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A simulation model of home improvement with neighborhood spillover

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ABSTRACT

This paper develops a simulation model of home improvement with neighborhood spillover. The goal is to explore how the household decisions between home improvement and moving shape urban land development and housing markets, and the role of neighborhood spillover. The model is implemented based on a monocentric city framework. The existence of neighborhood spillover effects slows down the pace of urban land development, while it also significantly increases average household duration of residence and amount of home improvement investment. In practice, the neighborhood spillover effects can be considered as a form of social capital which connects homeownership and neighborhood quality. Based on the simulation results and sensitivity analysis of key policy relevant parameters (social interaction strength, neighborhood size, transportation cost), the paper further explores implications for public policymaking related to transportation, housing markets, and land use. The dynamic simulation tool developed in this paper can also be found useful in other land use, urban and regional modeling.

1. Introduction

Improvement on existing housing stock is an important alternative to the production of new housing. In the U.S., the household expenditures on home improvement have increased substantially in recent decades. According to the Survey of Residential Improvements and Repairs from the U.S. Census, in 1966, out of 46,500 million dollars of total expenditures on residential improvements and repairs by U.S. households, 58.9% was spent on home improvements. In 1996, the corresponding number is 69.4% out of 527,900 million dollars, and 75.8% out of 908,400 million dollars in 2007. However, the literature has not until recently started paying attention on the fact that home improvement is a substantial source of housing supply. Dipasquale (1999) points out that homeowners' decision on rehabilitation and home improvement are substantial adjustments to the existing housing stock. The improving decisions are complicated since the homeowners play the roles of both suppliers and consumers of housing. An early literature review on household home improvement decisions is given in Bogdon (1992). Her research suggests that the classic modeling approach to home improvement decisions based on maximizing the value of the net benefit from the housing unit may be inadequate, and home improvement expenditures tend to be inelastic to income level. Lately, Gyourko and Saiz (2004) urge urban scholars and policymakers to start paying attention to the supply side of housing market, especially the reinvestment and redevelopment of existing housing stock. Their analysis suggests that physical costs are an important determinant of improving effort, and when home values go below replacement cost households' effort in reinvestment is found to be substantially reduced.

Home improvement can be simply defined as any construction activities which significantly increase the stock of housing capital (therefore the housing service) without developing new dwellings. Examples of home improvement include putting a recreation room in an unfinished basement, converting a garage into a room, adding another bathroom or bedroom, putting on a new roof, or even paving the driveway to increase parking space. Home improvement usually increases property value. Home improvement activities should be distinguished from regular home maintenance or repair activities, as Potepan (1989) points out, the latter are only aimed at maintaining housing units in good condition and offsetting physical deterioration of housing capital. Home maintenance and repairs usually do not add value to a housing unit or prolong its life. Home improvement is also substantially different from new housing production, due to the so-called fixed capital constraint (see Potepan, 1989). Home improvement and new housing development present two options of limited substitutability for households who choose to adjust their current housing consumptions. This paper focuses on the quantity extension type of home improvement.

At micro level, home improvement investment is a major adjustment to household consumption bundle and asset portfolio. Home improvement investment can also have significant social consequences which go beyond the household level. Home improvement is a constituent part of homeownership. And the value of homeownership depends on the quality and vitalization of neighborhood, which connects home improvement decisions and neighborhood quality. The empirical analysis of Boehm and Ihlanfeldt (1986), for example, shows that neighborhood

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quality has significant impacts on the improvement expenditures of city homeowners. Rohe and Stewart (1996) find that there is considerable association between homeownership, property improvement, and neighborhood stability. One causal explanation for this relationship is that, home improvement as part of homeownership generates a positive neighborhood spillover. The existence of neighborhood spillover effects has important implications for public policy because the aggregated outcome could go beyond the simple summation of individual household behaviors or any representative household's behavior. As Rossi-Hansberg, Sarte, and Owens (2010) argue that, housing spillover effects imply that equilibrium allocations will differ from efficient outcomes and hence potentially justify a role for government intervention. The goal of this paper is to explore the relationship between home improvement and new land development as different forms of housing supply in a dynamic context, and the role of neighborhood spillover.

As one of the first discussions on neighborhood spillover effects of home improvement, Shear (1983) points out that one of the main concerns in housing policy is which households benefit and which households bear costs due to investment in housing capital in a neighborhood. Helms (2003) empirically finds that the housing renovation activities exhibit spatial dependence. Neighborhood spillover effects may cause renovations performed on one building to increase the likelihood that other nearby buildings will be renovated. Glaeser and Sacerdote (2000), Ellen and Voicu (2006), and Rossi-Hansberg et al. (2010) among other authors have studied the neighborhood spillover effects associated with housing investment in general. In order to thoroughly understand household decision-making on home improvement from a supply side perspective, and how these individual decisions shape the urban landscape, a dynamic simulation model of home improvement is developed in this paper. The basic model is then further developed to incorporate neighborhood spillover effects.

Simulation models have been widely used in land use, urban and regional modeling. One of the main advantages of simulation approach is that it can capture Emergent Phenomena which results from the interactions among individual agents (Bonabeau, 2002). The rationale behind the methodology is that the interactions among the parts can lead the whole to be more than the sum of parts. One of the earliest urban housing market simulation dates back to the NBER Urban Simulation Model (Kain & Apgar, 1979) in 1970s. In recent literature, for example, Yin (2009) examines the patterns of residential segregation and its evolution through Agent-based modeling (ABM) simulation based on the socio-economic scenario of the City of Buffalo. Magliocca, Safirova, McConnell, and Walls (2011) present an economic ABM simulation of housing and land markets that captures the conversion of farmland to residential housing over time. Huang, Parker, Filatova, and Sun (2014) provide a review on recent development of ABM in urban residential land use modeling.

In this paper, the analytical framework is built upon individual household decisions between two options — improving current housing unit or moving out through new development within a given monocentric city. The simulation model is implemented on a two-dimension space with system stochasticity and agent heterogeneity considered. The paper is organized as follows. Section 2 develops the analytical models for home improvement decisions. Section 3 introduces the setup and algorithm of simulations, followed by discussions of simulation results. Section 4 explores the implications for public policymaking. Section 5 concludes the paper.

2. Model development

2.1. Urban spatial structure

A basic principle of urban spatial structure is that the transportation cost differences must be compensated for by the differences in housing prices and spatial distribution of amenities (Alonso, 1964; Herbert & Stevens, 1960; Mills, 1967; Muth, 1969; Roback, 1982; Rosen, 1979). Assuming that all households are homogeneous and identical, the spatial equilibrium of a city should guarantee identical utility levels (or more plainly, the quality of life) for its all households. The spatial variation of unit housing prices (e.g., the price per square foot) is the key instrument to achieve identical utilities across the entire urban area (Brueckner, 1987).

In a simple monocentric city model, everyone who lives in the city commute to the central business district (CBD) and a fixed unit transportation cost t occurs. Assuming that the utility of each household depends on two types of consumption: housing and non-housing, and the housing consumption is featured by one single attribute — lot size or living space S. Denoting the unit housing price and non-housing consumption as p and M, respectively; at any given location D (measured by the distance to the CBD) the budget constraint is given as:

$$Y = pS + tD + M \tag{1}$$

where Y is household income. The price of non-housing goods is standardized to 1. The household's consumer problem can be given in the form of utility maximization:

$$\max_S \quad U(M,S) = U(Y - pS - tD, S). \tag{2}$$

Given housing price p, the optimal choice of living space can be derived from the first order conditions of Eq. (2). If the household's desired utility level is further set at U^0 following Brueckner (1987), the (p,S) pair which satisfies both the desired utility level and the first order conditions of Eq. (2) can be solved from the following simultaneous system:

$$\begin{cases} p^* = \dfrac{\partial U/\partial S}{\partial U/\partial M} \\ U^0 = U(Y - pS^* - tD, S^*). \end{cases} \tag{3}$$

At any given location D, the (p,S) pair can be solved conditional on the specification of other parameter values in the system: Y, U^0, and t. The set of solved (p,S) across all locations represents a simple spatial structure of the city through housing markets. If we assume a Cobb–Douglas preference structure, $U = S^{\alpha_s} M^{\alpha_m}$ with $0 < \alpha_s, \alpha_m \le 1$ and $\alpha_s + \alpha_m \le 1$, we can have a useful result for developing the analytical model of home improvement:

$$p = \alpha_s \left[\frac{\alpha_m^{\alpha_m} \left(\frac{Y - tD}{\alpha_s + \alpha_m} \right)^{\alpha_s + \alpha_m}}{U^0} \right]^{\frac{1}{\alpha_s}} \tag{4}$$

where U^0 can also be considered as the desired quality of living of a household. Eq. (4) shows that the housing price decays in a nonlinear way with respect to the distance D. It can be shown by total differentiating Eq. (4) that $\partial p/\partial D < 0$. The shape of the nonlinear decay is governed by preference parameters α_s and α_m. Since $1 + \alpha_m/\alpha_s > 1$, the distance decay function is concave. The derivation of Eq. (4) can be found in Appendix A1 in supplementary data.

2.2. A model of home improvement

At every stage of family life cycle, a household has to make decisions regarding its housing consumption, to stay and make no change, to stay and invest in existing housing unit(s), or to move. The adjustment decision depends on housing market conditions, household income, technological and regulatory constraints. For example, based on survey data from Australia, Seek (1983) finds that home improvements are undertaken as response to changes in household demographic and economic conditions. The level of home improvement investment is mainly constrained by income level, financial and wealth status. In general, a