Houdini: a system dynamics model for housing market reforms[1]

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Abstract

This paper describes work in progress on Houdini: a system dynamics model of the Dutch housing market focused on explaining institutional structures leading to high price increases and obstructing new supply and on proposed reforms. The model is largely based on extensive literature on the woes of the Dutch housing market and was reviewed by a well-established expert panel, consisting of representatives of universities, ministries and national research and policy analysis institutes. The core model structure has its foundation in the diPasquale and Wheaton real estate markets model, an implicit system dynamics model. We report on the Houdini model structure, validation, base run, policy experiments and follow up activities.

1. Introduction

This paper described the work in progress on Houdini, a system dynamics model of the Dutch housing market. System dynamics is a methodological discipline, focused on using computer simulation for tackling highly complex, non-linear policy problems. Fundamental to the system dynamics approach is the concept of endogeneity: dynamic behavior of complex social systems is generated by their internal structure, rather than from exogenous impulses (Richardson, 2011. System dynamics elaborates models in terms of feedback loops, stocks and flows within the closed system boundary (Forrester, 1969). Human actors are embedded within such (information) feedback loops and strive to attain their goals by influencing the flow variables.

System dynamics originated in the 1960's and helped to kick start general awareness of environmental and climate issues through the books World Dynamics (Forrester, 1971), Limits to Growth (Meadows et al, 1972) and the Club of Rome. Undoubtedly, Jay Forrester's (1969) Urban Dynamics is still the most influential system dynamics study on urban development. Even though its insights helped policy makers design robust urban policies, Urban Dynamics never got firmly connected to other academic disciplines like housing and urban economics, planning and geographical science (for an in-depth account, see Alfeld, 1995).

Nevertheless, system dynamics is highly relevant for housing and real estate research for a number of reasons. First of all, both disciplines shares several conceptual cornerstones. Core system dynamics building blocks like stocks, flows and feedback loops have been present in real estate and housing economics at least since Poterba (1984). Secondly,

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system dynamics developed many techniques for using knowledge of non-statistical nature (see e.g. Vennix, 1996) and is thus capable of overcoming limitations imposed by the availability of statistical data (diPasquale, 1999). Thirdly, it is innately capable of dealing with high order complexity, far beyond the capability of analytical solutions of simplified models (Wheaton, 1999). It therefore allows to model all kinds of institutional feedback loops which may be essential for explaining real world real estate markets with cyclicality (Wheaton, 1999), with low explanatory power of both prices and construction costs for new housing production (diPasquale, 1999; Rouwendal & Vermeulen, 2007). System dynamics is capable of formulating and testing dynamic hypotheses or models behaving like the real world system. Common empirical analysis only refutes that such behavior can stem from rational economic models, but does not positively answer the question what structures create real world dynamics.

Crucial to the development of Houdini, it was found that diPasquale and Wheaton (1996) present an implicit system dynamics model connecting the three main 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 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 are being capitalized into asset *prices*, which in turn determine *new construction started* [4]. 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.

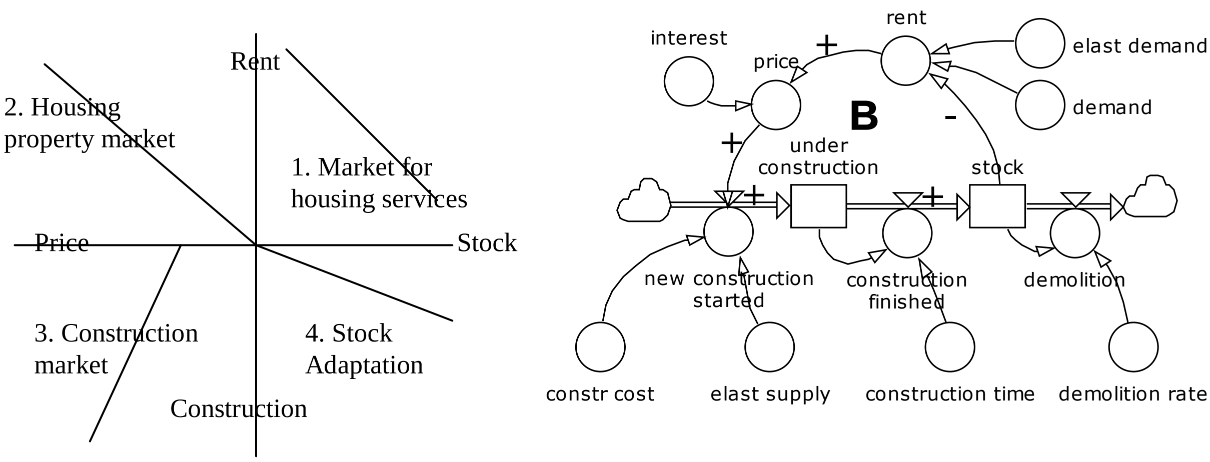

Figure 1
dP&W model in traditional and system dynamics form

As illustrated in figure 1, the model and the policy experiments mentioned by diPasquale & Wheaton (1996, p.6 – 17) are easily replicated with system dynamics software. Barlas, Özbas & Özgün (2007) refer to diPasquale and Wheaton but do not explicitly acknowledge the system dynamics nature of their model. Mashayeki, Ghili & Pourhabib

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[4] 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.

(2009) do use the system dynamics properties of the dP&W model when investigating real estate market cyclicality.

Houdini is a system dynamics model of Dutch regional housing markets with the dP&W model as a conceptual cornerstone. Houdini is being developed in a setting of possibly drastic changes in Dutch housing policy, where the predominant planners' paradigm is more and more disputed from an housing economics viewpoint. Its main focus is explaining the structure of the Dutch housing market driving its problematic behavior illustrated in the next section: rapid house price increases but virtually no response of new construction, as would be expected from the simple dP&W basis.

2. Context of the system dynamics modeling project

From the post World War II reconstruction period onwards, Dutch housing policy has been dominated by the planners or government interventionist approach rather than by market economy principles. Eskinasi , Rouwette & Vennix (2009) tell the tale of different *state* housing policy approaches from post war mass housing provision through the 1970s new towns and urban rehabilitation for low income groups to the 1990s and early 2000s, when housing policies started to pay lip service to market principles. Housing associations were privatized to a certain extent, consumer demand became more important for new construction and socioeconomic revitalization became a prime objective of urban renewal. But more fundamental reforms of the housing market were postponed: rent regulation, mortgage interest tax reductions and tight spatial planning were still in place.

The 1990s witnessed decreasing mortgage interest rates, growing incomes and improved availability of mortgage credits for households. As supply could not match demand, average house prices increased from under 100k euro in 1995 to nearly 250k in 2007. Measuring house prices in multitudes of median incomes, in 2007, 100.000-inhabitant Eindhoven out-priced New York and Amsterdam was the 13th most expensive worldwide (Romijn & Besseling, 2008, p. 27). Households and the state budget were increasingly at risk from high mortgages and interest fluctuations, rent regulation discouraged commercial investors to build rental housing and tenants to move from cheap apartments, thus obstructing housing market fluidity. It is estimated that direct and indirect subsidies on housing by state and housing associations amount to 29 bln euro annually (Don, 2008, p. 3).

But following the logic of the balancing loop in the dP&W model, high prices should lead to an increase in new construction. Dutch construction statistics, however, show ever *decreasing* construction volumes from 1990 onwards. Price elasticity of supply is low if not negligible and the spatial planning system is a probable culprit (Besseling et al, 2008, p. 27).

The Balkenende IV coalition government with Christian democrats -advocating homeowners' interests- and social democrats -reluctant to ease rent regulation- made a compromise to once more postpone fundamental housing market reforms. This moratorium spurred an unprecedented stream of economic studies, mostly very critical of the state housing and planning policy, demonstrating many negative effects and calling for fundamental reforms. (e.g. Romijn & Besseling; 2008, Don, 2008; Conijn, 2008; Donders et al. 2010 and many others).

The Ministry of Housing, the traditional stronghold of the planners' interventionist paradigm was forced into the defense before it was broken up by the new 2010 conservative Rutte I government. Its sections were split over different ministries: Housing to the Ministry of the Interior, Spatial Planning and Environmental Issues were added to the Ministry of Infrastructure and the Environment. The new government set out to decentralize housing and spatial planning to provinces and municipalities . And finally, the Ministry of Finance had already started to tighten the fiscal and legal leashes for housing associations.

3. The system dynamics modeling project

The development of Houdini started in 2008 as a private project out of interest for the substantive matter and caught the interest of a leading academic for its prospects of generating insights into transition paths towards a more stable housing market. At this stage, only limited time could be invested in Houdini, but as much literature was available[5], a simple prototype was built and producing plausible first results near the end of 2009.

Houdini was brought to the attention of the Netherlands Environmental Assessment Agency (PBL). Its staff was putting lots of effort into a large scale demographic style housing market model on the municipal level. The prospect of using (parts of) Houdini for this large model made PBL hire the modeler. As PBL is concerned mainly with regional housing markets, it was decided to translate Houdini into a regional model. The prototype saw many improvements and three regional versions were made, i.e. three models with different regional data. Region A represents the national average, region B is the densely populated northeastern part of the Randstad around Amsterdam, and Utrecht, region C is the declining far southeast of Limburg. Regional interactions were still missing at this stage. This so-called model version 1.0 was validated, documented and many policy experiments were carried out, focusing on reducing rent regulation, mortgage tax deduction and interventions in the spatial planning system and comparing differences for the three regions (Eskinasi, 2011).

An expert panel was formed to provide guidance to the modeling project. It consisted of two leading housing academics, housing experts from CPB, SCP[6] and the Economic Research Institute of the Construction Industry (EIB), policy makers from the (former) Ministry of Housing and expert staff from PBL. A first plenary session was held in June

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[5] Most notably modeling studies of the Economic Assessment Agency on the rental (Romijn & Besseling, 2008) and owner occupied (van Ewijk et al., 2006) sectors, a household behavioral model (Ras et al., 2006) an anthology of housing market critiques (Don, 2008) and of course the dP&W real estate markets model (DiPasquale & Wheaton, 1996).

[6]CPB Netherlands Bureau for Economic Policy Analysis deals with economic aspects of many policy fields, mostly on the national level. PBL Netherlands Environmental Assessment Agency deals with environmental issues, land use, agriculture and food quality, water management, regional development, regional economies and housing markets. SCP is the Netherlands Institute for Social Research, taking mostly the household viewpoint. All three agencies therefore work on housing market models and studies but sometimes have different viewpoints and opinions.

2010, when work on version 1.0 of the model was in full swing. Later on, the modeler regularly contacted members of the expert panel for advice and feedback.

The shift in purpose of the model should be noted: the initial purpose was to model the problematic housing market behavior on the national level. At that time, CPB only just published their own national housing market model (Donders et al., April, 2010) , based on the integration of two separate studies of the owner occupied (van Ewijk et al., 2006) and the rental sector (Romijn & Besseling, 2008). Only with PBL hiring the Houdini modeler, the regional aspect was added to the modeling purpose. Possibly, this saved Houdini from a competing model issue with the CPB housing market model (Eskinasi & Fokkema, 2006; Donders et al., 2010), but necessitates future fundamental rethinking of the model's focus as regional interactions need to be added.

4. The resulting model

4.1 Overview of model sectors and general aspects

Houdini 1.0 was built in Powersim Studio 8, SR5 and consists of five main sectors: 1) demand side; 2) the housing market based on dP&W; 3) market parties on the supply side; 4) government interventions and 5) effect indicators. Many variables exist in pairs for both the rental and the owner occupied sector (suffixes R and O respectively).

The rent axis in the dP&W model is defined here in terms of *user costs*: the real economic costs for using real estate, the standard approach in the national and international housing economic literature (e.g. Poterba, 1984; Wheaton & diPasquale, 1996). An important feature of user costs is the inclusion of housing appreciation for owner occupiers: increases in house prices build up equity and should be taken as income. The exact specification is very relevant and played a role in CPB criticisms of the first model.

Furthermore, houses are very heterogeneous as to size, quality, amenities and location. Housing economic literature defines the housing stock in terms of abstract housing services or quality units. Larger or better houses (housing structures or housing units) then provide more housing services than smaller ones. Economists criticize planners for overemphasizing housing units and demographic prognosis and underestimating demand for housing quality based on income growth (Eichholtz & Lindenthal, 2008, p. 80) and the negative welfare effects of all government interventions.

4.2 Main feedback structure

Figure 2 depicts the essential stocks, flows, variables and loops of Houdini. Modeling details were removed here for clarity's sake. The main feedback structure consists of three pairs of balancing loops B1, 2, 3 , two single balancing loops B4 and B5, plus two reinforcing loops. First of all, both housing sectors have main dP&W loops B1a and B1b. As mentioned above, these connect housing stock to user cost to asset price to construction to housing stock, with negative polarity on the link between housing stock and user cost. Note that the asset price in owner occupied housing determines profitability also for the rental sector. In B1b, rent regulation RRG hampers movement of user cost UCR and creates a value gap between the investment value and the free market price of rental dwellings.

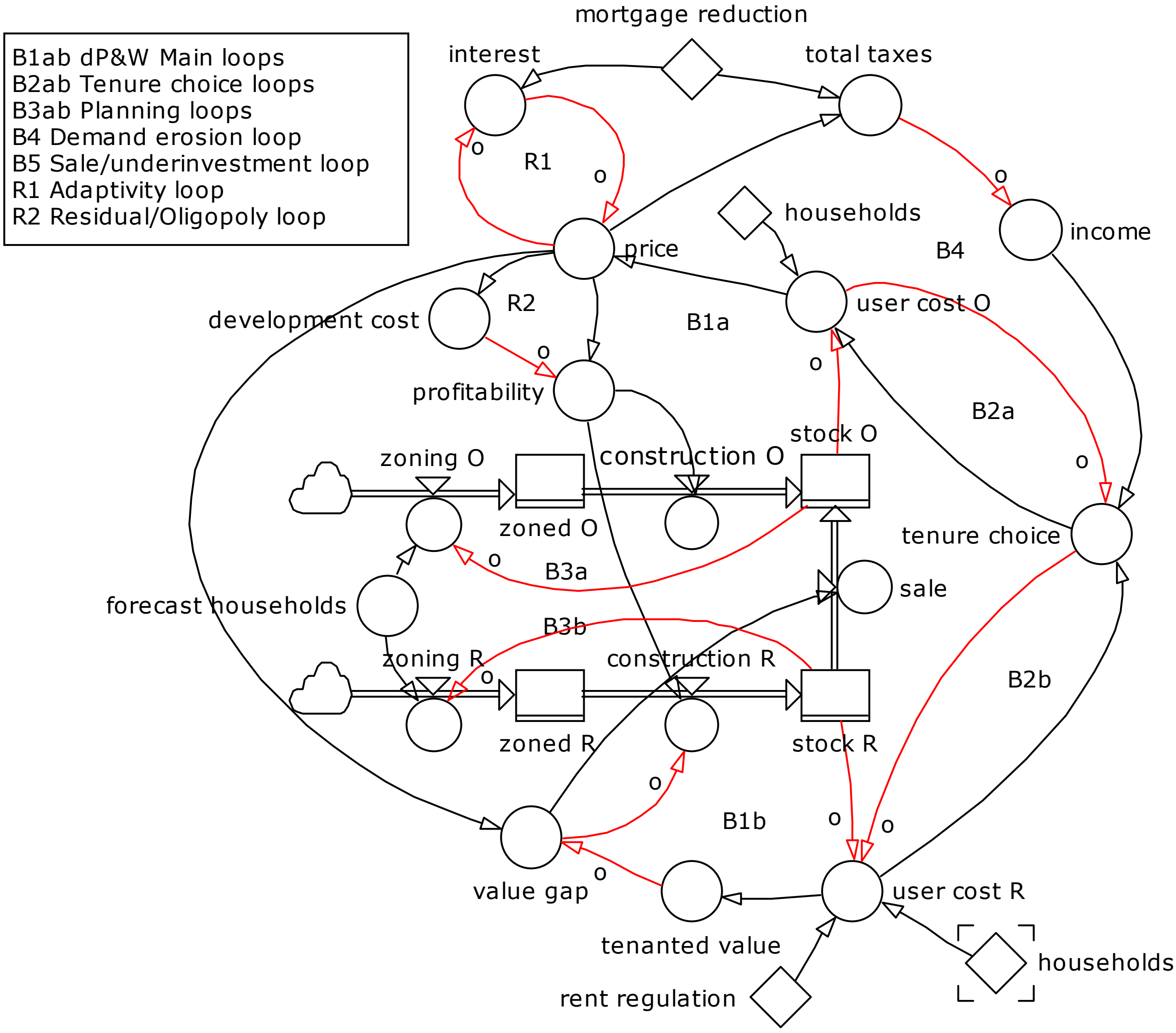

Figure 2
Causal loop structure. Arrows labeled with [o] are opposing causal links

Two reinforcing loops interfere with the dP&W loop for the owner occupied sector, forming an *out of control* archetype (Wolstenholme, 2003). R1 depicts so-called adaptive behavior of housing market consumers. R2, the residual land price / oligopoly loop, has increasing development costs erode profitability and thus harms construction. B2O and B2R represent households tenure choice being influenced by user costs in both sectors in *relative outcome* structure (Wolstenholme, 2003). B3a and B3b represent the government planning system, trying to fill the gap between future demand and current housing stock by zoning land. Intake of zoned land for new construction, however, is in the span of control of the dP&W market mechanism and the erosive residual / oligopoly loop R2. B4 depicts that mortgage tax reduction affects state expenditure financed from income taxes. It thus suppresses effective demand for housing by lowering net consumable incomes. Finally, B5 shows how increasing house prices in the owner occupied sector widen the value gap with the rental sector. This erodes new construction of rental housing and stimulates sale of rental housing. The owner occupied sector grows and prices decrease. This loop is existent only with rent regulations and mortgage tax reductions in place.

4.3 Detailed model description

A full model print is included in appendix 1. Numbers in this description refer to the diagram.

Sector 1: demand side first depicts the development of three main exogenous variables.

(1A.) Stock HH represents the total number of households. It has a combined in/outflow governed by the equation dHH = (a + b * TIME) *HH. Parameters a and b were estimated from a demographic prognosis. B is negative, so in due time, the population will decline rather than grow. The three regions in (Eskinasi, 2011) were chosen in order to display large variation in population growth: region C was already declining in 2010, whereas region B would continue grow for nearly a century. In average region A, population growth decays to near zero at the end of the simulation period, i.e. 50 years.

(1A2) Secondly, stock CHI (consumable household income) is governed by a single inflow and an annual growth rate. (1A.3) Finally, stock avIR represents the mortgage interest rate. avIR is far less volatile than the capital market interest rate exIR, because Dutch household mostly fix interest rates for long periods, so that significant smoothing takes place with a five year delay.

The main stocks are translated into actual demand for housing. So, in order to properly model tension between the planners' and economists' approaches, two pairs of demand variables are needed: one pair in terms of number of houses and one pair in terms of housing quality.

(1B.1) Tenure choice TCO is the fraction of households preferring owner occupied housing over rental housing. Its dynamics are based on a probit regression taken from (Ras et al., 2006), where household income CHI and the ratio of user costs in both housing sectors are the main determinants. (1B.2) Multiplying HH and TCO yields the base demand BDO for owner occupied housing in numbers of houses and HH*(1-TCO) base demand for rental BDR. (1B.3) For the second pair (DQO and DQR), demand in terms of quality was derived from user costs, income and tenure choice with equations and data taken again from (Ras et al., 2006).

Please note that the model needs three units different units for its variables to capture stock and demand properly: households, housing units and quality units. One physical housing unit then has a certain number of quality units as a property. Likewise, one household exerts demand for one housing unit but also or a certain number of quality units. Auxiliary variables were used for conversion of housing units and quality units. The demand equations also need explicit conversion of households into housing units. This seems pretty straightforward, but the assumption of one housing unit per household is a very fundamental cornerstone of planners thinking. Vennix (1996, p. 220 - 221) also encountered this issue. It is exactly the point of economist critique: housing units are very heterogeneous as to quality and demand is exerted on both numbers and quality of housing. Whereas economists would model only demand and supply of quality units (e.g. Donders et al., 2010), Houdini does take into account both housing units and quality. If the current housing market planning system delivers sufficient housing units but insufficient quality units (i.e. deliver houses with too low quality), this is a sign of system underperformance.

Sector 2: dP&W models for rental and owner occupied sector consist of a production pipeline and its main governing balancing feedback loop. (2A.1, 2B.1) The production pipeline consists of three stages: zoned land (ZLO and ZLR), housing in construction (ICO and ICR) and the standing housing stock (HSO and HSR). The inflow to ZLO represents the government zoning new land for residential purposes (see sector 4). Developers, contractors and housing associations are, however, in control over their investment decision to take zoned land into development, i.e. the connecting flow CS between ZL and IC. Connecting flow CF depicts houses in construction being finalized after a two year construction time tC and added to the main stock. From the main stock, annually a small fixed share of houses is being demolished (outflow DM and demolition rate pDM).

(2A.2; 2B.2) The main governing balancing feedback loops first connects the housing stock HS and the demand variables into the user costs UC. This relation has a negative polarity. User costs are then translated into asset prices VP, which in turn influence the investment decision CS for new construction. The second and third step of the loop have a positive polarity.

(2A.2, 2B.2) For translating stock HS and demand DQ into user costs UC, the equations used before for demand DQ from (Ras et al., 2006) were rewritten in order to calculate an auxiliary variable for user costs auxUC. This yielded inelegant equations with meaningless constants in exotic units. CPB also criticized this particular modeling element and suggested a better solution discussed below. The final user cost variables UC are first order material delays with delay times taUC. In the owner occupied sector, taUCO = 12 years as owner-occupiers fix their annual mortgage payments for a long period. Adaptation time in the rental sector is one year.

(2B.2) In the rental sector, three forces influence the final setting of user costs. First, the demand side user costs (CMR), based on the consumers' willingness to pay. Secondly, the investor's side market rents, covering for the investment (IMR) and finally, state rent regulation (RRG), overruling CMR and IMR.

(2A.3, 2B.3) The *second step* takes user costs to asset prices. In the basic dP&W framework, user costs are simply divided by a capitalization rate to obtain house prices. In the Netherlands, the situation is far less straightforward.

(2B.3) First, there is no direct market price for rental dwellings. In reality and in the model, it is deduced from prices of owner occupied housing, by comparing rental houses being sold or using hedonic pricing techniques[7]. Stocks VPO and VPR represent the market prices for vacant properties to be sold. For rental housing, also an tenanted investment value TVR[8] exists, based upon regulated rents divided by a constant capitalization factor IFR taken from (Donders et al. 2010) . TVR is, due to rent regulation, far lower than VPR (Conijn & Schilder, 2009). A so-called value gap VGP (=

[7] We modeled VPR to be proportional to VPO on basis of the average ratio of quality between both sectors.
[8] A simple single capitalization rate IFR was used for translating rental user costs UCR into the tenanted value TVR. TVR = UCR/IFR.

VPR-TVR) exists, discouraging construction (CSR) and stimulating sale (SRH) of rental houses.

(2A.3.) Second, in the owner occupied sector, mortgage interest tax reduction plays a fundamental role. Housing supply hardly reacts to price increases (Vermeulen & Rouwendal, 2007), so all tax benefits only increase house prices, rather than supply of houses. (Conijn, 2008, p.156). As mentioned above, user cost theory takes into account owner occupiers profits from house price increases in the annual economic costs. DiPasquale & Wheaton (1996, p. 247-255) describe three variants: exogenous, adaptive and rational price expectations. Exogenous means that owner occupiers do not base price expectations on housing market trends but on e.g. inflation or general GDP growth.

Adaptivity has households take into account *historic* price increases as a basis for current decision making and introduces a reinforcing feedback loop which feeds asset price increases back into the capitalization factor, potentially allowing for booms and busts in the housing market[9]. Rationality, on the other hand, allows households to correctly forecast *future* price increases (based on income growth, interest rates, supply responses etc.) and act accordingly.

The first version of our model has the capitalization factor for the owner occupied sector IFO based on a) a fixed component representing transaction and maintenance costs b) a component representing the interest rate avIR and the mortgage tax reduction rate MTR and c) an adaptive component (scaled down historic price increases smoothed over five years) which, however, proved a stone of content as described below.

Sector 3: Supply side behavior is the final step in the main governing feedback loop (3.A). The dP&W model determines construction (starts CS) from a) the gap between asset prices VP and construction costs DC and b) an elasticity variable: asset prices higher than construction cost entice developers to start building new houses. Vermeulen and Rouwendal (2007) however claim that due to government interventions, housing supply is nearly fully inelastic to price increases in the short and medium run.

Notwithstanding, annually about 80,000 houses are being built in the Netherlands (CBS, 2010), As commercial developers and housing associations build houses (and not the national or local government), it is plausible that the mechanism explaining recorded construction is to some extent price related but more complex than the simple linear scheme presented in the basic dP&W model.

Buitelaar (2010) explains financial reasons for active land policy by Dutch municipalities: recovery of costs made and value capturing of very lucrative green field development. Value capturing is possible by means of residual land pricing. Brick and mortar construction costs grew only moderately (Besseling et al., 2008) from the 1970s onwards, so land prices must absorb the remaining share of house price increases.

[9] Note that Barlas et al. (2007) use only the dP&W graph of market behavior responses under the adaptive system for demonstrating cyclicality. dP&W (1996, p. 247-255) simulated all three modes.

Furthermore, a high level of market concentration characterizes the Dutch development and construction industry (Buitelaar and Pouls, 2009): a small number of large firms dominates the market and owns most land to be zoned for residential development, especially in the densely populated Randstad. As price levels in the housing stock, rather than the flow of new construction determines house prices in the Netherlands (de Wildt et al., 2005, p. 9), we modeled development costs DC to closely follow house prices VP in the stock. Upward adaptation time is fast, but downward adaptation -when house prices fall- is slow because of new negotiations, postponing of new construction starts etc. Development costs and house prices determine profitability DPF (= (VP-DC)/VP) which in turn sets the absorption of zoned land ZL for new construction starts CS. [10]And because development costs rapidly adapt to house prices, high profitability is maintained only when house prices *rise.* Initially, the modeler also assumed that oversupply of zoned land would put downward pressure on the development cost: with surplus supply, land would become cheaper. Land market experts questioned this loop because most land is already owner by developers.

(3A) The rental sector has a comparable structure, but additionally takes into account the value gap VGP: a higher value gap puts extra downward pressure on construction starts.

(3B) Finally, rental housing can be sold to individual owner occupiers. Because of the existence of the value gap, selling is very profitable and the annual sale rate SRH reacts accordingly. Housing associations, however, tend to be reluctant to sell as they strive for a sufficient stock of rental housing. Market driven sale can be switched on and off. In order to properly convert rental into owner occupied housing, we must take into account the different levels of housing services per housing unit. Although quality differences between the rental and owner occupied sector are being taken into account in the demand and user cost equations, Houdini version 1.0 does not yet have a full double bookkeeping for housing and quality units and particularly the housing sale section is therefore not yet flawless.

Sector 4 depicts government interventions in the housing market. (4A) First, local governments regulate land being zoned for new construction (LZ). As Eichholtz and Lindenthal (2008) argue, government overemphasizes demographic development in land zoning. We first modeled a household forecast variable FHH with the same form as actual households HH (see demand sector 1), giving a prediction of the household 15 years ahead of simulation time. We then followed the logic of the planners' paradigm by subtracting the current housing stock from the future number of households to obtain the future housing shortage FST and to determine total annual inflow of newly zoned land (LZT= FST/tF). The obvious unit error (households are not houses) was avoided by explicating the one to one conversion rate. The tenure choice variable TCO sets distribution of newly zoned land over rental and owner occupied housing.

(4B) Second, the government regulates rents. Especially for social rental housing, both rent levels and annual rent increases are tied to a ceiling. Housing associations rent out houses for even less than state set maxima because of their social objectives. In rural

[10] This structure is similar to the Cournot oligopoly equilibrium (Varian, 1992, p. 286), in which a limited number of firms set quantities produced in order to influence prices and to have an extra oligopoly profit.

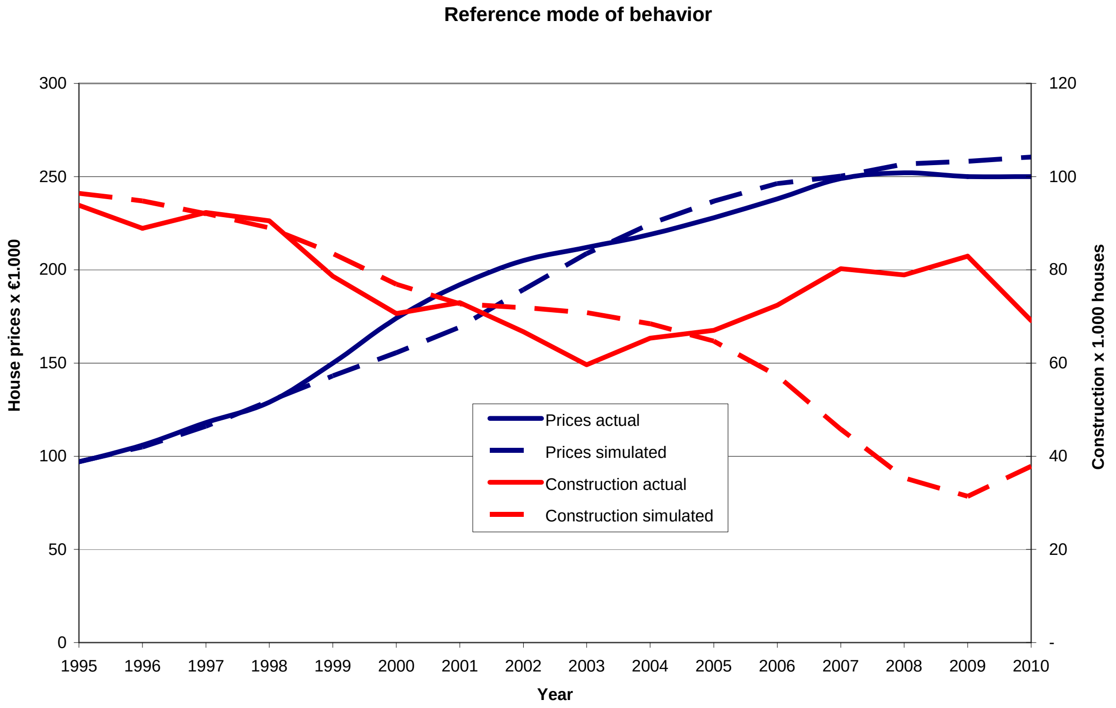

Figure 3
Reference mode of behavior and simulation

areas, market rents may be below set maxima, but certainly not in the larger cities. In the model, a stock variable RRG (rent regulation) limits the final user cost variable. By increasing the inflow of RRG to a high percentage, it is possible to simulate rent deregulation policy experiments.

(4C) Finally, public expenditure on mortgage interest tax reductions (MTR) is financed from income and company taxes. It therefore influences net consumable household income CHI. Lowering public expenditure may harm demand for housing, but can be compensated by decreasing taxes, so-called 'back funneling'. The model comes with different alternative taxation mechanisms for policy experiments, e.g. taxing deregulated rents (RPT) or sale of rental housing (SRT). In times of government budget cuts, not all revenues must be funneled back, hence the existence of a back funneling parameter BFF.

Sector 5 of the model also contains several effect indicators. The house price to income ratio PIR, the average user cost to income ratio UIR and the percentage of total income spent on fiscal measures for the housing market pFEI relate to the economist's perspective. Quantitative housing shortage HST, average quality of housing stock HQR and average demanded housing quality BDQ refer to the planners' way of thinking. Furthermore, the ratio of user costs in owner occupied and rental houses is used as an indicator for neutral treatment of both tenure categories. These variables were used for comparing regions and policy experiments and are all relative measures, i.e. not related to the size of a region.

4.4 Validation tests

Several validation tests were carried out with the model (Forrester & Senge, 1980). Boundary adequacy tests were not yet carried out in this stage, but may be based on comments received from the expert panel (see below). Structure and parameter verification were based on existing housing literature and statistical sources (e.g. CBS, 2010). Dimensional consistency was safeguarded with the modeling software and is correct. Only the demand equation in (2A.2, 2B.2) was to some extent problematic, and in many places conversions between household, housing units and quality units had to be added for consistency's sake (compare Vennix, 1996, p. 220 - 221).

As for behavior reproduction, the simulation was tested against statistical data over 1995-2000 with Theil's inequality statistics (Sterman, 1984). Figure 3 shows the reference mode of behavior and simulation results for housing prices and new construction. The model is very precise as to housing stock development at a 1% RMSPE error and has acceptable statistics for price development[11]. Housing supply is notably difficult to model (diPasquale,1999) and leaves room for improvement as well[12]: Houdini misses the upswing of construction from 2004 onwards, swings further down until 2009, when actual construction declined due to the credit crunch. The upswing of actual construction is strongest in the rental sector from 2006, when housing associations intensified their efforts. This is not yet conceptually reflected in the model.

Several parameter sensitivity analyses were run using software facilities. The sensitivity of the model to capital market interest rate exIR reflects well documented responses of real housing markets: increasing interest rates decrease house prices and make construction collapse. Also varying household income growth yields recognizable responses.

The response of the model to price and especially income elasticity of demand is difficult to interpret. This confirms the unit consistency test in the sense that the demand section (2A.2, 2B.2) is pointed out as a conceptually weak point in the model. Sensitivity analysis with the time offset of the planning system (4A), albeit far fetched at first sight, yields a proper system dynamics counterintuitive insight: a longer offset has the planning system anticipate earlier on future population decline. Fewer houses are built when demand is still growing so shortages and prices increase. In the regulated situation, this tempers demand so much that the quality fit of demand and supply improves. A short time offset causes the opposite effect in that the planning system produces more in the first years, leading to over supply when population declines. In addition, demand is stimulated to such an extent that the quality fit worsens rather than improves.

4.5 Base run and policy experiments

The base runs in figure 4 show the long run effect of unchanged housing policies on the three regions. Starting year 0 equals 1995 and the simulation runs for 50 years. Region A represents the national average, region B is the densely populated northeastern part of the Randstad around Amsterdam, and Utrecht, region C is the declining far southeast of Limburg. B has a higher and C a lower income growth ratio than average A. In Region A, population growth slows down and reaches 0 near year 50. Region B keeps growing, but the population of region C declines from year 15 already.

The 1990s saw significant decreases in mortgage interest rates, with very limited regional differentiation. For the long term, a fixed assumption of interest level was made of 3% in real terms. The simulation shows the recognizable rapid growth of prices in all three regions. Differences in income growth, demography and starting situation of the

[11] RSMPE ≈ 5% & Uc ≈ 0,85 (Eskinasi, 2011, p.62)
[12] RSMPE ≈ 13% & Uc ≈ 0,85 for owner occupied and RSMPE ≈ 25% & Uc = 0,95 for rental (ib).

housing stock (prices, ratio of rental) explain different growth curves. Adaptivity (loop R1) starts stimulating price developments. But economic growth slows down (income growth decreases and interest rate climbs) and house price growth levels off quite suddenly. Development costs used to lag to house price development, but now rapidly catch up, decimating profitability and construction. When the system recovers from this external shock (interest rates and income growth stabilize, demography slows down), it is effectively exhibiting zero real growth in house prices in region A, returning growth in B and accelerating decline in C. This closely matches the reference mode of behavior as described above. Construction recovers in A and B, but not in C.

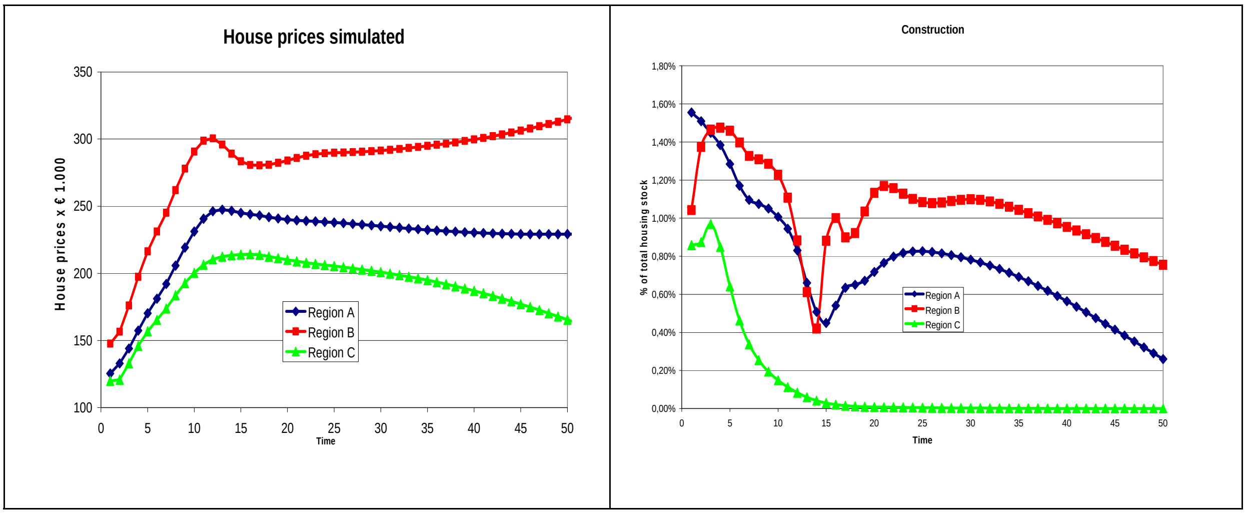

Figure 4
Base simulation of prices and construction for three regions

Policy experiments were carried out from year 20, focusing on the mortgage interest tax reduction and rent regulation. Rent deregulation is simulated by allowing higher rent increases. Causally speaking, the hindrances to balancing loop B1b are gradually lifted. Rents and asset prices rise, but shifts the balance in the tenure choice loops towards owner occupied housing. Rents will grow until market rents are reached: that is when investors have a certain return level on the asset price of rental dwellings, which is connected to the asset price of owner occupied dwellings. Because growing region B has relatively high house prices, it takes a longer time to reach market rents than in average region A. Likewise, declining region C with lower prices reaches market rents earlier. Higher rents lead to a shift in tenure choice towards owner occupied housing, increasing both price and construction levels in it.

Decreasing the mortgage tax reduction from an average 25% to 15% in year 20 leads to somewhat lower prices. In causal terms, lower mortgage tax reductions increase the effective interest rate IFO. Construction responds dramatically in the short term and shrinks 40% relative to the baseline simulations. Because the growth of the housing stock stops and demand continues to grow, the initial price loss is compensated to some extent in the medium term. On the longer term, the market prices stabilize only just under the level of the baseline. Region B and C respond similarly, albeit with construction in declining region C coming to a complete halt by year 15 .

Combining both experiments shows that the effect more or less add up. Higher rents shift demand to owner occupied housing. Reducing mortgage tax reductions decreases house prices (due to an increased effective interest rate IFO) and construction of owner occupied housing even more. The transition time of regulated rents to market rents, however, is shortened: lower house prices lower market rents as well.

5. Follow up activities and reactions to Houdini

The modeling report was shared with the members of the expert panel and several meetings were held to obtain their feedback of the model structure and model outcomes. The first meeting of the expert panel in June 2010 yielded suggestions as to the relevance of housing quality, the necessity of regional interactions, modeling simplicity and the importance of a well chosen base line simulation.

Within PBL, Houdini was received positively, but no very targeted feedback was provided. This may be caused by the lack of a sufficiently specific purpose for Houdini. One surveyor, generally critical of large scale modeling, however, found the system dynamics approach in comparison more attractive as it incorporates behavioral responses of actors and support what-if policy experiments.

Simulation of future house prices nevertheless causes some nervosity. A draft article containing price graphs for a professional magazine was postponed awaiting further support of well-established academics because of potential fuzz with national and local policy makers. The same attitude towards the price graphs was found with the CPB housing economists in the expert panel.. Their model would only show the deviation of policy experiments from the base path.

Moreover, the CPB housing economists contributed to a strong but constructive debate on the underlying principles of Houdini. First, they criticized the lack of economic rigor on the demand side: Houdini has no explicit bookkeeping of expenditure on housing. As mentioned before, the demand equations in 2A.2 and 2B.2 were weak as it comes to meaningful units. The CPB experts suggested using a behavioral system of housing consumers consisting of a budget constraint and maximization of utility. These suggestions provided a clear framework for modeling demand with straightforward equations in comprehensible units and will be implemented in a next model version.

The adaptive price expectations in 2A.3 were most controversial. Notwithstanding empirical support for households acting adaptively on the housing market (e.g. Hamilton & Schwab, 1985, Case & Shiller, 1988, DiPasquale & Wheaton, 1996, p. 251), rationality is axiomatic in mainstream economics. And with CPB mainstream economists as partners in the modeling project, the rationality/adaptivity issue was a hurdle to take in building confidence in the model (Forrester & Senge, 1980). On the other hand, straying from axiomatic perfect competition in reference to the structure of the Dutch supply side (with planning system and oligopoly) provoked questions of clarification rather than an axiomatic debate. Overall, CPB is supportive of Houdini, in particular with regard to the regional differences and interactions and explicit modeling of the planning system. CPB was the first to mention Houdini on their website.

Houdini was put to the test in a project on long term spatial scenarios for the Netherlands. A land use model, TIGRIS XL (Zondag & de Jong, 2011) provides the main quantitative framework. It is a large scale model of employment, transport, housing and other land use. It does not explicitly model house prices. Both Houdini and TIGRIS used inputs from several demographic and economic scenarios. Both Houdini and TIGRIS simulated new housing construction. A sufficient fit between both models in terms of Theil statistics then allowed the house price output of Houdini to be accepted for the project. Furthermore, data collected for Houdini contributed to the forthcoming final project report. (PBL, 2011)

6. Evaluation of the project

Houdini 1.0 is only the starting point, so no final conclusions can be formulated at this point. The impact of Houdini 1.0 is limited, because its purpose is not well defined: it started as a 'hobby project' with a regional dimension added only later. Positioning Houdini, however, as part of a modeling framework with TIGRIS XL necessitates regional interactions and a solid foundation in economic theory. Development of Houdini 2.0, incorporating regional interactions, has already started. On the other hand, the introduction of Houdini within PBL demonstrates once more the agility of system dynamics modeling in comparison to large scale modeling. The reactions of the expert panel are generally positive and constructive as described above.

7. Conclusion and discussion

Upon their first encounter in the early seventies, urban dynamics and housing economics clashed and thereafter developed in isolation of one another. Nevertheless, stock, flows, feedback loops and real world policy problems are innate to both fields. At least one implicit system dynamics model, dP&W, exists within housing or real estate economics. Only since 2007, references to it are found in system dynamics literature. It may be useful to explore other implicit system dynamics models in urban, real estate and housing economics and related sciences (geography, urban sociology, planning) and to model them using formal system dynamics methodology. Notwithstanding the inspirational sparks of Urban Dynamics, a closer connection between system dynamics and the substantive sciences may be to the benefit of both fields.

Houdini is a housing market model based on both system dynamics and housing economics. Its development indicates that a reasonably trained system dynamics modeler with a background in the substantive field can make construct a targeted and working housing market model in a very limited amount of time, at least in comparison with other modeling approaches. The most important stakeholders support the development of Houdini and the choices made during the project. Notwithstanding a significant wish list for a major revision, Houdini 1.0 is a functional model, complying to several validity tests, with a first practical application in the long term spatial scenario project finished. It offers a perspective of a system dynamics model becoming part of a national government modeling framework.

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Appendix 1: structure of the full model