The implications of alternative developer decision-making strategies on land-use and land-cover in an agent-based land market model

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Abstract: Land developers play a key role in land-use and land cover change, as they directly make land development decisions and bridge the land and housing markets. Developers choose and purchase land from rural land owners, develop and subdivide land into parcel lots, build structures on lots, and sell houses to residential households. Developers determine the initial landscaping states of developed parcels, affecting the state and future trajectories of residential land cover, as well as land market activity. Despite their importance, developers are underrepresented in land use change models due to paucity of data and knowledge regarding their decision-making. Drawing on economic theories and empirical literature, we have developed a generalized model of land development decision-making within a broader agent-based model of land-use change via land markets. Developer's strategies combine their specialty in developing of particular subdivision types, their perception of and attitude towards market uncertainty, and their learning and adaptation strategies based on the dynamics of the simulated land and housing markets. We present a new agent-based land market model that includes these elements. The model will be used to experiment with these different development decision-making methods and compare their impacts on model outputs, particularly on the quantity and spatial pattern of resultant land use changes. Coupling between the land market and a carbon sequestration model, developed for the larger SLUCE2 project, will allow us, in future work, to examine how different developer's strategies will affect the carbon balance in residential landscapes

Keywords: Agent-based modelling; Land markets; Land developers; Risk

1 INTRODUCTION

Developers play a key role in land and housing markets. Developer's decisions determine the mix, timing, and intensity of development. Their decisions are based upon the developer's internal characteristics (i.e. capital, preferences, risk attitude, and experience), available site characteristics (i.e. biogeophysical factors, accessibility conditions, and existing development type), market conditions (the type and intensity of demand for housing), and the regulatory environment (zoning and incentives).

Developer behavior has been incorporated into a variety of urban land-use change models, which simulate behaviors of multiple systems such as demographic evolution of the population, the transport system, location choice of residents and firms, and daily activities and travel patterns. In these models, multiple types of agents, including farmers, households, firms, and the government, interact with each other and with the environment. Empirical urban land-use change studies

incorporating developer behavior have been carried out in the Netherlands (Ettema et al. 2007), USA (Waddell 2002), Germany (Wagner and Wegener 2007), and Canada (Miller et al. 2008; Salvini and Miller 2005).

Recent agent-based models that incorporate developers also simulate their behavior in land and housing markets. For example, Magliocca et al. (2011) endogenously modeled a single, representative developer's expected rent in the land market and the developer's market interactions with sellers and buyers. Ligmann-Zielinska et al. (2009) analyzed the effects of risk attitudes on land-use patterns based on open-space amenity preferences and land prices. Diappi and Bolchi (2008) evaluate the effects of available capital on land use pattern based on the Smith's rent gap theory.

Although these recent works include developer behavior, none comprehensively capture their heterogeneity, interactions and product mix choices, although each includes an individual element. In this paper, we present a model that offers several important advances. First, rather than modeling a representative developer, we model multiple developers who are heterogeneous with respect their experience and expertise in particular development types, their risk perceptions, and their access to capital. These developers also compete with each other in a fully represented land market to acquire rural parcels for development, and to sell their newly developed houses. In the housing sales market, they also compete with residential buyers, who may have become dissatisfied and have chosen to relocate, adding an additional dimension to housing market interactions.

Our agent-based Land Market Model (LMM) is developed as part of the larger SLUCEII project (Spatial Land Use Change and Ecological Effects at the Rural-Urban Interface: Interactions of Exurban Land Management and Carbon Dynamics), which explores relationships between the landscaping practices of developers and households and patterns of land development and carbon sequestration in ex-urban residential landscapes in Southeastern Michigan. As previously agricultural land has been converted to residential development, the diverse landscaping practices of developers have lead to varying degrees of reforestation of these landscapes. Among many more detailed research questions, the overall intent of the modeling effort is to determine whether such ex-urban residential development will result in a net carbon source or sink. The overall model includes land cover change, land management, and land-use change modules. The SLUCEII-LMM model described here provides the land-use change component of the model. In the larger model, the land-use change events described here will affect land cover and carbon storage through the land management decisions of developers and new residential land managers. Details of the coupling between the land-use change model, land management, and carbon model are provided in Robinson et al. (Under Review).

2.   SLUCEII-ABM

The SLUCEII-ABM land market model is an expansion of the first-generation LMM model, a prototype that models interactions between residential buyers and rural land sellers, omitting the process of land development and the role of developers. (Details of the LMM are provided in Parker et al. (2012).) Here we describe the new features of SLUCEII-LMM in detail, using for reference the framework and associated open questions outlined in Parker and Filatova (2008). (Our new model addresses a selected subset, but not all, of the potential model features mentioned in the framework.)

The general structure of SLUCEII-ABM is shown in Figure 1. The model includes three classes of agents, who interact in two connected markets. Farmer/rural land owner agents, whose behaviour is represented very simply, sell lots for development on the land market. Land developer agents participate as buyers in the land market. They then develop new homes and sell them in the housing market. Residential households participate in the housing market as both buyers

and sellers of land. Buyers may purchase either new homes from developers or existing homes from residential sellers. If the household makes a decision to relocate, it becomes a seller of an existing house, and subsequently a buyer again.
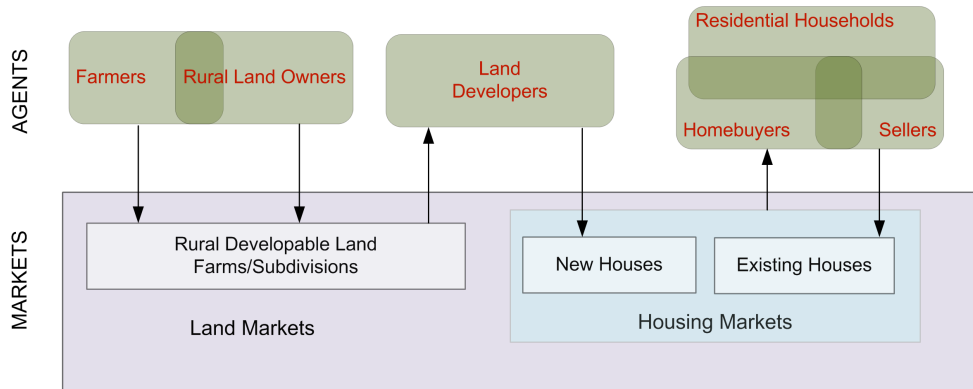

Figure 1. Agent types participating in coupled land and housing markets.

2.1 Expanded utility function

Because our developers differentiate their residential properties by lot size, we have modified the utility function from the one used in ALMA (Agent-based Land MArket Model) and LMM (Filatova, Parker, and van der Veen 2009; Parker et al. 2012) to include lot size. The form of the utility function is still Cobb-Douglas, with the addition of a third normalized variable, lot size, in addition to proximity to city centre and the proportion of open space (undeveloped land) in a fixed neighbourhood. Currently the utility function constrains all three utility coefficients to sum to one (per Cobb-Douglas), and further constraints the coefficient on lot size and open space amenities to be equal, for simplicity.

2.2 Endogenous Relocation

Following Approach1 for Question 3 (Q3-A1) in Parker and Filatova (2008), a seller who has purchased a home in a previous time period will attempt to relocate if the current utility he gains from his house falls below a certain threshold (set by a parameter, and currently 15%) below the utility level he gained when he purchased the house. In our current model, all agent level characteristics and model parameters remain fixed during the model run. The only variable factor that will induce a change in the resident's utility is the proportion of open space in his neighborhood, which will change as surrounding cells are developed. Current residents recalculate their utility in each time period, updated based on changes in the open space surrounding their property, to determine whether or not they will attempt to relocate.

A dissatisfied resident will then put his house up for sale on the market. Having made this decision, open questions 4 and 5 from Parker and Filatova (2008) must be addressed: *How should willingness to accept (WTA) be determined for selling households?* and *How do seller households set their ask prices?* In our current model, the relocating seller initially sets his WTA to the price he originally paid for his current house—in other words, he seeks to break even on the sale. As the current model does not focus on strategic interactions, the ask price (the price at which he lists the property) is set equal to his WTA. If his house does not sell in the current iteration, in the next iteration he will lower his ask price by a set percentage. If the resident is successful at selling his home, he will enter the pool of buyers in the next time period. The sales price of that home is then added to the net housing budget that he had following the initial purchase of his first home.

In models with endogenous relocation, it can be difficult to jump-start market activity if a model does have a fixed population of agents. In short, if a seller can't buy until they have sold their current home, there needs to be an active pool of buyers able to bid on that home. Yet, those buyers can't become active on the market until they sell their own homes. Ettema (2010) solves this problem by having an equal proportion of incoming buyers and sellers, such that the total population remains fixed. Magliocci et al. (2011) solve the problem by having a growing urban population over time. As we would like to try to replicated a static land market, in the current model we solve the issue as described, by allowing sellers to sell before finding a new home, which often occurs in the real world.

Although simple, we plan one modification to our current algorithm. Currently a relocating seller does not check the prices of houses currently on the market, to ensure that having sold his current home, he could afford to purchase a home that would give him sufficiently higher utility to compensate him for the move. In practical terms, under the current model rules, relocation may lower a seller's utility. This issue can be resolved by having him assess current market conditions and set his WTP equal to the lowest current sales price (or recent transaction price) of a home that would offer him a higher level of utility than his current home.)

2.2   Developers

Modeling developer behavior is a central goal of our new model. In this section, we review the model design choices that we have made for developer behavior in terms of the open questions raised in Parker and Filatova (2008). We further introduce two additional questions and describe our current approach, along with potential alternatives that may be implemented in future models. These questions focus on risk and the timing of development. We are currently exploring hypotheses as to how combinations of specialized knowledge and heterogeneous risk perception on the part of developers may explain empirically observed patterns of product differentiation, and these new model features are essential to address these questions.

Parker and Filatova's (2008) Open Question 7: *How should the profit-maximizing choice of development type be modeled?* focuses on how developers might choose their product mix or development type. The SLUCEII-LMM is developed to represent land development in a particular region and time period. Extensive ethnographic and empirical research has been conducted for this case study, and from this, four primary empirically motivated development types have been established: country, small horticultural, large horticultural and remnant (Brown et al. 2008; Robinson and Brown 2009). In the current version of the model, these developments vary only by lot size (0.5, 1, 3, and 5 acres respectively). This variation is consistent with monopolistic competition, where developers differentiate an otherwise homogeneous product over a single dimension, per approach 2 to question 7 from Parker and Filatova (2008). A more empirically grounded version of the model, in the development stages, includes detailed spatial templates to differentiate properties by initial landscaping as well as lot size.

A full specification of the developer's perceived profits from development are required in order to answer Parker and Filatova's Open Question 8: *How should the willingness to pay of particular groups of individual buyers that appears in developers' profit function be estimated?* and Open question 9: *How should developers' WTP (expected price) for agricultural land be determined?* In addition, as described in Figure 1, development is a multi-state process, and developers must anticipate both the type and timing of development costs when assessing their profits. We thus add a new question: *How is the timing of development modeled?* Finally, many of our research questions of interest center on how developers' perceived risks affect their product offerings. We thus discuss an additional question: *How can risk be incorporated into developer's estimated profit function?*

In our current model, in principle, each developer could potentially implement any of the four subdivision development types. However, developers are heterogeneous across two dimensions: their development costs and their perceived risk of failure to sell the newly developed housing stock.

In general, developers' calculate an estimated expected net present value from development for each rural parcel available for sale. Provided they have sufficient capital to cover short-run development costs, they then bid on the parcel that they estimate will provide them the highest profits from development. Their bid price (again, equal to their WTP, as we do not include strategic bidding in this model) is given by their estimated profitability from the rural parcel that would provide them with the next highest level of profits, plus a parametrically set premium equal to a fixed percentage of the difference in profits between the second highest profitable parcels. Thus, the developer essentially sets a bid that is between their opportunity cost of purchasing this property and their shadow value of the current property.

The land development procedure that we conceptualized in our model has multiple stages: 1) land purchase 2) land development, and home construction and 3) marketing and sale (Rybczynski 2007). We allow our developers to differ in terms of each of these costs. Revenues are only recovered at the third stage. However, this revenue stream is uncertain.

For the purpose of simplification, we assume that a land development project starts when a developer purchases a farm, which we denote as T0. From then until time T1, the developer develops the land by acquiring permissions, clearing the field, building the infrastructure, etc. After land is developed, the developer then starts the housing construction procedure, which is also the time when the developer can start marketing and selling. In the real world, developers and builders also build a few model homes. Then they build only when buyers sign contracts. This implies that the construction, sales, and marketing quite often occur simultaneously. We assume this phase lasts until time T2, at which time there is a discrete risk of project failure. The multi-year forward-looking profit function that we implement, however, could be expanded to account for sales over sequential years, or the possibility that land might be re-sold without being developed.

Expected revenues from house sales must be estimated. Developers currently estimate potential sales prices using a simple average of historical sales prices, adjusted for a proximity factor. We are also experimenting with a simple hedonic sales price estimation algorithm, which includes parcel characteristics (lot size, open space, and proximity) as independent variables. Such an approach would assume that developers have access to information on sales prices and property characteristics of previous sales (public information), but not on the characteristics of the buyers (private information), potentially leading to biased sales price estimates (Filatova, van der Veen, and Parker 2009).

Developers also hold discrete, heterogeneous perceived risks of project failure—failing to sell the developed houses. In this case, the developer would lose the costs of development and would earn negative profits from the development activity. Using standard expected value calculations for discrete risks, these risk affect expected payoffs at the sales time for the houses. In our current model, developers have lower perceived risks of development for a particular subdivision type, thus building in an advantage to specialization. Perceived failure risk also depends on the standard deviation of previous house sales prices.

A developers' estimated expected profits from development then are simply the present value sum of expected revenues at T2, less costs: land acquisition cost at T0, land development and home construction costs at T1, and marketing and sales costs at T2.

Our current model specification is based on profits (a linear function), implying that developers are risk neutral. We plan to expand the model to explore alternative attitudes to risk (Ligmann-Zielinska 2009). As our representation of risk currently has two elements (the standard deviation of prices, plus an individual risk perception), the model structure also allows us to potentially model biases in risk perception. In the future, we would also model developers' attitudes to risks (i.e., risk aversion). We current assume that developers can correctly anticipate development cost, but clearly have imperfect information about future consumer demand and revenues, which are estimated. Thus, as appropriate for a complex systems, model, our developers are boundedly rational (Nolan, Parker, and van Kooten 2009).

Planned model expansion will introduce additional sources of heterogeneity and can potentially endogenize perceived risk. One approach for this would be to have each developer form expectations for both the level and variance of housing sales prices based on private information. Specifically, a developer who had sold a property of a given type in the past could use their private information on the characteristics of the buyers, as well as the parcel and neighborhood characteristics. The higher number of such observations a developer had for a particular development type, the lower the degree of bias and variance there would be for that developer's price estimates. If developers were risk averse, such an approach would endogenously raise their expected utility from development types where they had greater experience—provided those development types were profitable.

Developer's borrowing costs (interest rates used to calculate present value) could also be heterogeneous. If these costs increased with the both the level and variance of previous probabilities of project failure, representing risk aversion by lenders, this would also create a reinforcement effect that would be expected to lead to lock–in of previously successful development types.

4. NEXT STEPS AND CONCLUSIONS

Model verification experiments using SLUCEII-LMM are currently underway, and preliminary results were presented at the 2012 meetings of the Association of American Geographers. We plan to investigate a series of research questions, some using only the LMM module, and other exploiting the coupling with land management and carbon models. We will first compare the results of the SLUCEII-LMM, which contains multiple, competing developers, to a simpler version of the model using the representative developer approach taken by Magliocca et al. (2011). We also plan to explore, as suggested above, the effects of various sources of developer heterogeneity on patterns of specialization, specifically exploring how differential risk perceptions, experience, and information could lead to lock-in of a relatively small range of development types. Among other applications, we plan to use the fully coupled model to explore how the initial landscaping decisions of developers may combine with social norms and neighbour imitation effects to shape patterns of landscaping and carbon sequestration. In one scenario, a set of fairly homogeneous buyers may be drawn to a particular development type. Social pressures to conform to neighbouring landscaping styles could then lead to lock-in of the initial landscaping established by developers, and with it, the initially mandated carbon profile. In another scenario, if a set of residents with diverse landscaping preferences and practices locate in an initially homogeneous subdivision, and if neighbours imitate each other's land management practices, a very diverse residential landscape, with dynamically varying carbon sequestration properties, may evolve. We look forward to exploring these and other questions using our new modelling framework.

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