Collected system dynamics works on recent real estate dynamics

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Abstract

This paper presents an overview of recent system dynamics works in the field of housing and real estate. It points out several connection points between system dynamics and real estate economics. In particular, we demonstrate that a common real estate model is easily translated to system dynamics as a useful template. We summarize the highlights of about ten recent real estate system dynamics papers and suggest that compiling literature reviews of system dynamics works in a particular area of interest is an easy starting point for relating to other academics and fostering the wider use of system dynamics.

Keywords: system dynamics, real estate, housing, credit crunch, construction, housing equity, market cyclicality, real estate finance

Purpose of this paper

System dynamics unmistakably has perfect innate capabilities for helping responsible decision making in an increasingly complex world. But as Forrester (2007) sighed, the system dynamics community is not yet making the change for policy making it should aim at. One possible cause is that many system dynamicists are specialists in the SD method and generalists as regards to the themes involved. As a result, there are few position papers collecting the system dynamics insights of all relevant studies in one particular area of application. The purpose of this paper is providing such an overview of system dynamics works on recent dynamics in global real estate markets.

The promise of system dynamics

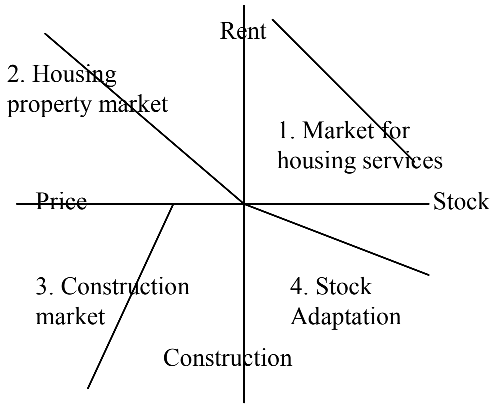
System dynamics deserves proper attention from the policy-making community and as system dynamicists, we may and should contribute to this goal. We can do so by digging more deeply in the problems experienced in the substantive sciences and by policy makers, by systematically building up the knowledge stemming from our modeling effect and by tackling especially those problems in which nonlinearity, complexity and data problems hamper progress. Bringing in system dynamics may help redefining research agendas for those fields. If we can do so in close relation to substantive academics and policy makers, small interdisciplinary groups of dedicated academics and professionals may to bring surprising results within years.

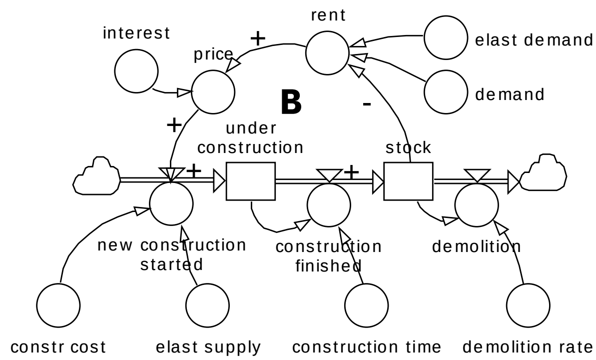
One particularly easy starting point is writing literature reviews of system dynamics on the many themes our field covers. We did so for housing and real estate, a theme that gained particular interest after the US housing market crashed and wreaked havoc on the global economy since 2008.

Implicit system dynamics in real estate economics

First, it is important to acknowledge that some basic concepts of system dynamics are also present in mainstream real estate economics. Most notably, Di Pasquale and Wheaton (1996) present an implicit system dynamics model connecting the main three real estate markets: the consumer market for e.g. office or housing space, the asset market for real estate property and the construction market. The dP&W model (further: 4qm) consists of a single (real estate) *stock* with *construction finished* and *demolition* as its governing flows. The stock level, combined with demographic and economic *demand* factors and price *elasticity of demand*, determines the annual *rent*. By means of an *interest rate*, rents capitalize into asset *prices*, which in turn determine *new construction started*[1]. With all relations except one having positive polarity (a larger real estate *stock* leads ceteris paribus to lower *rents*), the main feedback loop is balancing.

[1] Taking into account construction costs and price elasticity of supply. Figure 1 contains a first order material delay, as new real estate takes time to build.





It should be a standard student assignment to replicate this model in system dynamics software. Di Pasquale and Wheaton describe several policy experiments, which we can also exactly replicate. Both DiPasquale (1999) and Wheaton (1999) found several difficulties in continuing real estate research, namely the lack of statistical data on the behavior of companies in the market and the difficulty to work with higher levels of dynamic complexity, at least when trying to solve models analytically. This is important as Wheaton demonstrates that the occurrence of real estate booms and busts critically depends on behavioral responses of actors within the system and the presence of additional (institutional) feedback loops of reinforcing nature.

A literature review of real estate dynamics

For the literature review, we found 154 entries in the system dynamics bibliography matching search terms “urban", "hous*", "real estate". We analyzed all and discerned three main ‘schools’ and many isolated efforts. The first school of course relates to Urban Dynamics (Forrester, 1969) and contains many classic and modern studies. A second, smaller school is locally based in the Netherlands and focuses at housing policy models. We will publish a more extensive analysis later on.

We named the third school the “Housing Markets and Real Estate Dynamics School”. Defining characteristics are the use of concepts from mainstream real estate economics and an interest for actor and institutional behavior and market cyclicality.

Recent studies housing and real estate dynamics

Barlas et al (2007) focuses on modeling supply side from the viewpoint of a real estate construction company with a large enough market shares to influence the market. In other words, Barlas modeled an oligopoly market with a vacancies structure. He finds that the level of vacancies and supply delays play an important role as a cycle producing mechanism. Barlas initially modeled backward looking expectations of developers (ib. p1). With these, sensitivity analysis indicates stronger oscillation with increasing supply delays or lags, reconfirming Wheaton's (1999, p. 228) results. But on conducting policy experiments with developers' expectations, Barlas found two factors dampening oscillatory market behavior: a) by taking into account the number of houses already in production and b) by making better forecast of future demand trends. *Özbas et al* (2008) performed a rigorous sensitivity analysis of Barlas' model. They found three important variables determining properties of the real estate cycles: construction time influences mainly the period length of cycles, sale times have large impact on cycle amplitude and profit margins in the oligopoly market strongly determine final prices.

Mashayeki et al (2009) coined the term "cycle producing mechanism". They take the four-quadrant model as found in (Wheaton, 1999) as a starting point for the rental market, but add an additional stock variable for vacant housing units for the owner occupied sector (see also e.g. Wheaton & diPasquale, 1996, Wheaton (1999). They proceed to simulate the very different dynamic properties of both structures. Initially, both markets exhibit oscillation due to the cycle-producing mechanism of the supply lag. When removing the supply lag, the rental market loses its cycles as opposed to the owner occupied market with the vacancies stock added. Barlas et al carried out further experiments with the average life span of houses, finding again different effects for the rental and the owner occupied market. Mashayekhi et al concludes that different markets with different structures have very different dynamics properties and react differently to the same stimuli. Moreover, markets and cycle-producing mechanisms interact dynamically.

As mentioned, Mashayekhi et al take Wheaton's (1999) model as a starting point. On the one hand, this provides for proper connection to real estate economics, but also brings to the fore an interesting technical and conceptual discussion point of the role of elasticity variables in system dynamics modeling. The equations used follow widely accepted standards in econometric modeling, where elasticity variables describe the overall behavioral relationship between procentual changes in two economic variables, mostly in the form of an exponent on the independent variable.

For system dynamics, however, this is questionable from the viewpoint of unit consistency. E.g. equation 6 is: construction starts = stock * alpha2 * price forecast ^ beta2. With construction starts in units per time, stock in units and price forecast in money per unit leaves alpha2 to be in units per moneytime if elasticity is to be dimensionless. From the system dynamics point of view, alpha2 is a difficult variable to explain in real world terms. The solution to this puzzle is that elasticity variables describe statistical behavioral characteristics of a relationship and that system dynamics must focus on describing structural or causal relations exhibiting such behavior. We will return to this issue in our conclusions and discussion.

Atefi et al (2010) base on Mashayeki (2009) and several international housing and real estate authors (e.g. Poterba, 1984; Wheaton, 1999; Meen, 2000). They focus on identifying several mechanisms of affordability, including the provision of housing loans. Their resulting model is somewhat reminiscent of the 4qm but is not very explicit as to the rent/ price mechanism: there is no interest rate in this model. However, an archetype balancing demand and supply by means of prices is present is several submarkets in their model. The effects of demand on prices are based rather on empiry than on theory (e.g. the user cost approach, adopting a price expectations approach; rational, adaptive or exogenous). The model is put through several validation tests. Its behavior shows increasing oscillation for some important variables and an overall decrease of affordability, notwithstanding income growth.

Mukerji & Saeed (2011) approach the causes of the credit crunch from the viewpoint of household finance on the micro level. They therefore cover the demand and finance sectors of the four-quadrant model for the owner occupied housing sector. The model has four sectors for a) household cash flows, b) their investments in real estate, c) the level of indebtedness and d) price formation of real estate (again with backward looking or adaptive expectations as a working hypothesis). They proceed with several policy experiments mimicking the interplay of several factors causing the US housing market credit crunch: the loosening of bank capital requirements, government policies fostering home ownership, household equity increases as a result of the housing boom, loose monetary policies and changes in bankruptcy rules. Their overall conclusion is that most reasons only offer a partial explanation of the crisis. In other words, only an accumulation of factors can cause the housing market crisis. Loose monetary policies were found to worsen the bust as low interest rates lead to low savings and leaves households ill equipped as the crisis strikes.

Hu & Lo (1992) predate the US housing market crisis by more than a decade, but they also find recurrent cyclical patterns in the Taiwan housing market and describe this behavior by means of a model consisting of six main feedback loops. Three reinforcing feedback loops were found causing land prices to increase and triggering speculative behavior on the demand and the supply side respectively. Simulations with the model indicate that a base run with stable demand does not trigger cyclical patterns. When demand increases because of demographic or economic growth, house prices increase, as do the share of speculative demand (in expectation of further price increases) but also the number of unsold houses, left over after the speculative effects have disappeared. The internal market structure causes the cyclical behavior pattern but needs an external trigger.

Jie Chen (2007) constructs a comparable model to gain insight in the sustained growth of house prices in Shanghai. The six-sector model contains a more elaborate feedback structure with eight reinforcing and four balancing feedback loops. Chen emphasizes not only speculative behavior of consumers and suppliers, but also of (foreign) investors buying properties and then striving to increase prices. The main simulation experiments discern between speculative and non-speculative markets. However, no feedback loops on the government provision of land are included as the total land area for Shanghai is limited. Again, the internal market structure causes the cyclical behavior pattern but needs an external trigger.

Hwang et al (2009) model the dynamics of the Korean mortgage market. Rather than focusing on the interaction between housing consumers and mortgage banks, they venture into the secondary mortgage market where the mortgage banks sell mortgage related securities to secondary investors. They simulate for assessing the effects of government deregulation policies and finds that these measures will have only limited positive if not negative effects. After the housing boom in the early 2000's, the Korean government decided to restrict mortgage lending in order to regulate speculative demand and to maximize housing loans. But with the 2008 housing bust, the government set out to stimulate the housing market by deregulation the mortgage system. The market did not take off because secondary investors were not allowed to supply additional capital for fears of increasing risks even more.

Park et al (2008) evaluate a controversial package of measures taken by the Korean government to resolve increasing socio-economic problems in the housing sector, especially the construction of New Towns. They claim that most government interventions do not take into account longer-term negative effects and are in fact functional only for a short period of two to three years, have detrimental results in the long run and suffer from wrong timing in regards to market cycles. Their model structure has housing demand, prices and supply as main elements. Main feedback loops connect prices of newly built houses with the existing stock, prices, construction and supply through a 4qm-style balancing loop and a final reinforcing speculation loop. The leverage points in the government policy package yield only temporary effects as they do not take into account speculative behavior as is apparent from a case study simulation for the city of Kangnam.

Rafferty and Farshchi (2009) investigate the relationship between finance availability and the output of the housing construction industry in the UK. They find that a fairly low but consistent level of finance and a high level of transaction are important preconditions for a stable market. A combination of both high transaction and finance availability levels was found to generate high levels of price inflation.

Ho et al (2010) model the housing market in Taichung, Taiwan. Their model contains five sectors, including demand, supply and finance, thus covering the full 4qm. From simulation experiments, they conclude that a combined strategy with higher interest rates, lower unemployment rates and gradual prices increases can decrease housing market risk

Eskinasi et al (2011) report on Houdini, a system dynamics model explaining the negative response of housing construction to house prices in the period from 1995 to 2008. The model is solidly based on the 4qm and adds an array of institutional structures. First, the land use planning system focusing mainly on demographics prognoses and secondly the land market with residual land pricing and an oligopoly development market structure. Compare e.g. Poterba (1984) assuming perfect competition on the supply side but excluding land market from his analysis.

Also rent regulation and fiscal treatments of mortgage interest were included. Fiscal treatments are fed back to net household incomes as they are financed or compensated by income taxes. The model mimics statistical development of house prices and construction to a sufficient level. The institutional feature of land prices rapidly adapting to house prices levels explains why housing production is high only in time of house price increases, which were triggered by (exogenous) income growth and declining mortgage interest rates. Eskinasi et al also document strong debates with mainstream economists on household price expectations of households but also their contributions to better models in regards to unit consistency requirements.

Conclusion and discussion

All the above indicates that it is very useful to summarize system dynamics efforts in a particular substantive field against a background of the findings of common methodologies.

First, we found that real estate economics acknowledges several methodological and data problems system dynamics can easily overcome. Second, we found stock, flow and feedback structures present also in mainstream real estate economics. Moreover, one common real estate model is an implicit system dynamics model. Translation between mathematical and system dynamics notation is easy and flawless.

Third, even without close cooperation with real estate researchers, system dynamics studies on real estate and construction markets provide many opportunities for extending the real estate model with the institutional features Wheaton (1999) found difficult to scrutinize. Many works in what we labeled the Housing Economics and Real Estate Dynamics School relate to mechanisms producing cyclical behavior of real estate markets, others base on the 4qm and add institutional features.

Barlas et al (2007) and Ozbas et al (2008) model a housing market with vacancies and oligopoly on the supply side and simulate for different modes of behavior of actors. Mashayekhi et al (2009) also have a system dynamics vacancy housing market model. Hu & Lo (1992) and Jie Chen (2007) model the relation between speculation and cyclicality in certain detail. Jie Chen also adds the dimension of influx of foreign capital. Mukerji & Saeed (2011) focus on the demand and finance sectors, especially on the impact of bank regulations and inflow of capital on household finance, housing equity and the US housing market. Hwang et al (2009) add the interaction between primary mortgage lenders and secondary investors buying mortgage based securities to the palette. Rafferty & Farshchi (2009) relate housing construction industry output and finance availability. Eskinasi et al (2011) base on the 4qm and explain low performance of the Dutch housing market through a number of institutional features such as rent regulation, mortgage subsidies, land use planning and land market structures. Several (Hu & Lo 1992; Jie Chen 2007; Eskinasi et al, 2011) studies indicate that causes for low performance of undesirable cycles lie within the structure of the market and its institutions and external triggers bring about this chaotic or lethargic behavior.

In short, our short endeavor indicates that in this particular field system dynamics has lot of value to add for research. What we need to do is connect closely to academics and policy makers in a single field, dig deeply into the substantive problems and build up confidence in our modeling but also in deep understanding of the substance involved. Isomorphism between e.g. disease control and real estate markets is important for system dynamics, but may not necessarily be helpful in establishing rapport with real estate economists.

By further thematic specialization, the system dynamics community and the special interest groups may become important ambassadors for connecting system dynamics more deeply into academia and policy-making circles. Our small literature review shows that the treasure cove is there, so we should now start mining!

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