Negotiated Heights: An Agent-Based Model of Density in Residential Patterns

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Introduction

Neo-classical economics has produced theories of land markets that ignored the role of many relevant factors in the production of land use patterns, namely, the role of space, of institutions, the diversity in human behavior and the swift dynamics of land use, which undercuts the importance of equilibrium models of land use. These shortcomings have all been overcome to some extent, but land use models rarely address all of them, and have been especially neglectful of institutions.

Institutions are the "formal or informal", "humanly devised constraints that structure political, economic and social interactions" (North, 1991); "the prescriptions that humans use to organize all forms of repetitive and structured interactions including those within families, neighborhoods, markets, firms, sports leagues, churches, private associations, and governments at all scales" (Ostrom, 2005, p. 3). Institutions have been at the centre of an important debate in land use and real estate market research. It is undeniable that land market interactions do not operate in a vacuum, but are embedded in an institutional framework, and are affected significantly by it. The market itself is an institution, as are the rules that comprise the spatial planning system. The recognition of the central role of institutions has spurred the development of many institutional accounts of land use change. New institutional economics formalizes the role of institutions as imposing costs on the market transactions that neoclassical economics assumed costless. Williamson (1981) pioneered the transaction costs approach to institutions, which was fruitful but did not make its way to urban land use models.

New institutional economics tends to treat the institutional setting as imposing constraints on the actions of rational agents. These constraints are usually treated as bulky and impervious. Actors act rationally and try to maximize utility, but within the limits set by institutions (Needham et al., 2011). Similarly, land use plans and regulations are sometimes conceived of too simplistically as maps of future land use patterns, as if planning could guarantee the fulfillment of the planned goals. Hopkins (2001) warns that people tend to either "think of plans as all-controlling, comprehensive solutions or all-controlling disruptions of individual decision-making", when in fact they do not have to be nor comprehensive nor authoritative. If a land use plan designates land for agriculture, that does not mean that the land will not be used for housing in the future, for it is relatively easy to change the plan or to give exemption from it (Needham, 2011). In reality, the planner can exert a certain level of freedom of choice when it comes to granting building permits to projects.

Schaeffer and Hopkins (1987) point out that projects may be transformed in the process of obtaining approval from the planning authorities. They point out: "If the project stays within the current constraints set by zoning regulations and building codes, the approval should be obtained easily. The [developer] may, however, want to apply for a zoning change, for a variation of other existing regulations, or for other changes in the rights and obligations attached to the land (...) It may be necessary to compromise with the regulatory agencies. In the process of negotiation that may precede approval, the final shape of the project will be determined".

These insights suggest that the relationship between the planning system and the market is not as simple as the planning system imposing constraints on the actions of an otherwise free market, but is more fluid and negotiated. In addition, approval time is an important variable. Long permit approval times affect developers' decisions because they imply a delay to realize profits, during which the money invested in the project is "stalled" and thus unproductive. Furthermore, the final form of the development (the density or building height) is affected by negotiation during the permit application period. The model we develop addresses the effects of negotiation over development densities on urban development patterns, by comparing a scenario where negotiation in project approval is possible to a strict regulation and a free market scenarios.

We develop a model of urban dynamics to explore the urban patterns resulting from a negotiated approach to urban planning. We use the

(Alonso-Muth-Mills) monocentric city model as a starting point. Households search for a residential location that maximizes their utility, subject to a budget constraint. We improve on previous land use models by allowing for vertical development, and therefore, for multiple households to locate in one cell. We compare a scenario where negotiation about the density of developments is possible to a scenario where density is pre-set by an urban plan (strict regulation) and a scenario where the density is decided by the market. The model presented is intended to investigate the effects of these different types of interactions between the planning system and the market, rather than to provide realistic simulations of residential development patterns. Consequently, it is kept as simple as possible in what concerns the outcomes it produces. Residential development patterns are characterized by the location and density of development at each location. The paper is organized as follows. In Section 2, we briefly discuss the literature on urban land use models. In Section 3, we present the model and in Section 4 we present and discuss the results.

1. Literature review

Land use models

The history of land use modeling is deeply rooted in Von Thunen's agricultural land rent theory (1826), which prescribed the optimum spatial distribution of agricultural crops around a central market area. Von Thunen's theory was developed in an urban context by Alonso (1964). Refinements to Alonso's model gave rise to the Alonso-Mills-Muth monocentric city model, which became a recurrent starting point for urban economic analysis. The model assumes a monocentric city with a point sized central business district (CBD) where households commute to for work. Each household spends its total income on housing, commuting costs and a bundle of all other commodities. Both transport costs and the price of land depend on distance from the city centre. The household's residential location choice entails a trade-off between the cost of housing and the cost of commuting. The central concept of Alonso's urban land market theory is the bid-rent function, defined as the "maximum rent that can be paid for a unit of land at some distance from the city centre if the household is to maintain a given level of utility". Alonso assumes a competitive land market where households bid for land. While Alonso assumed a fixed city size, Muth relaxed this assumption and allowed the city to extend as far as necessary for the demand for land to equal the supply. Mills (1972) analyzed also the location of employment, relaxing the assumption of location of all employment at the CBD. In Mills' model, commodity production competes with transportation for land.

The new economic geography (Krugman) took an innovative approach by making the geographical distributions of population, demand, and supply endogenous. In these models, spatial structure emerges from the rational location decisions of individual agents (households, firms), which in turn are affected by the spatial distribution of firms, markets and labor. In addition, the role of market-size effects, agglomeration economies and thick labor markets becomes clear as driving forces for city growth. Thus, While the monocentric city model postulates the existence of a CBD, in the new economic geography the creation of new centers is endogenous. The seminal Fujita and Ogawa (Ogawa and Fujita 1980; Fujita and Ogawa 1982) papers presented a model of urban development where, depending on parameter specification, none, one or multiple centers could emerge.

However, when dealing with residential patterns the canonical monocentric city model remains the starting point in many models of residential patterns. Customary refinements of the basic model include the introduction of income heterogeneity, taste heterogeneity, and of externalities and constraints in the use of land (congestion, zoning, segregation, fiscal jurisdictions) (Capello and Nijkamp 2004) as determinants of location choice. A few authors have developed variations on the Alonso-Muth-Mills and the Fujita-Ogawa models in cellular automata (CA) and ABM environments. CA and ABMs are particularly useful to model neighborhood effects and heterogeneity of space and agent tastes without having to deal with intractable mathematics. Filatova et al. (2009; 2011) present agent-based models of land markets, first reproducing the structure of the Alonso/Von Thünen model, and then adding to it, to investigate how urban morphology and land rents change are affected by the relative market power of buyers and sellers (Filatova, Parker et al. 2009), or by taxes on land use in a coastal zone (Filatova, Voinov et al. 2011). Caruso et al. (2007; 2009) present a model of residential growth that emphasizes the path-dependency and uses a cellular automata (CA) approach to introduce endogenous neighborhood effects. Households are assumed to trade-off neighborhood density with housing space consumption and commuting costs, giving rise to the emergence of discontinuous spatial patterns. The CHALMS model by Magliocca et al. (2011) simulates the conversion of farmland to housing development over time, by modeling both land and housing markets in a spatially disaggregated way.

Effects of Accessibility on residential patterns

When no neighborhood externalities are considered, and space is isotropic, each location can be differentiated from another only by its distance to the CBD. Households will then choose to be as close as possible to the CBD, so as to minimize commuting costs. This leads to a compact concentric growth around the CBD (Caruso, Peeters et al. 2009). Accessibility is the main driver of location choice in Alonso-Muth-Mills type models. There is no end of accessibility measures, and each measure will reflect some nuance in the concept of accessibility. The simplest measures compute accessibility as inversely proportional to the distance to a destination of interest. In the transport literature, however, the use of negative exponential as a distance weighting functions is widespread. In the original model of Alonso (1964), accessibility enters the utility function directly, not just in the budget constraint. As Filatova et al. (2011) point out, in this way, the disutility of commuting time is represented separately from travel costs.

Effects of Open-space amenities on residential patterns

There is considerable empirical evidence that households value the existence of green areas in the proximity of their houses. This is especially true if green areas are contiguous to the housing location, allowing for a sense of living in open-space, with broad views and close to nature. The effect of preferences for green neighborhoods on residential patterns is the emergence of a discontinuous urban fringe at the edge of the city. Furthermore, Caruso et al. (2009) show that when greenness is more valued, the discontinuous fringe (mixed area) is wider, the speed of expansion of the commuting field increases, and the compact core of the city emerges later (the expansion of the commuting field slows down later). When households consider openness over a larger neighborhood, the commuting field expansion is more rapid, rural interstices are larger, and the local arrangement patterns are more diverse (Caruso, Peeters et al. 2009). However, these results were obtained under quite restrictive assumptions of only one household per cell, and irreversible urban development. In their ABM of residential location, Zellner et al. (Zellner, Riolo et al. 2010) also find that externalities caused by development of neighboring cells induce the dispersal of agents. The effect of zoning in the presence of these externalities is to limit the areas into which households can move, reducing their utility.

Effects of Household Income on residential patterns

Increasing household income or decreasing the cost of commuting leads to increased urban expansion. This suburbanisation effect (Caruso, Peeters et al. 2009) partially explains the growth of the world's cities with the evolution of transport technology, and decreasing commuting costs all throughout the 20^{th} century.

Effects of Agent Heterogeneity on residential patterns

Zellner et al. (2010) have performed several experiments on a model of residential location to study the influence of three factors (preferences regarding density, externalities arising from development, and zoning enforcement) and their interactions on residential patterns in an exurban setting. They find that, when compared to a homogeneous population with a preference for low density development, assuming an heterogeneous population with an average preference for low density development will lead to more compact urban forms. Conversely, when high densities are preferred on average, heterogeneity disperses development, but there are utility gains from allowing more compact forms to emerge. According to Zellner et al. (2010), however, forcing these forms into a monocentric pattern through zoning eliminates utility gains because it does not allow higher densities to concentrate where residents want them.

Effects of Zoning on residential patterns

A vast array of studies on city zoning can be found in the location theory literature. Hamoudi and Risueño (2011) develop a location model to illustrate the effect of zoning on competition. A central planner or regulatory authority is in charge of designing a new city located in a circular space with perimeter one. The circle is divided in two different regions: one neighborhood is zoned commercial while the other is zoned for residential use. The regulator maximizes a welfare function with different weights attached to consumer and firm surpluses. The important interpretation derived from this welfare function relates to the political profile of the public authority. A "social" government or planner will have more incentives to overvalue consumer surplus whereas a "liberal authority" will value the surplus of firms more highly. In between the two types, a center-oriented government will assign similar weights to both firms and consumers. Ligmann-Zielinska et al. (2010) examine the impact of regional-scale top-down urban plans on the local property market. They find that under the simulated planning situation, a potentially acceptable solution for planners and developers involves a relatively high compactness of development, which could satisfy agents' overall disutility.

Developer's behavior and residential patterns

Czamanski et al. (2011; 2012) introduce the concept of characteristic time to explain urban development patterns. Characteristic time represents the "duration of the process of land development, from the purchase of land rights by developers until the realization of income from it" (Czamanski and Roth 2011). In their model, developers face a simultaneous decision about location and development density. Czamanski and Roth (2011) demonstrated that, because the profitability of construction projects is influenced by variations in the time incidence of costs and revenues, despite declining willingness to pay and land gradients with distance from central business districts, profitability can experience local maxima away from urban centers, which can explain the leapfrogging of vertical development, especially in times when interest rates are low or negligible (Czamanski and Roth, 2011). Broitman et al. (2012a, 2012b) explore how differences in characteristic times between neighboring municipalities affect the distribution of heights along a line connecting the two city centers. According to the authors, competition between cities can result in intentional leapfrogging or in scattered development.

Developer's behavior and municipal regulation and administration

According to Czamanski et al. (2012), the construct of characteristic time is helpful in explaining developer's behavior in reaction to a time variable that reflects political or administratively-motivated differences in permit processing. According to the authors, characteristic time may vary in space, and with the intensity of the proposed development (with higher buildings being subject to longer characteristic times) Furthermore, variations in characteristic time may reflect policies, regulations and not the least by the intervention of NGOs and the public in the decision-making process (interaction of an independent planning authority and of others involved in the planning process) or the existence of historic preservation constraints, limited and outdated urban infrastructure, and opposition from neighbors (Broitman et al 2012a, 2012b).

In our model, we make characteristic time an endogenous variable. Characteristic time is operationalized as the sum of permit processing time and construction time. Construction time equals one in any instance, whereas permit processing time will depend on several factors.

- the governance mode (different governance modes entail different administrative procedures, which leads to different approval times)
- the intensity (density) of the proposed development
- the location of the proposed development (indirectly, since the Urban plan prescribes a maximum density allowed for each location)
- opposition from neighbors (in the negotiation scenario)

2. The model

2.1. Environment

The model is set on an m x m discrete square grid. The Central Business District (CBD) consists of a point located at the centre of the grid, at coordinates (0, 0). Each grid cell is taken as the areal unit and represents a plot of land. Each plot can house a varying number of households depending on the density at which it is built.

2.2. Agents

Agents in the model include households, developers and one planner.

Households' residential choice

Each household is represented by a single agent. Households from the "rest-of-the-world" migrate into the city at a given exogenous rate, and search for a place to live. The households' choice of a home location depends on the available rental opportunities at the time of their arrival to the city and on their preferences regarding house location and neighborhood. More specifically, households decide where to live by evaluating and comparing the utility of all available and affordable locations. Households' utility for a particular house depends on]three factors: Accessibility, A, representing preferences for proximity to services and contacts, schools, public transport etc, Environmental, E, representing preferences for open and natural surroundings, and Density, representing the households preferences for high or low density neighborhoods. The households' evaluation of a particular house can be expressed by a Cobb-Douglas utility function:

$$U(A,E,D) = A^{\alpha}E^{\beta}D^{\gamma}$$

Accessibility of a location to the CBD is computed using a negative exponential formula, which is considered by many authors the most suitable approach to modeling accessibility (Bodenmann and Axhausen 2010), and in any case the most often used and most closely tied to travel behavior theory (Handy and Niemeier 1997). The accessibility measure has the following form:

$$A_{ij} = c \times \exp(-\theta.\text{distanceCBD}_{ij})$$

For which ij is the cell for which accessibility is being computed; c is a constant; θ is a distance decay parameter and distanceCBDij is the topographical distance of the cell to the CBD. For chosen parameters, Equation 1 renders values that normalize to a 100 to 0 scale (see Fig. **1**):

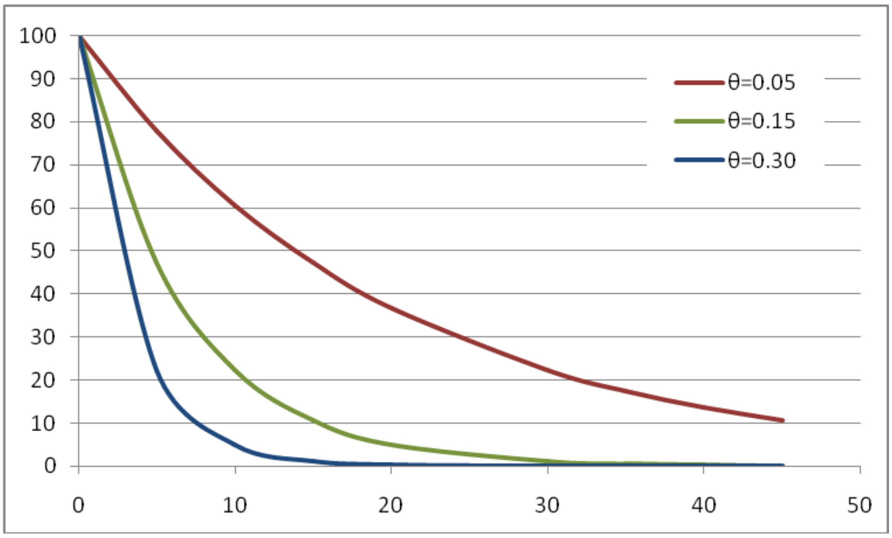

Fig. 1 Accessibility with distance from CBD for c = 100 and θ = 0.30, θ = 0.15 and θ = 0.05.

The presence of nature in the surroundings of a location gives rise to the environmental externality E. This externality is inversely proportional to bij, the number of developed cells in the 8-cell neighborhood of ij. E is a proximity effect that decreases rapidly with distance, reaching no further than the location's immediate neighborhood (i.e., the directly adjacent cells). Eij is therefore a local dispersion force (Caruso, Peeters et al. 2007), contrasting with Accessibility, which is a "global centripetal" force. As in

Caruso et al. (Caruso, Peeters et al. 2007), we assume E to take a negative exponential form.

$$E_{ij} = \exp(-\eta \times b_{ij})$$

Neighborhood density refers to the development density in the cell and the 8 surrounding cells. Households have an ideal value for density, which varies between 1 and 90 and is drawn randomly from a normal distribution. Utility of a location for a household is smaller when the neighborhood density is further away from the household's ideal density. The externality D is a negative exponential of hij, the neighborhood density.

$$D_{ij} = \exp(-\kappa \times d)$$

$$D = \left(100 - \left|id_h - h_{ij}\right|\right)$$

The value of the exponents η and κ determines the shape of the externalities E and D.

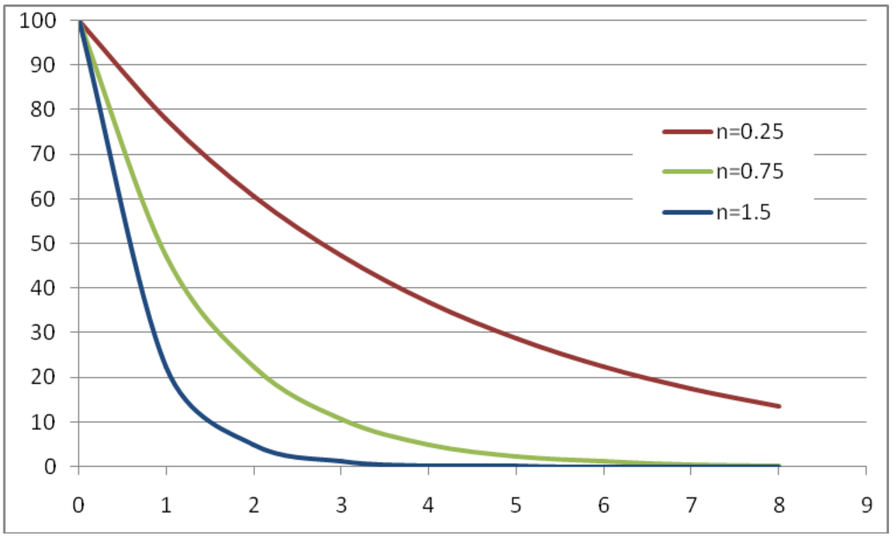

Fig. 2. Environmental externality vs number of developed cells in the neighborhood for various values of the exponent n (the same shapes apply to Density externality vs the difference between neighborhood density and the households ideal density for the same values of exponent k)

Households are heterogeneous in what concerns their preference profile for the location's attributes. Some households attribute more importance to accessibility while others find that the presence of nature or density of development weighs more in their decision. The households' preference profile is the vector of weights [α,β,γ]. Alpha, Beta and Gamma reflect the strength of households' preferences concerning, respectively, Accessibility, Environmental and Picket-fence externalities. The preferences of the households for each factor are assumed to be independent of each other and of income.

When choosing a house, households choose out of the available rental opportunities, the one that maximizes their utility U and is affordable given their budget, net of transport costs. The exponents θ, η and κ are chosen after a sensitivity analysis. Alpha, Beta and Gamma are random parameters controlling for taste heterogeneity and are taken out of a normal distribution.

Developers

A number of developers operate in the city. Their goal is to build houses and sell them at the highest profit, and their program is to find the best locations, assess the potential future revenue that can be obtained from building in a determined location at a certain density, obtain a building permit, set the price and sell the houses. A developer is only free to initiate another process when he has sold at least 60% of the houses in his latest development.

Finding the best locations

Developers have access to limited information about the housing preferences of their potential tenants. In our model, this is translated in the fact that developers only have access to the average preferences of the households that are looking for a house. Also, developers do not evaluate all possible locations for building, but rather probe a large number of randomly chosen locations, from which they select the 3 most promising for further evaluation. For each location they generate a number of alternative projects, with different densities, ranging from 1 to 10. Developers then select the project that offers the best combination of location and density. They do this by estimating and comparing the future value of their profits for each alternative.

Developer’s objective function

Each developer chooses the location and density of development that maximizes their future value of their cash-flow (Czamanski and Roth, 2011). Equation 1 assumes the developer has two costs: the the initial investment I (Equation 2), which is essentially the cost of purchasing the land, and “overnight costs” c that represent all the other multi period costs, such as building costs. The cost of the land, *land*, depends on its accessibility and the quality of its surroundings. Because this investment has to be made in a time well before the realization of income from the project, it is penalized by interest rate r for the number of years that separate investment from revenue realization. This time is the Characteristic time τ, and includes construction time plus approval time. Approval time varies according to location and scenario.

$$\max_{x,h} FV(t=\tau) = -I - c(h) + p(x)h \qquad \text{Equation 1}$$

$$I = land(x,h)(1+r)^{\tau} \qquad \text{Equation 2}$$

The "overnight costs" are a function of the building's height c(h). Developers are heterogeneous in their technology, meaning each developer has a different cost function. However, there is always some scale economy to building denser developments.

$$c(h) = a + b \times h$$

The developers' estimate of the revenue from selling the houses depends on the price at which he can sell each house and the number of houses per plot. The developer chooses the project that maximizes the future value estimated with equation 1. He then submits the project to the planning authorities for approval.

Planner

The planner's job is to decide whether to grant building permits to projects submitted for approval by the developer. In the **strict regulation** scenario, the planner strictly follows the maximum density prescriptions provided in the Urban Plan. He grants building permits to projects if and only if the density proposed by the developer is the same or below the maximum density prescribed by the plan for the plot. In the **free-market** scenario, the planner always grants the building permit to the developer. In the **negotiation** scenario, planner and developer can negotiate of each particular development. As a result of negotiation, the project approved can have a very different density from the initially proposed. Negotiation can also fail and no project is approved as a result.

2.3. Scenarios

Strict regulation scenario

The planner's job is to decide whether to grant building permits to projects submitted for approval by the developer. In this scenario, the planner strictly follows the maximum density prescriptions in the Urban Plan. The Urban Plan sets the maximum permitted development densities for each urban area. For simplicity, and following roughly the same approach as Zellner et al. (2010), the Urban Plan defines three concentric zones. The three zones are defined by two circles of radius 10 and 20 cells. The maximum density allowed by the plan is highest near the CBD, inside the inner circle of radius 10. In the periphery, beyond the outer circle of radius 20, only single-household developments are allowed.

	maximum density prescribed by the Urban Plan
distance to CBD <= 10	10 households per cell
distance to CBD <= 20	5 households per cell
distance to CBD > 20	1 households per cell

Table 1. Urban Plan

The planner grants building permits to projects if and only if the density proposed by the developer is the same or below the maximum density prescribed by the plan for the plot. The approval time amounts to one if the project's proposed density is equal or below the maximum density for the location, and equals ∞ (the project is never approved) if the proposed density is higher than the Plan.

In the free-market scenario

In the free market scenario, the planner always grants the building permit to the developer and the approval time is always equal to one.

Negotiation

In the negotiation scenario, when the developer submits a project for approval by the planner, the two parties start a negotiation process about the density of the development. In the negotiation, the developer's goal is to get density h_d approved, which is the density of the original project submitted (the one that maximizes his future profits). The planner's goal is to keep existing local residents as happy as possible, and thus he monitors the changes to the utility of neighbors that would result from building the development. The negotiation process is conservative, in the sense that it evolves from lower to higher densities, only if at each density increase there is no opposition from existing local populations. The first proposal on the negotiation table is equivalent to the height of the highest building in the neighborhood (h_{neigh}). If the planner agrees, the negotiation advances to the next round, where the developer proposes to build one more floor in relation to the previous round (h_n + 1). The negotiation process ends when $h_n = h_d$, or when it reaches a stand off, where the planner does not agree to raise the height any further. In this case, the developer evaluates if it is still profitable to build at the last negotiated density h_n, lower than the original density h_d.

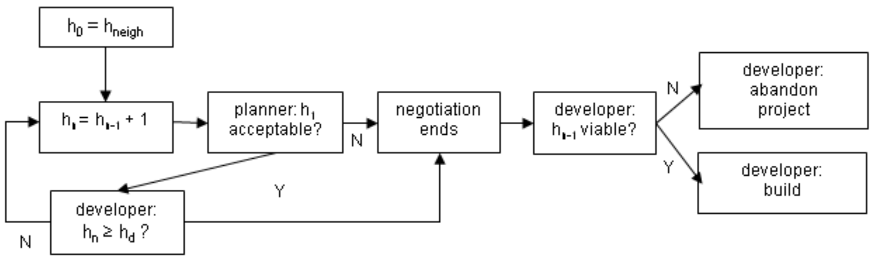

Fig 3. Negotiation process. (h_d is the development density of the original project, h_n is the development density being negotiated in round n, h_{max} is de maximum density permitted by the plan)

Only one negotiation round takes place per time step. Therefore, the negotiation process can span through several time steps, as many as necessary until the loop reaches an exit condition. In principle, the negotiation takes longer when the difference between the density proposed by the developer (h_d) and the maximum density allowed by the Urban Plan (h_{max}) is greater. The approval time in the case of the negotiation scenario is equal to the negotiation time. A significant difference between this scenario and the other scenarios is that the project can be transformed as a result of the approval process.

2.4. Dynamics

The model is run for 200 time steps. At each time step, a number of new households enter the model, evaluate all available (empty) houses for their utility constrained to their budget and choose to locate at the house that maximizes their utility. A household that fails to find a house that renders positive utility and is affordable given the budget leaves the model. Households that find a house stay there for the remainder of the model run. In addition, at each time step, idle developers are called upon to choose a location and submit a project. Developers which are in the middle of a negotiation process resume the negotiation, and developers who have just finished building have to sell at least 60% of their last development before they are able to move on to the next project.

3. Results and conclusions

Simulations were run for the three governance scenarios and for several values of average ideal density of the population. Because of the randomness built in the model, the results of any one run are always different. However, the macroscopic patterns are very similar for any run of the model using the same parameters, but differ visibly from the macro-patterns produced in other scenarios and even for different values of average ideal density of the population. The residential patterns produced are always very close to circular, given the importance of accessibility, which decreases from the center outwards.

Because of the open-city assumption, population size varies considerably between scenarios. The strict regulation scenario produces considerably smaller cities (in any measure including population, city radius and number of buildings) than the free market and negotiation scenarios. This is possibly due to the fact that developers do not find it profitable to build buildings whose poor accessibility is not compensated by the scale economies of more dense developments. In addition, cities grow much larger in the presence of a population with average preferences for medium densities than with preferences for more extreme densities.

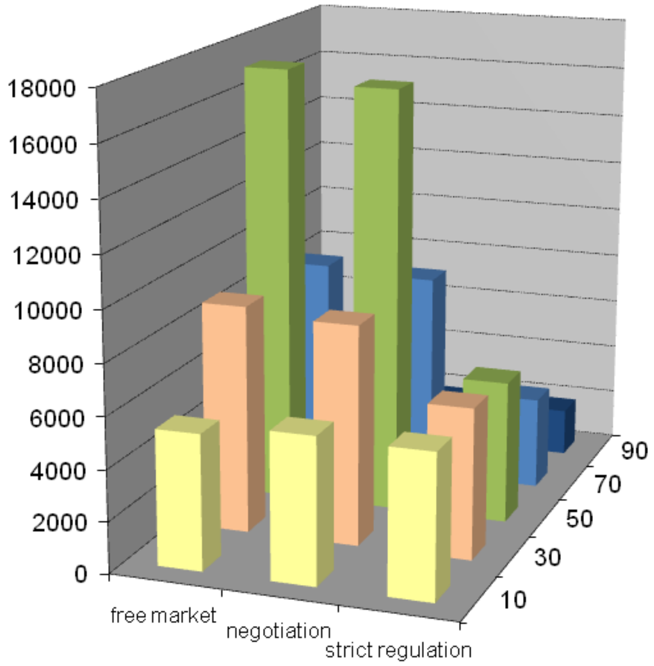

Fig 4. Average population (in number of households) for each of the three scenarios and for populations with ideal neighborhood density averaging 10, 30, 50, 70 or 90.

In general, the strict regulation scenario produces an orderly pattern that replicates the plan's maximum density prescriptions. However, it does not produce much diversity in terms of building options. In sharp contrast, the free market scenario produces a seemingly chaotic pattern where developments of all densities can be mixed. In this scenario, low density preferences on the part of the population are hardly taken into account by developers, that prefer to build the more profitable higher densities. The negotiation scenario produces a city that offers relatively homogenous areas with buildings of similar heights. These clustered picture offers more diversity in terms of building density options.

Number of buildings / Population	Strict_regulation		Negotiation		Free market	
	Id 10	Id 45	Id 10	Id 45	Id 10	Id 45
single-family developments	0%	0%	16%	9%	0%	0%
2 to 5 household / cell developments	49%	46%	80%	54%	7%	9%
6 to 9 household / cell developments	0%	0%	4%	7%	6%	4%
10 household / cell developments	51%	54%	0%	30%	87%	87%

Table 2. Average percentage of each type of development for each scenario and for average ideal neighbourhood densities 10 and 45 households per neighborhood.

In terms of the utility of residents, it seems that the free market scenario is outperformed by both the negotiation and the strict regulation scenario, except in the case of very high density preferences by the population. However, this is a result of the fact that, in our model, dense developments are in general more profitable than low density developments, which may not always be the case in reality. More importantly, the strictly regulated city protects the utility of exiting residents only by keeping population low.

The negotiation scenario succeeds to create that grows as in the free market case, while at the same time maintaining the utility of residents as high as in the strict regulation case. Negotiation is especially successful when density preferences if the population are more moderate.

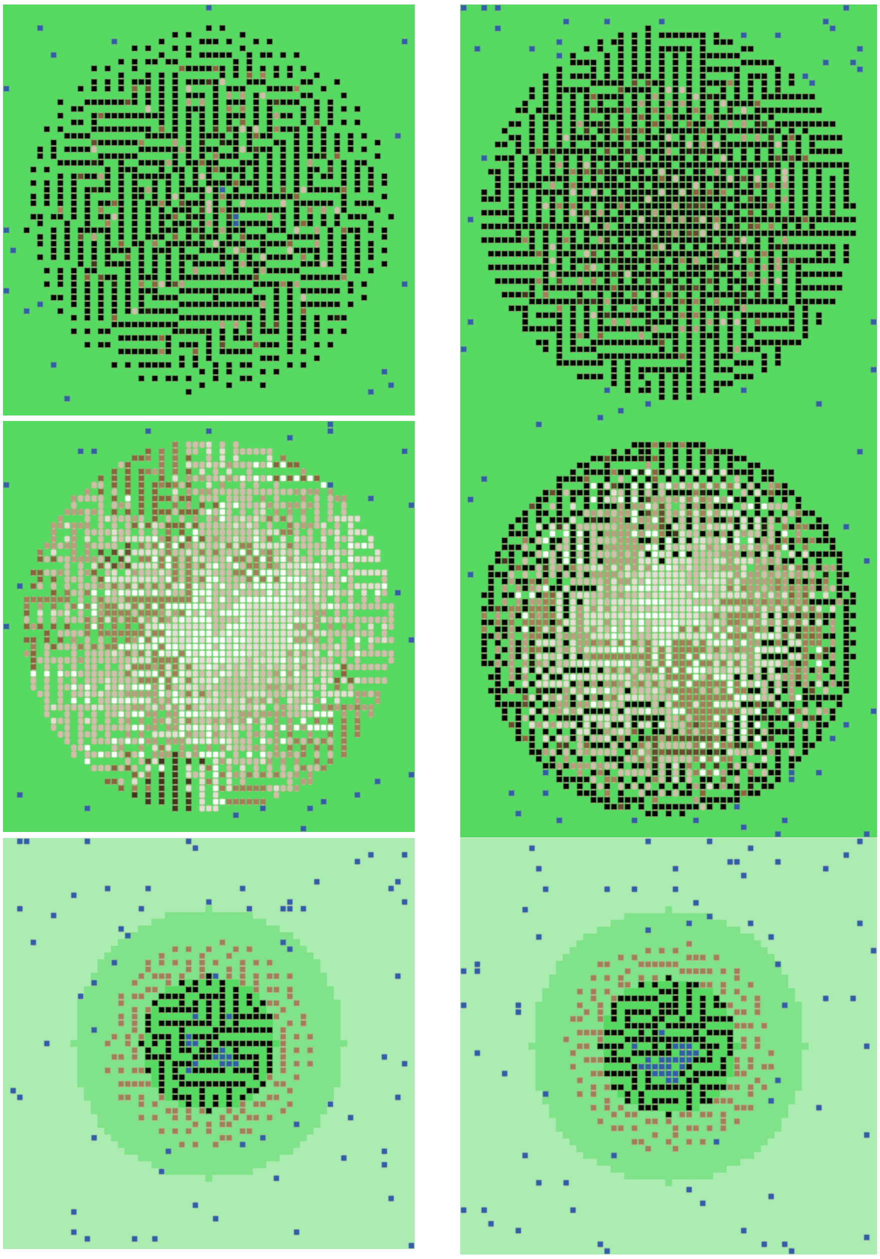

Figure 5. Residential patterns in the case of the (top to bottom) free market, negotiation and strict regulation scenario and for populations with average ideal neighbourhood densities of (left to right) 10 and 45 households per neighborhood.

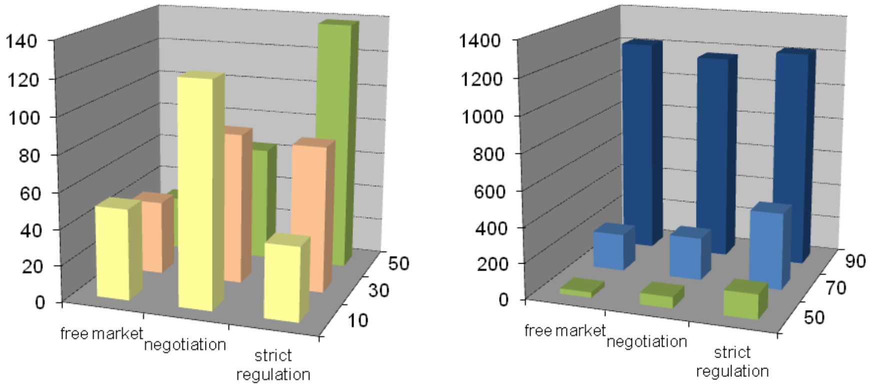

Fig 6. Average Utility of households for each of the three scenarios and for populations with ideal neighborhood density averaging 10, 30, 50, 70 or 90.

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