x}_0^*$, i.e., $t\,(P - 2\bar{x}_0^*) + T - t\bar{x}_0^* = 0$, then (43) can be rewritten as

$$\frac{d\,R_0(\bar{x}_0^*)|_{N_0=\bar{x}_0}}{d\bar{x}_0} = -T + F'(\bar{x}_0^*) - F'(P - \bar{x}_0^*) + \bar{x}_0^*\left[F''(\bar{x}_0^*) + F''(P - \bar{x}_0^*)\right]. \quad (44)$$

To show that this derivative is negative for all Γ, it is sufficient to prove that

$$F'(P-\bar{x}_0^*) - F'(\bar{x}_0^*) > \bar{x}_0^* \left[F''(\bar{x}_0^*) + F''(P-\bar{x}_0^*)\right]. \tag{45}$$

Now, note that the Mean Value Theorem implies that there exists an $a \in (\bar{x}_0^*, P-\bar{x}_0^*)$ such that

$$\frac{F'(P-\bar{x}_0^*) - F'(\bar{x}_0^*)}{P-2\bar{x}_0^*} = F''(a). \tag{46}$$

Also note that if $F''' = 0$, then $F''(a) = F''(\bar{x}_0^*) = F''(P-\bar{x}_0^*)$. Consequently, because $(P-2\bar{x}_0^*) > 0$, (46) implies

$$F'(P-\bar{x}_0^*) - F'(\bar{x}_0^*) > (P-2\bar{x}_0^*) \left[F''(\bar{x}_0^*) + F''(P-\bar{x}_0^*)\right]. \tag{47}$$

This inequality also holds when $F''' > 0$ or when $F''' < 0$ because then $F''(a) > F''(\bar{x}_0^*)$ and $F''(a) > F''(P-\bar{x}_0^*)$, respectively. Therefore, (47) is satisfied when $F''(N_i)$ is monotone. Finally, note that since $\bar{x}_0^* \geq \frac{1}{3}P$, $\bar{x}_0^* \geq (P-2\bar{x}_0^*)$. Recalling that $F'' < 0$, it can be concluded that (47) implies (45), verifying the claim. ■

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