Martin Janíčko

University of Economics, Prague

Housing price changes, general equilibrium and welfare

Abstract

This paper explores in detail individual as well as aggregate welfare effects of housing price changes and the effects of housing price changes on non-durable consumption and housing in the framework of heterogeneous agent general equilibrium model with multi-sector production side. First of all, the model includes two types of households: the credit-constrained ones and the unconstrained ones. These types differ not only because of the presence or absence of credit constraints, but also according to the structure of the factors of production that they possess. The modeling of the production side of the economy is based on Davis and Heathcote (2005) and includes an intermediate good production sector, a composite consumption good production sector, residential investment good production sector and housing good production sector. Besides welfare comparisons between steady states, the welfare changes during transition between steady states are also calculated. Finally, the model is used to explore the implications of the shocks corresponding to the ones observed in the US economy over the period 1991-2009.

Keywords: general equilibrium, housing price changes, aggregate welfare, binding credit constraints, multi-sector production, building permit regulation

1 Introduction

Over the last 16 years the US housing market has been characterized by drastic changes in housing prices. In particular, in the period from 1995 to 2006, according to National Association of Realtors, the median house price increased by absolutely unprecedented 190%, i.e. almost tripling. However, starting from 2007, because of the financial crisis and the bust in the housing market, the trend has reversed and the median house price has decreased by around 52%. This bubble-to-bust behaviour has motivated number of economists to try to better understand the very functioning of housing markets, including its inter-linkages with other economic sectors.

Such enormous housing price shocks have had considerable implications not only for the financial stability of the US and consequently the global economy, but also for household consumption and welfare, which was extensively explored in the previous literature both for individual groups of households as well as on the aggregate level. For exploring the effects of housing price changes on consumption and welfare of separate groups of households, mainly life-cycle models of housing choice have been used. For instance, Campbel and Cocco (2007), based on the life-cycle model and UK micro-level data on real non-durable consumption growth and real housing price growth, demonstrate high positive correlation between an increase in the growth rate of housing prices and growth rate of non-durable consumption. Further, Li and Yao (2004) also employ a life-cycle model of housing tenure choice, and they find that for homeowners less than 40 years old, an increase in housing prices leads to welfare losses, while in case of older homeowners it leads to an increase in both their welfare as well as consumption. Equally, Kiyotaki et al (2011) develop an open-economy life-cycle model of a production economy where residential and commercial structures are built by using land and capital. They use the model to investigate how housing prices, aggregate production and wealth distribution react to changes in technology and financial conditions and which groups of households gain and which lose from changes in fundamentals. They find that a permanent increase in the growth rate of labor productivity and a decrease in the world real interest rates substantially redistribute wealth from net buyers of houses to net sellers with a housing price hike.

Bajari et al. (2005) explore the aggregate welfare effects of housing price appreciation. In this paper the authors consider only exogenous changes in housing prices and assume that households are not credit-constrained. The authors develop a new approach to measuring the changes in consumer welfare due to changes in the prices of owner-occupied housing, which defines welfare adjustment as the transfer in the form of income required to keep expected discounted utility constant, given the change in housing prices. Using their measure of welfare adjustment, the authors show that there is no change in aggregate welfare due to an increase in the price of the existing stock of housing. Similarly, Tsharakyan and Janíčko (2010) analyze the effects of housing price appreciation on aggregate welfare, but generalize the previously available results by incorporating credit constraints and endogenous housing price into welfare effects calculation. At first the credit constraint is incorporated into the model with endogenous housing price, and it is shown that in this model housing price appreciation leads to an improvement in aggregate welfare due to the effect of credit constraint relaxation resulting from housing price appreciation. Then the housing price is endogenized by modeling the supply side of the housing market. Finally the demand and supply shocks causing housing price appreciation are calibrated according to US housing market data from years 1995-2006, and it is demonstrated that housing price appreciation is driven by the given combination of demand and supply shocks still leads to improvement in aggregate welfare.

It is important to note that while Tsharakyan and Janíčko (2010) keep the income formation exogenous, do not model the composite good production sector and use Bajari's (2005) definition of welfare adjustment, the present paper analyzes the aggregate welfare effects of housing price changes in a full general equilibrium environment. It contributes to the previous literature by building a heterogeneous agent general equilibrium model in which the aggregate welfare effects of housing price changes can be studied in a more comprehensive way. The model includes two types of households: the credit-constrained ones and the unconstrained ones. These types differ not only because of the presence or absence of credit constraints, but also from the point of view of factors of production which they own. All the factors of production, i.e. capital, land and labor, are owned by households and are supplied to the firms for production. There are two goods in this economy: a housing and a composite consumption good. Modeling of the production side of the economy is based on Davis and Heathcote (2005) and includes the composite good production sector, the housing production sector, and the intermediate good production sector.

A more explicitly and thoroughly modeled framework allows brand new and increasingly important insights into the question of interest to be gained. First and foremost, in this model households' income and factor prices are determined endogenously, so any shock causing housing price changes affects also the households' income and returns on alternative investment assets, such as bonds and housing. Moreover, if in the previous model the effect of housing price changes on consumption comes only through the borrowing/lending channel, in a general equilibrium setting, in addition, the consumption allocation is explicitly dependent on housing price, reflecting the direct wealth effect of housing price changes. Finally, since the model includes several production sub-sectors, it is possible to see how any shock causing a change in housing prices leads to redistribution of factors of production between those sectors.

After the model is defined, the steady state is calculated. Then it is explored what happens with aggregate welfare when different demand and supply-side shocks cause changes in housing price and economy transfers to a new steady state. Sources of housing price shocks include changes in productivity of different production sectors and changes in maximum loan-to-value ratios. Both the change of aggregate welfare in transition as well as change of aggregate welfare in the new steady state compared with the old steady state are calculated. Finally, both the effects of housing price appreciation as well as the effects of housing price decline, which is currently characteristic for the US housing market, are considered and their impact is properly elaborated on.

The rest of the article is organized as follows: Section 2.2 describes the model. Section 2.3 contains the derivation of the steady state. Section 2.4 contains log-linearization of the model, Section 2.5 contains the calibration. Section 2.5 presents numerical results.

2 The Model

2.1 Production Sector: Housing Construction and Composite Good Production

Modeling of the production of housing and composite good is based on Davies and Heathcote (2005), but is simplified for the purposes of the present paper. Perfectly competitive intermediate goods producing firms use capital rented from the household and labor supplied by the households to produce intermediate goods: construction (denoted by "c"), manufacturing (denoted by "m") and services (denoted by "s"). The production function for intermediate goods follows standard Cobb-Douglas functional form. The production of intermediate goods is subject to sector specific productivity shocks denoted by $z_{j,t}$. The productivity shocks follow standard AR(1) process, which are calibrated later. The production function for intermediate goods is given by $Y_{j,t} = z_{j,t} K_{j,t}^{\alpha_j} N_{j,t}^{1-\alpha_j}$ where $j \in c, m, s$ and K stands for capital and N stands for labor. The maximization problem for the intermediate goods producers is then given by

$$\max_{\{K_{j,t},N_{j,t}\}} [p_{j,t} z_{j,t} K_{j,t}^{\alpha_j} N_{j,t}^{1-\alpha j} - w_t N_{j,t} - r_t K_{j,t}] \text{for } j \in c, m, s \tag{1}$$

s.t.

$$K_{j,t}, N_{j,t} \geq 0 \tag{2}$$

$$z_{j,t} = \overline{z_j} + a z_{j,t-1} + e_{j,t}, \tag{3}$$

where $p_{j,t}$ is the price of the corresponding intermediate good.The profit maximizing conditions for intermediate good producing firms are given by

$$p_{j,t}\alpha_j z_{j,t} K_t^{\alpha_j-1} N_t^{1-\alpha_j} = r_t, \tag{4}$$

$$p_{j,t}(1-\alpha_j) z_{j,t} K_{j,t}^{\alpha_j} N_{j,t}^{-\alpha_j} = w_t. \tag{5}$$

The goods produced by intermediate good producers are used as inputs by final good producers for production of a composite consumption good and a residential investment good. Let us denote by subscript co the consumption good and by subscript res the residential investment good. The production function for final good $f \in co, res$ is given by $Y_{f,t} = X_{cf,t}^{\alpha_f} X_{mf,t}^{\beta_f} X_{sf,t}^{1-\alpha_f-\beta_f}$, where $X_{cf,t}$, $X_{mf,t}$ and $X_{sf,t}$ denote quantity of, correspondingly, construction, manufacturing and services used in the production of the final good f. The final good producer's problem is given by:

$$\max_{X_{cf,t}, X_{mf,t}, X_{sf,t}} [p_{f,t} X_{cf,t}^{\alpha_f} X_{mf,t}^{\beta_f} X_{sf,t}^{1-\alpha_f-\beta_f} - p_{c,t}X_{cf,t} - p_{m,t}X_{mf,t} - p_{s,t}X_{sf,t}] \text{for } f \in co, res \tag{6}$$

s.t.

$$X_{cf,t}, X_{mf,t}, X_{sf,t} \geq 0. \tag{7}$$

Here consumption good is considered *numeraire*, and, consequently, $p_{co,t}$ is normalized to 1

F.O.C. for this problem are given by

$$p_{f,t}\alpha_f X_{cf,t}^{\alpha_f-1} X_{mf,t}^{\beta_f} X_{sf,t}^{1-\alpha_f-\beta_f} = p_{c,t} \tag{8}$$

$$p_{f,t}\beta_f X_{cf,t}^{\alpha_f} X_{mf,t}^{\beta_f-1} X_{sf,t}^{1-\alpha_f-\beta_f} = p_{m,t} \tag{9}$$

$$p_{f,t}(1-\alpha_f-\beta_f) X_{cf,t}^{\alpha_f} X_{mf,t}^{\beta_f} X_{sf,t}^{-\alpha_f-\beta_f} = p_{s,t} \tag{10}$$

The housing construction sector combines residential investment good with land to produce housing units. It is subject to sector-specific productivity shock. The introduction of a specific productivity shock is intended for generating negative supply shock in the housing production. Being more specific, according to Glaeser and Guyourko (2005), this was characteristic for the US of the 1990s and played an important role in the observed housing price dynamics. Essentially, they argue that in the 1990s new housing construction in the US was considerably limited by increasing difficulty of obtaining regulatory approval for building houses. This can be attributed to changing judicial tastes (that is willingness of judicial authorities to reject building permit approvals), increasing political pressures of existing homeowners, decreasing ability to bribe regulators, and rising environmental concerns. Such changes made the process of getting building permit for developers more costly both in monetary terms as well as in terms of time, or in other words, increased implicit costs of housing construction. Therefore, in our paper, the increase in the strictness of building permit regulation works through decreasing productivity in housing production sector. Moreover, following Saiz (2010), the level of strictness of regulatory restrictions is determined endogenously depending on the housing price level and the net change in housing demand, that is investment of households into new housing. Such determination of the degree of regulation tightness is quite logical since in case of higher demand pressure or lower price of the housing the political pressure of existing homeowners against new construction as well as environmental concerns and other factors should be stronger. Denoting regulation variable by rg, we assume that regulation strictness level is determined according to the equation $rg_t = \psi q_{t-1} + \chi x_{t-1}$, where $x_{t-1} = x_{c,t-1} + g x_{u,t-1}$ and ψ and χ are coefficients estimated later on in the paper. When determining the process for productivity per se, it is assumed that it could change not only because of regulation but also because of production specific factors. Thus in our model productivity in housing sector in period t denoted by η_t is dependent both on regulation strictness rg as well as on its previous period value and stochastic component. That is, equation for productivity in housing sector is given by $\eta_t = \sigma + \rho\eta_{t-1} + \phi rg_t + \varsigma_t$. The housing production function is given by $Y_{h,t} = \eta_t (X_{res,t})^{\epsilon} (La_t)^{1-\epsilon}$, where $X_{res,t}$ stands for the amount of residential investment good used as input in production of housing units and

La_t stands for the amount of land used. The profit maximization problem of construction firm is thus given by

$$\max_{\{X_{res,t},La_t\}} [q_t \eta_t (X_{res,t})^{\varepsilon} (La_t)^{1-\varepsilon} - p_{res,t} X_{res,t} - p_{l,t} La_t], \tag{11}$$

s.t.

$$X_{res,t}, La_t \geq 0, \tag{12}$$

$$rg_t = \psi \log q_{t-1} + \chi \log x_{t-1}, \tag{13}$$

$$\eta_t = \sigma + \rho \eta_{t-1} + \phi rg_t + \varsigma_t, \tag{14}$$

where q_t stands for the price of a housing unit, $p_{l,t}$ stands for the price of land and $p_{res,t}$ stands for the price of residential investment good. The profit maximizing conditions for housing construction firms are given by

$$q_t \eta_t \varepsilon X_{res,t}^{\varepsilon-1} La_t^{1-\varepsilon} = p_{res,t}, \tag{15}$$

$$q_t \eta_t (1-\varepsilon) X_{res,t}^{\varepsilon} {La_t}^{-\varepsilon} = p_{l,t}. \tag{16}$$

2.2 Households

There are two types of households in the model, credit constrained households with a population of size 1 and unconstrained households with a population of size g. [3] The most important difference between these types is, correspondingly, the presence and the absence of credit constraints in their optimization problems. In addition, to ensure that in equilibrium unconstrained households lend funds to the constrained ones, a different structure of owned assets is assumed.

[3] This may be perceived as quite unusual since in standard literature most frequent split is into homeowners and renters.

Both credit constrained and unconstrained households own land and the total amount of land in the economy, $\overline{L}$, is evenly distributed between and among households. Constrained households supply labor to the intermediate good producing firms. For the time being the inelastic labor supply case is considered and labor supply is normalized to 1. Constrained households derive utility from consumption of housing units and the composite consumption good and their utility function is denoted by $u(c_{c,t}, h_{c,t})$. The composite consumption good is assumed to be a *numraire* and its price is normalized to 1. Constrained households can invest into risk-free bonds and if the bond holdings chosen by them are negative, it means that households are borrowers.[4]

Constrained households are subject to credit constraint in the form of $b_{c,t+1} \geq -mq_t h_{c,t+1}$, implying that in each period households can borrow only up to a certain fraction m of the current value of their housing. When solving the model and simulating transitional dynamics, the credit constraint is used with strict equality. This means that in this paper credit constrained households are those who have to borrow up to the maximum limit when financing a housing purchase. On one hand, it can be interpreted as the upper limit on the degree of being credit constrained. On the other hand, such assumptions exclude from credit constrained households those that have enough cash to buy a house without a mortgage but find it more profitable in terms of net present value to finance their housing purchase with a mortgage. Such households would typically not borrow the maximum possible amount since this implies a higher interest rate. Thus, only the households that have enough savings for a low down payment and have to borrow the rest, are considered credit-constrained.

Housing depreciates at a constant rate δ_h. In what follows the allocations chosen by credit-constrained households are distinguished by subscript c. Households choose how many bonds to carry into the next period, $b_{c,t+1}$, how much housing stock to carry into next period $h_{c,t+1}$, and how much of the composite good to consume in current period, $c_{c,t}$. Based on the assumptions above the constrained household's problem can be formulated as follows:

[4]This essentially means the interest rate reflects purely a reward for postponed consumption.

$$V_c(h_{c,t}, b_{c,t}, \eta_t, z_{m,t}, z_{s,t}, z_{c,t}) = \max_{\{c_{c,t}, h_{c,t+1}, b_{c,t+1}\}} \{u(c_{c,t}, h_{c,t}) + \\ +\beta E_t V_c(h_{c,t+1}, b_{c,t+1}, \eta_{t+1}, z_{m,t+1}, z_{s,t+1} z_{c,t+1})\}, \quad (17)$$

s.t.

$$c_{c,t} + q_t x_{c,t} + s_{c,t} = w_t + p_{l,t}(\overline{L}/(1+g)) + i_t b_{c,t}, \quad (18)$$

$$b_{c,t+1} - b_{c,t} = s_{c,t}, \quad (19)$$

$$h_{c,t+1} - h_{c,t} = x_{c,t} - \delta_h h_{c,t}, \quad (20)$$

$$b_{c,t+1} \geq -m q_t h_{c,t+1}. \quad (21)$$

Taking F.O.C., rearranging, and using utility function of the form $u(c,h) = \frac{c^{1-\gamma}}{1-\gamma} + \theta \frac{h^{1-\gamma}}{1-\gamma}$, based on Campbell and Cocco (2007) yields the following Euler equations for credit-constrained households:

$$\upsilon_t = c_{c,t}^{-\gamma} - \beta E_t c_{c,t+1}^{-\gamma}(1 + i_{t+1}), \quad (22)$$

$$q_t c_{c,t}^{-\gamma} = \beta\theta h_{c,t+1}^{-\gamma} + \beta E_t c_{c,t+1}^{-\gamma} q_{t+1}(1-\delta_h) + \\ + m q_t \upsilon_t, \quad (23)$$

where υ_t is the multiplier of credit constraint.

Each of unconstrained households possesses the same quantity of land as a constrained one. Each of them supplies one unit of labor to the intermediate good producers. In addition, unconstrained households own capital, which they supply to the intermediate good producers. Assuming an additional source of income for the unconstrained households is justified from the modeling perspective for ensuring that they have additional wealth to lend in the equilibrium. On top of this, in real economy unconstrained households usually have higher net worth than the constrained ones. Capital depreciates at rate δ_k. Investment of unconstrained households into capital is denoted by I_t. The allocations made by unconstrained households are denoted by subscript u. Unconstrained households choose how many bonds to carry into the next period, $b_{u,t+1}$, how much housing stock to carry into next period, $h_{u,t+1}$, how much of the composite good to consume in current period, $c_{u,t}$, and how much capital to carry into the next period, k_{t+1}. The optimization problem of unconstrained households is given by:

$$\begin{aligned} V_u(h_{u,t}, b_{u,t}, k_t, \eta_t, z_{m,t}, z_{s,t}, z_{c,t}) \quad = \quad & \max_{\{c_{u,t}, h_{u,t+1}, b_{u,t+1}, k_{t+1}\}} \{u(c_{u,t}, h_{u,t}) + \\ & +\beta E_t V_u(h_{u,t+1}, b_{u,t+1}, k_{t+1}, \eta_{t+1}, z_{m,t+1}, z_{s,t+1}, z_{c,t+1})\}, \end{aligned} \tag{24}$$

s.t.

$$c_{u,t} + q_t x_{u,t} + s_{u,t} + I_t = w_t + p_{l,t}(\overline{L}/(1+g)) + i_t b_{u,t} + r_t k_t, \tag{25}$$

$$b_{u,t+1} - b_{u,t} = s_{u,t}, \tag{26}$$

$$h_{u,t+1} - h_{u,t} = x_{u,t} - \delta_h h_{u,t}, \tag{27}$$

$$k_{t+1} - k_t = I_t - \delta_k k_t. \tag{28}$$

Taking F.O.C., rearranging, and using the utility function above yields the following Euler equations for unconstrained households:

$$c_{u,t}^{-\gamma} = \beta E_t c_{u,t+1}^{-\gamma}(1 + i_{t+1}), \tag{29}$$

$$q_t c_{u,t}^{-\gamma} = \beta\theta E_t h_{u,t+1}^{-\gamma} + \beta E_t c_{u,t+1}^{-\gamma} q_{t+1}(1 - \delta_h), \tag{30}$$

$$c_{u,t}^{-\gamma} = \beta E_t c_{u,t+1}^{-\gamma}(1 + r_{t+1} - \delta_k). \tag{31}$$

2.3 Definition of equilibrium

The equilibrium consists of prices $\{q_t, r_t, w_t, p_{m,t}, p_{s,t}, p_{l,t}, p_{res,t}\}_{t=0}^{\infty}$, shadow price of credit constraint $\{v_t\}_{t=0}^{\infty}$ interest rate $\{i_t\}_{t=0}^{\infty}$, allocations $\{c_{c,t}, h_{c,t+1}, b_{c,t+1}, c_{u,t}, h_{u,t+1}, b_{u,t+1}, k_{t+1}\}_{t=0}^{\infty}$ by households, the profit maximizing input demands of firms $\{K_{c,t}, K_{m,t}, K_{s,t}, N_{c,t}, N_{m,t}, N_{s,t}, La_t, X_{mres,t}, X_{cres,t}, X_{sres,t}, X_{mco,t}, X_{sco,t}, X_{cco,t}, X_{res,t}\}_{t=o}^{\infty}$ and level of regulation $\{rg_t\}_{t=0}^{\infty}$ such that:

a) given prices, households solve their optimization problem (conditions (22)-(23) and (29) -(31)) and firms maximize their profits (conditions(4)-(5), conditions(8)-(10), conditions(15)-(16));

b) Markets clear,

i)

$$x_{c,t} + gx_{u,t} = Y_{h,t} \tag{32}$$

(housing market),

ii)

$$c_{c,t} + gc_{u,t} + gI_t = Y_{co,t} \tag{33}$$

(composite good market),

iii)

$$K_{m,t} + K_{c,t} + K_{s,t} = gk_t \tag{34}$$

(capital market),

iv)

$$b_{c,t+1} = -gb_{u,t+1} \tag{35}$$

(credit market),

v)

$$N_{c,t} + N_{s,t} + N_{m,t} = g + 1 \tag{36}$$

(labor market),

vi)

$$X_{cco,t} + X_{cres,t} = Y_{c,t} \tag{37}$$

(intermediate good market (construction)),

$$X_{mco,t} + X_{mres,t} = Y_{m,t} \tag{38}$$

(intermediate good market (manufacturing)),

$$X_{sco,t} + X_{sres,t} = Y_{s,t} \tag{39}$$

(intermediate good market (services),

vii)

$$X_{res,t} = Y_{res,t} \tag{40}$$

(residential investment good market)

viii)

$$La_t = \overline{L} \tag{41}$$

(land market).

3 Derivation of the Steady State

In what follows we consider the situation in which credit constraints are binding for constrained households bind. In terms of the model this assumption implies that following should hold: $\frac{1}{(i_{t+1}+1)} < \frac{c_{c,t}^{-\gamma}}{\beta c_{c,t+1}^{-\gamma}}$.

In other words, the intertemporal marginal rate of substitution of credit constrained households should be higher than the real rate of return on bonds.

Given the assumption of s binding credit constraint, the steady state satisfies the following conditions:

$h_{c,t+1} = h_{c,t} = h_c^{ss}$

$h_{u,t+1} = h_{u,t} = h_u^{ss}$

$c_{c,t+1} = c_{c,t} = c_c^{ss}$

$c_{u,t+1} = c_{u,t} = c_u^{ss}$

$b_{c,t+1} = b_{c,t} = b_c^{ss}$

$b_{u,t+1} = b_{u,t} = b_u^{ss}$

$k_{t+1} = k_t = k^{ss}$

$s_c^{ss} = b_c^{ss} - b_c^{ss} = 0$

$s_u^{ss} = b_u^{ss} - b_u^{ss} = 0$

$x_c^{ss} = h_c^{ss} - (1-\delta_h)h_c^{ss} = \delta_h h_c^{ss}$

$x_u^{ss} = h_u^{ss} - (1-\delta_h)h_u^{ss} = \delta_h h_u^{ss}$

$I_{ss} = k^{ss} - (1-\delta_k)k^{ss} = \delta_k k^{ss}$

Using the above conditions, budgets constraints (18)and (25) for the constrained and unconstrained households in the steady state can be rewritten as:

$$c_c^{ss} = w^{ss} + p_l^{ss}(\overline{L}/(1+g)) + i^{ss}b_c^{ss} - \delta_h q^{ss}h_c^{ss} \tag{42}$$

$$c_u^{ss} = w^{ss} + p_l^{ss}(\overline{L}/(1+g)) + (r^{ss}-\delta_k)k^{ss} + i^{ss}b_u^{ss} - \delta_h q^{ss}h_u^{ss} \tag{43}$$

Rewriting binding credit constraint(21) and credit market equilibrium condition(35) in steady state yields the following expressions for b_c^{ss} and b_u^{ss}:

$$b_c^{ss} = -m^{ss}q^{ss}h_c^{ss} \tag{44}$$

$$b_u^{ss} = -\frac{b_c^{ss}}{g} \tag{45}$$

Conditions(22)-(23) in the steady state can be rewritten as

$$\upsilon^{ss} = (c_c^{ss})^{-\gamma} - \beta(c_c^{ss})^{-\gamma}(i^{ss}+1); \tag{46}$$

$$q^{ss} = \beta\frac{\theta(h_c^{ss})^{-\gamma}}{(c_c^{ss})^{-\gamma}} + \beta q^{ss}(1-\delta_h) + m^{ss}q^{ss}(1-\beta(i^{ss}+1)). \tag{47}$$

Conditions(29)-(31) in the steady state are given by the following:

$$1 = \beta(i^{ss}+1); \tag{48}$$

$$q^{ss} = \beta \frac{\theta (h_u^{ss})^{-\gamma}}{(c_u^{ss})^{-\gamma}} + \beta q^{ss}(1-\delta_h); \tag{49}$$

$$1 = \beta(1 + r^{ss} - \delta_k). \tag{50}$$

Rearranging (47) yields

$$c_c^{ss} = \left(\frac{1-\beta(1-\delta_h) - m(1-\beta(1+i^{ss}))}{\beta\theta} q^{ss} \right)^{1/\gamma} h_c^{ss}. \tag{51}$$

Rearranging (48)yields

$$\frac{1-\beta}{\beta} = i^{ss}. \tag{52}$$

Rearranging (49)yields

$$c_{uc}^{ss} = \left(\frac{1-\beta}{1-\delta_h} \beta\theta q_{ss}^{ss} \right)^{1/\gamma} h_u^{ss}. \tag{53}$$

Rearranging (50)yields

$$r^{ss} = \frac{1}{\beta - 1 + \delta_k}. \tag{54}$$

The steady state level of capital and the rest of the prices can be determined by solving the supply side of the model and using market clearing conditions. Rewriting the conditions (4)-(5) in the steady state yields

$$p_j^{ss} z_j^{ss} \alpha (K_j^{ss})^{\alpha_j - 1} (N_j^{ss})^{1-\alpha_j} = r^{ss}; \tag{55}$$

$$p_j^{ss} z_j^{ss} (1-\alpha_j)(K_j^{ss})^{\alpha_j} (N_j^{ss})^{-\alpha_j} = w^{ss}. \tag{56}$$

Rearranging (55) yields:

$$K_j^{ss} = \left(\frac{p_j^{ss} z_j^{ss} \alpha_j}{r^{ss}} \right)^{1/(1-\alpha_j)} N_j^{ss}. \tag{57}$$

Substituting the (57) into (56) and rearranging yields

$$w^{ss} = \left(\frac{\alpha_j}{r^{ss}} \right)^{\alpha_j/(1-\alpha_j)} \left(p_j^{ss} z_j^{ss} \right)^{1/(1-\alpha_j)} (1-\alpha_j). \tag{58}$$

The production volume of the intermediate good j in the steady state is given by

$$Y_j^{ss} = (z_j^{ss})^{(1/(1-\alpha_j))} \left(\frac{p_j^{ss}\alpha_j}{r^{ss}}\right)^{(\alpha/(1-\alpha_j)} N_j^{ss}. \tag{59}$$

Rewriting the profit maximizing conditions of final good producers in the steady state yields:

$$p_f^{ss}\alpha_f(X_{cf}^{ss})^{\alpha_f-1}(X_{mf}^{ss})^{\beta_f}(X_{sf}^{ss})^{1-\alpha_f-\beta_f} = p_c^{ss} \tag{60}$$

$$p_f^{ss}\beta_f(X_{cf}^{ss})^{\alpha_f}(X_{mf}^{ss})^{\beta_f-1}(X_{sf}^{ss})^{1-\alpha_f-\beta_f} = p_m^{ss} \tag{61}$$

$$p_f^{ss}(1-\alpha_f-\beta_f)(X_{cf}^{ss})^{\alpha_f}(X_{mf}^{ss})^{\beta_f}(X_{sf}^{ss})^{-\alpha_f-\beta_f} = p_s^{ss} \tag{62}$$

Rewriting the conditions (15)-(16) in the steady state yields

$$q^{ss}\varepsilon(X_h^{ss})^{\varepsilon-1}(La^{ss})^{1-\varepsilon} = p_{res}^{ss}; \tag{63}$$

$$q^{ss}(1-\varepsilon)(X_h^{ss})^{\varepsilon}(La^{ss})^{-\varepsilon} = p_l^{ss}. \tag{64}$$

Using land market clearing condition and solving (63) for X_h^{ss} yields:

$$X_h^{ss} = \left(\frac{\varepsilon q^{ss}}{p_{res}^{ss}}\right)^{\frac{1}{1-\varepsilon}} \overline{L} \tag{65}$$

This implies that quantity of new housing units produced in steady state is given by

$$Y_h^{ss} = \left(\frac{\varepsilon q^{ss}}{p_{res}^{ss}}\right)^{\frac{\varepsilon}{1-\varepsilon}} \overline{L}. \tag{66}$$

Finally housing market clearing condition (32) and composite good market clearing condition (33) in the steady state can be written as:

$$\delta_h h_c^{ss} + \delta_h g h_{uc}^{ss} = \left(\frac{\varepsilon q^{ss}}{p_{res}^{ss}}\right)^{\frac{\varepsilon}{1-\varepsilon}} \overline{L}; \tag{67}$$

$$c_c^{ss} + g c_{uc}^{ss} + g\delta_k k^{ss} = Y_{co}^{ss}. \tag{68}$$

Finally the level of regulation in the steady state and aggregate investment into housing in steady state are given by

$$rg^{ss} = \psi \log q^{ss} + \chi \log x^{ss}, \tag{69}$$

$$x^{ss} = x_c^{ss} + g x_u^{ss}. \tag{70}$$

Equations (42)-(46), (51)-(54), (57)-(59) for each intermediate good, (60)-(62) for each final good, (65) and (67)-(70), together with the rest of market clearing conditions represent a system of equations, which determines a unique steady state.

4 Calibration

The discount factor is set equal to the conventional 0.99. Following Campbell and Cocco (2007) we set $\theta = 1$ and $\gamma = 2$. The value of m is calibrated using Monthly Interest Rate Survey published by Federal Housing Finance Agency and is set to 0.76, which was the average loan-to-value ratio (LTV) for the most typical in the US 15 year mortgages in 1991. We also the value of m equal to 0.798, which corresponds to the average loan-to-value ratio (LTV) for the most typical in the US 15 year mortgages in 2002. Reason for using two values of LTV is elaborated on in Section 5.4. Depreciation rate for physical capital is set to 5.7% as in Davis and Heatcote (2005). The share of raw land in the housing production $1 - \varepsilon$, is set to 0.106 following an estimate from the US Census Bureau. This implies that $\varepsilon = 0.894$. The depreciation rate for housing is set to 1.4% based on Davis and Heatcote (2005).

In this article the Generalized Methods of Moments (GMM) for estimating unobservable parameters is used. [5] The GMM was performed with the aid of Stata-9 statistical software. Deriving the estimators is the necessary step to be able to come to the objective function which would fulfill the pre-defined criteria. This happens via deriving assumptions based on the GMM estimators. In our model, the number of so called moment conditions is higher than the number of parameters to estimate. The remaining parameters are estimated using

[5] Among other plausible methodologies for deriving estimators there is Bayesian estimation or Maximum likelihood approach. The GMM, however, best suits needs of this article, despite being generally more robust and less specific than the both mentioned methods.

GMM estimation and the following model variables which are observed for the period 1987-2009: a) real wage w, which is represented by real wage from Bureau of Labor Statistics divided by the NIPA price index for Personal Consumption Expenditure; b) interest rate i, which is represented by effective interest rate on mortgages from Monthly Interest Rate Survey of Federal Housing Finance Agency; c) relative price of housing q, which is represented by Freddie Mac Conventional Mortgage Home Price Index divided by NIPA price index for Personal Consumption Expenditure; d) relative price of land p_l which is represented by price index for land from Lincoln Institute of Land Policy divided by NIPA price index for Personal Consumption Expenditure; e) regulation level rg which is represented by Wharton Regulation Index from Saiz (2010); f) productivity in housing construction η, which is represented by multifactor productivity in construction sector from Bureau of Labor Statistics (originating from the EU-KLEMS database); g) productivity in manufacturing sector z_m, which is represented by multifactor productivity in manufacturing sector from the Bureau of Labor Statistics. The values of all the parameters are then summarized in Table 2. Using these variables we calculate steady state values of endogenous variables both for calibration corresponding to year 1991 as well as for calibration corresponding to 2002. The steady values are summarized in Table 1.

5 Simulation of results

5.1 Productivity shock in manufacturing good production

We use the Dynare toolbox to simulate the model. To check the consistency of the model we first simulate one-period one percentage shocks. Let us suppose that the economy is in the steady state when productivity in manufacturing good sector increases by 1 percent for one period and then shifts back. All other shocks at this point are excluded. Because of the increase in productivity, interest rate increases by 0.12 percentage points, rental price of capital increases by 0.15%, real wage increases by 0.17% and housing price increases by 0.031% in the first period in comparison with the initial steady state. Because of the increase in interest rate, which, in this case, outweighs the increase in wage, in the first period credit-constrained households decrease their consumption of composite good by 0.017% and their housing stock by 0.26%. Amount of borrowing by credit constrained households in the first period decreases by 0.328%. Period utility of credit-constrained households in the first period, according to expectations, decreases. However, the life-time utility does not decrease (even slightly increases), which can be explained by the fact that due to a decrease in borrowing credit-constrained households have to repay lower amount for their debt in the future. Hence, positive income effect derived from this prevails loss of first-period utility. Unconstrained households in the first period benefit both from higher interest rate as well as from higher wage and higher rental price of capital. In the first period composite good consumption of the unconstrained households increases by 0.022% and housing stock of the unconstrained households increases by 0.12%. They also increase capital stock by 0.045%. Their period utility as well as their lifetime utility increase in the first period. As for aggregate variables, the aggregate consumption increases by 0.01%, aggregate housing stock stays almost unchanged and aggregate lifetime utility somewhat increases. In the second period of transition, the interest rate and rental price of capital shift back to their steady state values. Housing price still slightly increases since the building permit regulation becomes stricter while wage decreases but remains higher than at the steady state. Credit-constrained households increase their composite good consumption and housing stock since the interest rate is the same but the wage is higher than in the steady state. Unconstrained households keep the same level of composite good consumption as in period 1 but decrease their housing stock by 0.09% compared with the previous period. Housing price returns to its initial steady state value after 16 periods, real wage and consumption by unconstrained households reach their steady state values by 20-th period, while consumption of credit-constrained ones reaches the initial steady state value by 22nd period. The housing stock of both credit constrained and unconstrained households comes back to its original value after 93 periods. The evolution of the main endogenous during transition is presented in Table 5 and Table 6.

Ultimately, we compare two situations: the actual transition path of the economy (resulting from the shock), and the situation without the shock, i.e. when the initial steady state persists for the same number of periods as the transition. For each of these situations we calculate the total present value of the major variables of interest. The results are presented in the Table 11. We can observe that the model behaves reasonably also in this respect. In particular, both credit constrained and unconstrained households as a result of the shock obtain higher present value composite good consumption. Unconstrained households also gain in terms of present value of housing stock while credit constrained households lose in terms of present value of housing stock (before calculating the present value the physical stock of housing is multiplies by housing price to be able to calculate the present value). One can also observe that eventually both credit-constrained as well unconstrained households acquire a higher lifetime as well as period utility compared with the case of unchanged steady state.

In the case of opposite shock, i.e. a decrease in productivity in manufacturing sector, the results are symmetrical.

5.2 Productivity shock in services production sector

Now let us suppose that the economy is in the steady state when the productivity in services production sector increases by 1 percent for one period and then shifts back. All other shocks at this point are excluded. Because of the increase in productivity interest rate increases by 0.6 percentage points,rental price of capital increases by 0.35%, real wage increases by 0.28% and housing price increases by 0.045% in the first period in comparison with the initial steady state. Because of the increase in interest rate in the first period credit-constrained households decrease their consumption of composite good by 0.029% and their housing stock by 0.41%. Amount of borrowing by credit constrained households in the first period decreases by 0.472%. Period utility of credit-constrained households in the first period, according to expectations, decreases and the life-time utility slightly decreases. Unconstrained households in the first period benefit both from higher interest rate as well as from higher wage and higher rental price of capital. In the first period composite good consumption of the unconstrained households increases by 0.031% and housing stock of the unconstrained households increases by 0.17%. They also increase capital stock by 0.058%. Their period utility as well as lifetime utility increase in the first period. As for aggregate variables, the aggregate consumption increases by 0.023%, aggregate housing stock and aggregate lifetime utility stay almost unchanged.

In the second period of transition the interest rate and rental price of capital shift back to their steady state values. The housing price still slightly increases while wage decreases but remains higher than at the steady state. Credit-constrained households increase their composite good consumption and housing stock since the interest rate is lower but the wage is higher than in the steady state. Unconstrained households keep the same level of composite good consumption as in the period 1 but decrease their housing stock by 0.05%. Housing price returns to its initial steady state value after 18 periods, real wage and consumption by unconstrained households reach their steady state values by 20-th period, while consumption of credit-constrained ones reaches the initial steady state value by 23-rd period. The housing stock of both credit constrained and unconstrained households comes back to its original value after 96 periods.

In the case of opposite shock, i.e. a decrease in productivity in manufacturing sector, the results are, again, symmetrical.

As we can see the results for both productivity shocks are quite similar so in the following sections we concentrate on considering the productivity shock in manufacturing good sector.

5.3 Changes in loan-to-value ratio

Let us suppose that the economy is in the steady state when loan-to-value ratio increases by 1 percent for one period and then shifts back. All other shocks at this point are again excluded. Because of the increase in loan-to-value ratio interest rate decreases by 0.12

percentage points, while rental price of capital, wage and housing price stay unchanged in the first period inc comparison with the initial steady state. Because of higher availability of credit, in the first period credit-constrained households increase their housing stock by 3.7%. Amount of borrowing by credit constrained households in the first period increases by 4.77%, whereas composite good consumption stays unchanged. Period utility of credit-constrained households in the first period, according to expectations, increases by 0.5%. Likewise, the life-time utility goes up, but only slightly. By contrast, the unconstrained households in the first period lose part of their income as the interest rate decreases, and, as a consequence, their housing stock decreases by approximately 1.6%. In the first period composite good consumption of the unconstrained households stays unchanged and the same holds true for capital stock. Their period utility decreases by around 0.3% and their lifetime utility marginally decreases. As for aggregate variables, the aggregate consumption remains unchanged, and aggregate housing stock and aggregate lifetime utility stay unchanged as well. In the second period all the variables shift back to their former steady state values. The evolution of the main endogenous during transition is presented in Table 3 and Table 4.

Again, we perform a similar comparison as in the previous subsections. The results are presented in the Table 11. In this case one can observe the decrease in present value of housing stock of credit-constrained households and decrease in that of unconstrained households. This , together with unchanged consumption leads to redistribution of utility and welfare from unconstrained to credit constrained households time one again we observe that the model behaves reasonably.

In the case of opposite shock, i.e. a decrease in loan-to-value ratio, the results are again symmetrical.

5.4 Simulation of the US housing market

5.4.1 Evolution of prices and individual variables

For the US market case we consider a shock to productivity in manufacturing sector and a shock to LTV. In order to calibrate the productivity shocks, multifactor productivity in the manufacturing sector from the US Bureau of labor statistics is employed. For calibrating the LTV shock, the LTV for fifteen-year conventional non-jumbo mortgages, which account for the largest share of total volume of conventional mortgages in the US, is used. The mortgages data is available from the Monthly Interest Survey published by Federal Housing Finance Agency. For both shocks we consider the period between 1991 and 2009. The series are plotted respectively on the Figure 2 and Figure 1. For simulation purposes, the period is split into 1991-2000 and 2003-2009 sub-periods.

As one can see from the Figure 2, the years 2001 and 2002 are characterized by drastic changes in the multifactor productivity, which could imply a structural break in the data for the US economy. As it is commonly agreed, this was caused by the IT bubble burst in the stock market as well as the consequences of 9/11 terrorist attacks. Hence, we do not consider the mentioned years in what follows.

First, let us consider the sub-period between 1992 and 2000. The initial steady state, in which the value of m is set to 0.76 and the value of $\overline{z_m}$, the intercept of the stochastic law of motion for the productivity in manufacturing sector, is set to 1.15, corresponds to the US economy in 1991. Now using the corresponding values of the calibrated series in 1992, $\overline{z_m}$ is decreased to 1.143 or by 0.6% and the value of m is increased to 0.797.

In this paragraph we consider the changes in the first period only. The decrease in productivity implies an immediate decrease in real wage. The decrease in productivity also leads to a decrease in capital accumulation (variable in in the model) which implies a decrease in capital stock. In its turn this reduces production of housing. However, because of the comparatively large increase in LTV, demand for housing by credit-constrained households goes up, which pushes the housing price up. Higher demand for housing combined with higher housing price as well as higher LTV results in substantially higher borrowing by credit-constrained households, which leads to an increase in the interest rate. Concerning the rental price of capital, the negative effect of a fall in productivity is exactly compensated by a greater demand for capital by intermediate good producers, arising from higher overall demand for housing. As a result, rental price of capital in the first period stays unchanged. The overall results of all those changes is the increase in borrowing of credit-constrained households by 6.4%, which leads to a rise in their composite good consumption as well as housing stock by correspondingly 6.8% and 3.3%. Regarding the unconstrained households, their composite good consumption increases by 0.97% and their housing stock goes down by 1.2%, which is a reflection of a typical substitutions effect. The period utility of credit-constrained households increases by 4.2%, while the one for unconstrained households also increases, but only fractionally.

In the second period, as per the US data, productivity in manufacturing sector shifts up and exceeds the initial steady state value (the value of $\overline{z_m}$ is set to 1.172). As for LTV ratio, this one increases further and reaches 0.809. As a result of a productivity increase real wage is higher by 0.14% compared with the steady state, and even by 0.3% compared with the previous period. What concerns the rental price of capital, it responds to higher productivity and increases 0.75% compared both with steady state as well as the previous period. The interest rate continues to increase since the effect of a rise in the rental price of capital, with which the interest rate is connected, dominates the effect of somewhat higher LTV as compared with the first period. It is important to note that in the second period a change in the strictness of the building permit regulation takes effect. Since in period 1 both investment into housing as well as housing price increase, the regulation in the second period becomes stricter compared with the initial steady state. Because of this productivity in the housing production sector decreases and the volume of housing production decreases as well (by 2.2%). This creates relative shortage of housing and the housing price further increases. As for the household allocations, the composite good consumption by credit-constrained households as well as their housing stock decrease respectively by 13.7% and 23% compared with the previous period since they have to repay comparatively large volume of loans with a high interest rate, which they took in the first period. Composite good consumption by unconstrained households as well as their housing stock, on the contrary increase by respectively 0.6% and 10.3% compared with the previous period. Finally, the period utility of credit constrained households goes down by 12.5% while period utility of unconstrained households rises by 2.3%. The results for the remaining periods of the transition are presented in Table 7 and Table 8 . Since the productivity continues to increase until the 9-th period both wages as well as rental price of capital increase. Interest rate starts to decline after the second period which reflects the effect of liberalization in the credit market and higher LTV. Finally, after the second period composite good consumption and housing stock of credit constrained households start to increase again compared with the second period while composite good consumption and housing stock of unconstrained households continue to increase.

Now let us consider the second subperiod, i.e. the one between 2003 and 2009. The initial steady state, in which the value of m is set tao 0.798 and the value of $\overline{z_m}$, the intercept of the stochastic law of motion for the productivity in manufacturing sector, is set to 1.15, corresponds to the US economy in 2002. Now using the corresponding values of the calibrated series in 2003, $\overline{z_m}$ is increased to 1.191 and the value of m is decreased to 0.795.

The increase in the productivity leads to a rise in the real wage by 0.62% in the first period. It also pushes up rental price of capital by around 0.6%. Since the LTV slightly decreases and rental price of capital rises, interest rate rises in the first period. Higher rental price of capital, higher wage and higher interest rate shift up the aggregate demand for housing and lead to the increase in housing price by 0.55%. Those changes lead to a decrease in borrowing of credit-constrained households by 3.1%, which leads to a fall in their housing good consumption by 2.8%. On the other hand, the consumption of composite good goes up by 1.62%. Regarding the unconstrained households, their composite good consumption increases by 0.7% and their housing stock progresses by 1.33%, which reflects the income effect. The aggregate investment into housing, however, in the first period increases. The period utility of credit-constrained households decreases by around 2.9%, while the one for unconstrained households increases by approximately 0.3%.

In the second period LTV further decreases and productivity continues to rise. Real wage and rental price of capital continue to rise. Interest rate rises even more substantially. As in the simulation for the first subperiod, in the second period the building permit regulation becomes stricter which is caused by the higher aggregate investment into housing and higher housing price in the first period. Stricter regulation decreases the productivity in housing sector and shifts down the supply of new housing. This causes an increase in housing price. Concerning household allocations, unconstrained households further increase both their composite good consumption as well as their housing stock while, on the contrary credit-constrained households are forced to decrease both. Due to a substantial increase in the interest rate causing the need for large cut in the borrowing, housing stock of credit-constrained households shifts down especially abruptly. The results for the remaining periods of the transition are presented Table 9 and Table 10. It is important to mention that in period 7 when both productivity as well as LTV ratio decrease compared with the previous period (situation corresponding to 2009), real wage, rental price of capital and interest rate decline. Unconstrained households react to those changes by the decreasing composite good consumption and increasing the housing stock, while credit-constrained households substitute housing for the composite good consumption.

For both subperiods we compare the total present values of the major variables of interest resulting from the actual transition path of the economy with those valid for the situation in which the initial steady state persists. The results are presented in Table 11. The results imply that because of the observed shocks the total present value of composite good consumption by credit constrained households over the first subperiod decreases by around 0.56% while the total present value of composite good consumption by unconstrained households over the first subperiod increases by 0.63% compared with the situation of unchanged steady state. They also imply that the total present value of housing stock of constrained households over the first subperiod decreases by around 1.05%, while the total present value of housing stock by unconstrained households over the first subperiod increases by 1.7% compared with the situation of unchanged steady state. As for the second subperiod, the present value of composite good consumption by credit constrained households decreases by 0.58% and the present value of housing stock of credit constrained households decreases by 2.7% while for unconstrained households both increase by respectively 0.53% and around 2.5%. Finally the total present value of credit constrained households' period utility decreases and the total present value of unconstrained households' period utility increases in both subperiods, but in the second subperiod utility loss by credit constrained households is relatively higher compared with the first subperiod.

5.4.2 Evolution of the aggregate variables and welfare

In this subsection we describe the evolution of aggregate allocations and lifetime utility. As can be seen from Table 8, in the first period of 1992-2000 subperiod the aggregate composite good consumption increases by around 2.7% compared with initial steady state since both credit constrained and unconstrained households increase their composite good consumption. Aggregate housing stock in the first period also increases but the increase is relatively small since increase of the stock of credit constrained households is almost compensated by the decrease of the housing stock of unconstrained households . In period 2 and 3 credit-constrained households have to significantly cut their composite good consumption because of which in those periods aggregate composite good consumption shifts below the steady state value in spite of an increase of composite good consumption by unconstrained households. As a result aggregate composite good consumption in period 3 is lower by around 3.2% compared with the initial steady state. After period 3 aggregate composite good consumption again exceeds the steady state value and it continues to increase until period 15. The situation is different for the aggregate housing stock for which the decrease of housing stock of credit constrained households is compensated by the increase of housing of unconstrained households. As result both in period 2 as well as in period 3 aggregate housing stock continues to increase. Aggregate housing stock in period 3 is higher by 0.13% compared with the initial steady state and it continues to increase until period 25. In total as a result of the actual transition the present value of composite good consumption is higher by around 0.3% while the present value of housing stock is higher by around 0.87% compared with the case of unchanged steady state.

The results for second subperiod are summarized in Table 10. As one can see the effects in the first period are similar to the ones observed in the first period of previous subperiod, but the increase in both aggregate composite good consumption as well as the increase aggregate housing stock are smaller. On the other hand in the second period the credit constrained households are hurt even more in the increase in the interest rate. Because of this aggregate composite good consumption in the second period falls by more than in the previous case and aggregate housing stock increases by less than in the previous case. Aggregate composite good consumption in this case starts to rise after period 2 and increases until period 10 while aggregate housing stock continues to increases until period 23. In total as a result of the actual transition the present value of composite good consumption is higher by around 0.26% while the present value of housing stock is higher by around 0.91% compared with the case of unchanged steady state.

Finally, let us comment on lifetime utility changes. To make it more interesting from the point of view of interpretation we express changes in lifetime utility in terms of change in composite good consumption necessary to make household indifferent between each point in transition and the initial steady state. Furthermore we express the resulting change in composite good consumption in terms of the percentage of average composite good consumption in the initial steady state. We make this calculation for every period of transition and after that calculate the present value of changes in composite good consumption necessary to make household indifferent between the current situation and the initial steady state.

The results imply that in the subperiod 1992-2000 in terms of present value it is necessary to decrease the composite good consumption by unconstrained households by 9.3% of the average composite good consumption in the steady state to make their lifetime utility the same as in the initial steady state and it is necessary to increase the composite good consumption by credit constrained households by 6.2% of the average composite good consumption to make their lifetime utility the same. For subperiod 2003-2009 those numbers account to correspondingly 11.5% and 7.8% . Concerning the aggregate lifetime utility we can see from Table 11 that it increases in both subperiods. In terms of average composite good consumption in the first subperiod it is necessary to decrease the composite good consumption by unconstrained households by 14% and increase the composite good consumption by credit constrained households by 10.5% to make the aggregate lifetime utility the same as in the initial steady state.

6 Conclusion

In this paper we have explored both individual as well as aggregate welfare effects of housing price changes in the dynamic stochastic general equilibrium framework. As the driving forces for the housing price changes we have used multifactor productivity and loan-to-value ratios. Also, the endogenously determined supply-side shock, arising from the building permit regulation changes, has been employed. The model has generally included two groups of households: the constrained ones and the unconstrained ones. The effects of the mentioned shocks on composite good consumption, housing allocation, and welfare for the mentioned groups have been quantified. First, the quantification has been made using one period one per cent deviations in the shock variables. The model's shocks have been then calibrated according to the development of the US economy for the period of 1992-2009. The results show that according to the simulation the aggregate composite good consumption, housing stock as well as aggregate welfare increased, however, on the individual level, the welfare was redistributed from constrained households to the unconstrained ones. The possible further extensions of this analysis include consideration of variable labor supply, explicit financial sector and banking optimization problem and incorporation of a mechanism for an endogenous determination of the proportion of credit constrained and unconstrained households.

References

[1] Bajari, P., Benkard, L., and Krainer, J.,"House prices and consumer welfare," *Journal of Urban Economics*, 58, pp. 474-488, 2005.

[2] Campbell,J., and Cocco, J.,"How do house prices affect consumption? Evidence from micro data," Journal of Monetary Economics, 54(3), pp. 591-621, 2007.

[3] Case, K., Quigley, J., and Shiller,R.,"Comparing wealth effects: Stock market versus housing market," Cowles Foundation Discussion Paper 1335, 2001.

[4] Davis, A., and Heathcote, J.,"Housing and the business cycle," *International Economic Review*, 46(3), pp. 751-784, 2005.

[5] Iacoviello, M., and Minetti, R.,"Financial Liberalisation and the Sensitivity of House Prices to Monetary Policy: Theory and Evidence," Boston College Working Papers in Economics 538, 2003.

[6] Kiyotaki, N., Michaelides, A., and Nikolov, N., "Winners and Losers in the Housing Market," Journal of Money, Credit and Banking 43(3), pp. 255-296, 2011.

[7] Kiyotaki, N., and Moore, J.,"Credit cycles," *Journal of Political Economy*, 105(2), pp. 211-248, 1997.

[8] Ortalo-Magne, F., and Rady, S.,"Housing market dynamics: On the contribution of income shocks and credit constraints," *Review of Economic Studies*, 73, pp. 459-485, 2006.

[9] Saiz, A.,"On local housing supply elasticity," University of Pennsylvania-Wharton School; Institute for the Study of Labor Working Paper, 2007.

[10] Tsharakyan, A., and Janíčko, M.,"The binding credit constraints and the welfare effects of housing price appreciation," *Prague Economic Papers*, No.4, pp. 359-381, 2010.

Figure 1: Evolution of loan-to-value ratio for 15 year conventional mortgages in the US

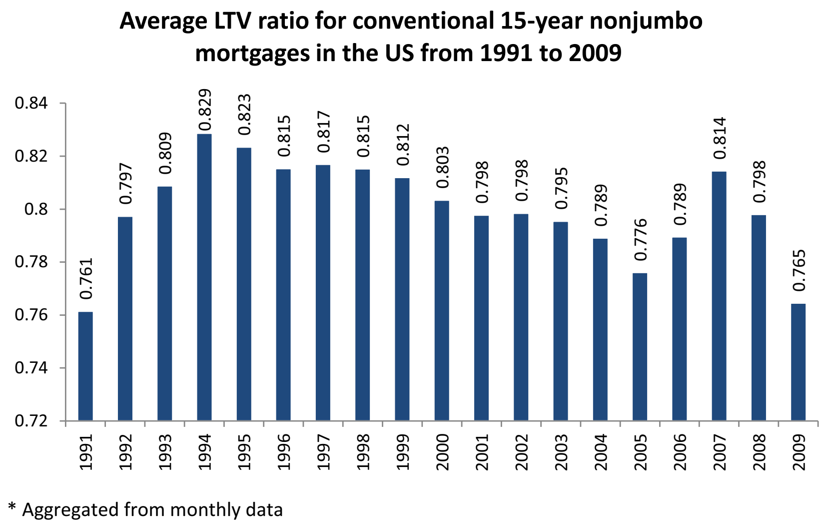
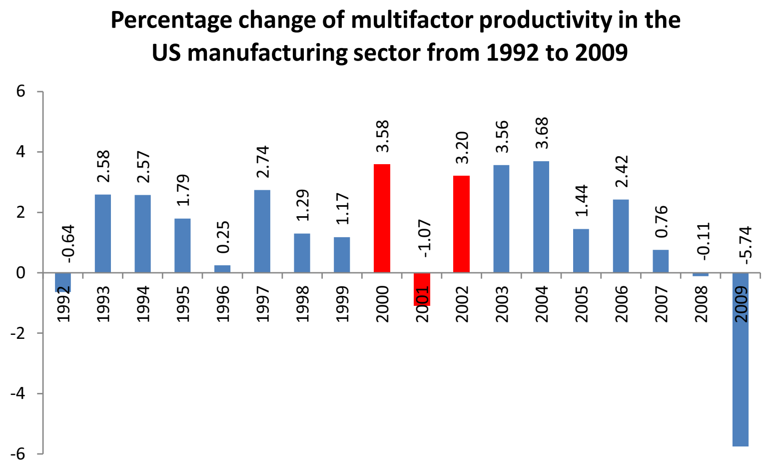


Figure 2: Evolution of multifactor productivity in the US manufacturing sector



* Calculated using multifactor productivity index published by Bureau of Labor Statistics.

Figure 3: Transitional dynamics, US case 1992-2000 subperiod

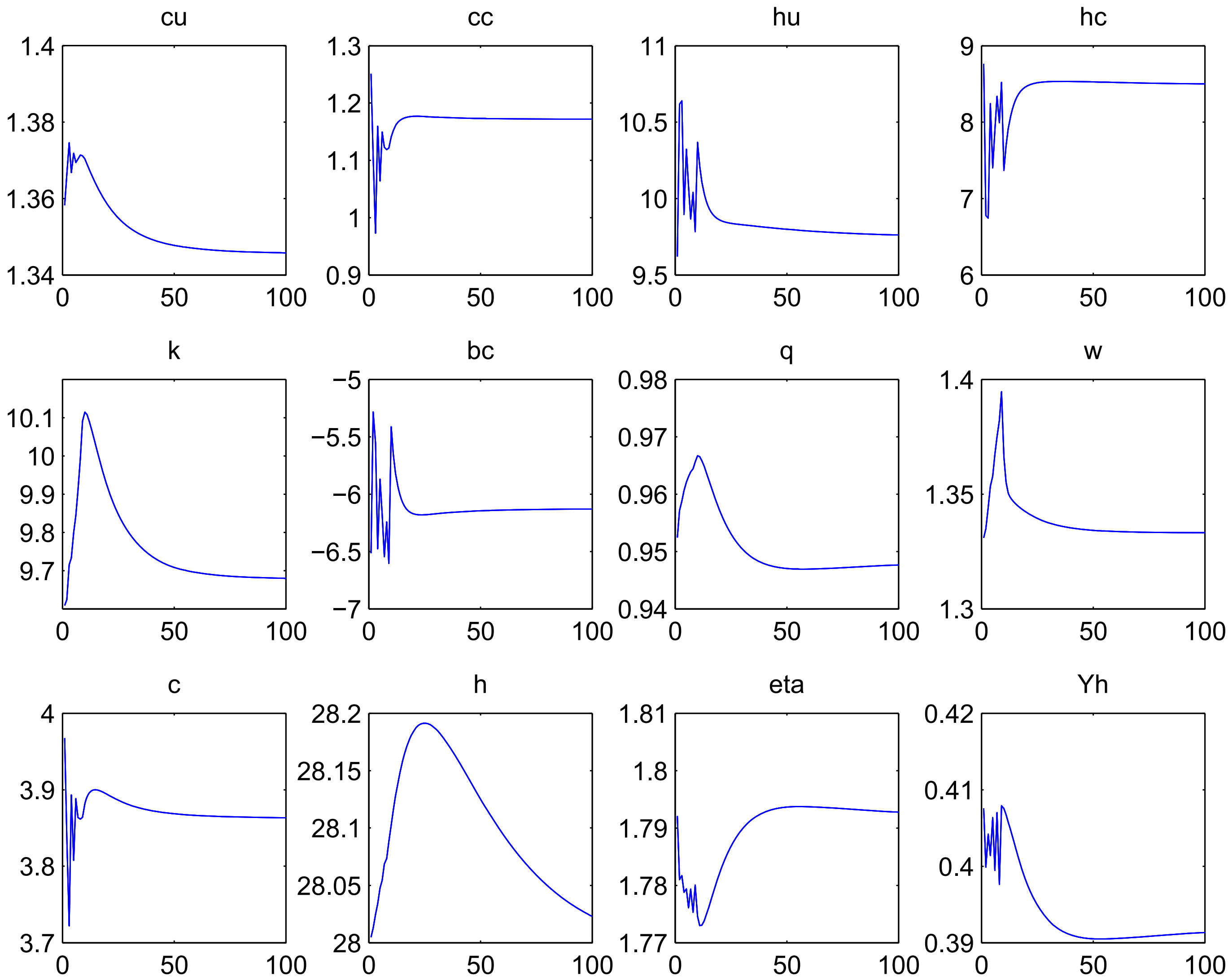


Figure 4: Transitional dynamics, US case 2003-20009 subperiod

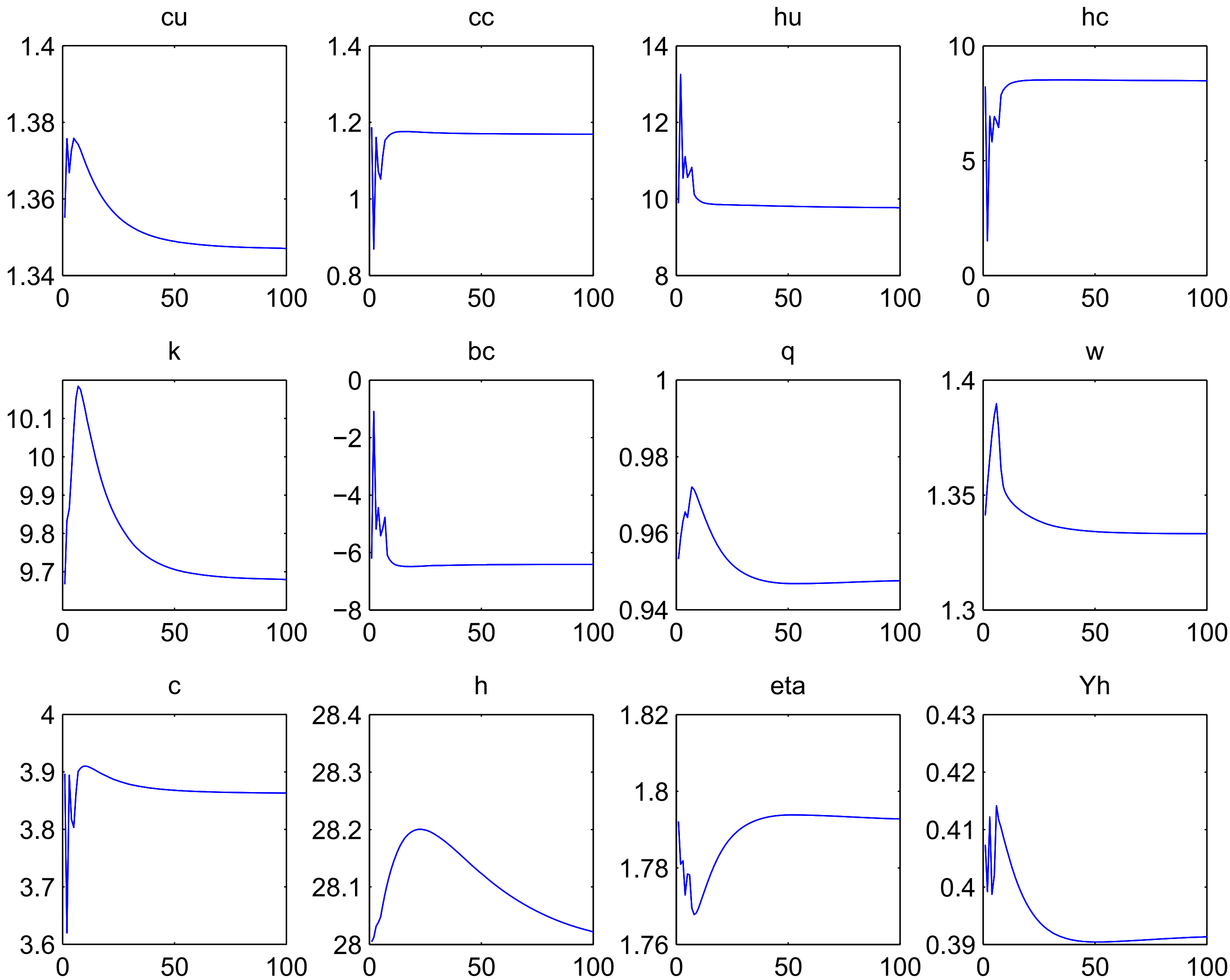


Table 1: Steady state values

Variable	Value for 1991	Value for 2002	Variable	Value for 1991	Value for 2002
c_u	1.34543	1.34673	r	0.067101	0.067101
c_c	1.17159	1.16898	ir	0.010101	0.010101
h_u	9.74959	9.75905	X_{res}	0.182588	0.182588
h_c	8.48991	8.47098	p_l	0.0393832	0.0393832
k	9.6763	9.67628	p_m	0.546677	0.546678
b_u	3.063	3.20476	p_s	0.461107	0.461107
b_c	-6.12599	-6.40952	p_{res}	1.81916	1.81916
q	0.948176	0.948176	in	0.551549	0.551548
w	1.33304	1.33304	x_u	0.136494	0.136627
K_c	1.0831	1.0831	x_c	0.118859	0.118594
K_m	6.44935	6.44932	rg	-0.438732	-0.438732
K_s	11.8201	11.8201	c	3.86244	3.86244
N_c	0.358511	0.358511	h	27.9891	27.9891
N_m	0.725975	0.725975	V_u	-86.6341	-86.5501
N_s	1.91551	1.91551	V_c	-99.4886	-99.711
$X_{c,res}$	0.500388	0.500389	V	-272.757	-272.811
$X_{m,res}$	0.385051	0.385051	Y_h	0.391847	0.391847
$X_{s,res}$	0.559806	0.559807	u_c	-0.994886	-0.99711
$X_{c,co}$	0.163361	0.163361	u_u	-0.866341	-0.865501
$X_{m,co}$	2.17681	2.1768	u	-2.72757	-2.72811
$X_{s,co}$	6.69794	6.69794			

Table 2: Parameters

Parameter	Value	Parameter	Value
β	0.99	ψ	0.322
α_c	0.132	χ	0.450
α_m	0.309	δ_h	0.014
α_{co}	0.0307	α_s	0.237
α_{res}	0.4697	β_{co}	0.2696
ϵ	0.894	β_{res}	0.2382
a_m	0.36	a_c	0.25
d	-0.58	a_s	0.35
σ	1	ρ	0.3
θ	1.2	g	2
δ_k	0.057	γ	2

Table 3: One-period one percentage increase in LTV: Evolution of prices and individual allocations

Period	Var.	Var.	Var.	Var.	Var.	Var.	Var.	Var.	Var.
	r	ir	w	q	c_c	c_u	h_c	h_u	b_c
1	0.0671	0.009	1.333	0.9482	1.1716	1.3454	8.8025	9.5933	-6.4182
2	0.0671	0.0101	1.333	0.9482	1.1716	1.3454	8.4899	9.7496	-6.126
3	0.0671	0.0101	1.333	0.9482	1.1716	1.3454	8.4899	9.7496	-6.126
4	0.0671	0.0101	1.333	0.9482	1.1716	1.3454	8.4899	9.7496	-6.126
5	0.0671	0.0101	1.333	0.9482	1.1716	1.3454	8.4899	9.7496	-6.126
6	0.0671	0.0101	1.333	0.9482	1.1716	1.3454	8.4899	9.7496	-6.126
7	0.0671	0.0101	1.333	0.9482	1.1716	1.3454	8.4899	9.7496	-6.126
8	0.0671	0.0101	1.333	0.9482	1.1716	1.3454	8.4899	9.7496	-6.126
9	0.0671	0.0101	1.333	0.9482	1.1716	1.3454	8.4899	9.7496	-6.126
10	0.0671	0.0101	1.333	0.9482	1.1716	1.3454	8.4899	9.7496	-6.126

Table 4: One-period one percentage increase in LTV: Evolution of aggregate variables and welfare

Period	Var.	Var.	Var.	Var.	Var.	Var.	Var.	Var.
	u_u	V_u	u_c	V_c	c	h	k	V
1	-0.8683	-86.6361	-0.9899	-99.4836	3.8624	27.9891	9.6763	-272.7559
2	-0.8663	-86.6341	-0.9949	-99.4886	3.8624	27.9891	9.6763	-272.7569
3	-0.8663	-86.6341	-0.9949	-99.4886	3.8624	27.9891	9.6763	-272.7569
4	-0.8663	-86.6341	-0.9949	-99.4886	3.8624	27.9891	9.6763	-272.7569
5	-0.8663	-86.6341	-0.9949	-99.4886	3.8624	27.9891	9.6763	-272.7569
6	-0.8663	-86.6341	-0.9949	-99.4886	3.8624	27.9891	9.6763	-272.7569
7	-0.8663	-86.6341	-0.9949	-99.4886	3.8624	27.9891	9.6763	-272.7569
8	-0.8663	-86.6341	-0.9949	-99.4886	3.8624	27.9891	9.6763	-272.7569
9	-0.8663	-86.6341	-0.9949	-99.4886	3.8624	27.9891	9.6763	-272.7569
10	-0.8663	-86.6341	-0.9949	-99.4886	3.8624	27.9891	9.6763	-272.7569

Table 5: One-period one percentage increase in productivity: Evolution of prices and individual allocations

Period	Var. r	Var. ir	Var. w	Var. q	Var. c_c	Var. c_u	Var. h_c	Var. h_u	Var. b_c
1	0.0672	0.0113	1.3353	0.9484	1.1714	1.3457	8.4678	9.7608	-6.11
2	0.0671	0.0101	1.334	0.9485	1.1715	1.3457	8.4808	9.7544	-6.1211
3	0.0671	0.0101	1.3335	0.9485	1.1716	1.3457	8.4847	9.7526	-6.1242
4	0.0671	0.0101	1.3333	0.9485	1.1716	1.3457	8.4866	9.7517	-6.1255
5	0.0671	0.0101	1.3333	0.9484	1.1717	1.3457	8.4877	9.7513	-6.1262
6	0.0671	0.0101	1.3332	0.9484	1.1717	1.3457	8.4883	9.751	-6.1265
7	0.0671	0.0101	1.3332	0.9484	1.1717	1.3457	8.4888	9.7509	-6.1267
8	0.0671	0.0101	1.3332	0.9484	1.1717	1.3456	8.4891	9.7508	-6.1268
9	0.0671	0.0101	1.3332	0.9484	1.1717	1.3456	8.4894	9.7507	-6.1269
10	0.0671	0.0101	1.3332	0.9483	1.1717	1.3456	8.4896	9.7506	-6.1269
11	0.0671	0.0101	1.3332	0.9483	1.1717	1.3456	8.4897	9.7506	-6.1269
12	0.0671	0.0101	1.3332	0.9483	1.1717	1.3456	8.4898	9.7506	-6.1269
13	0.0671	0.0101	1.3331	0.9483	1.1717	1.3456	8.4899	9.7506	-6.1268
14	0.0671	0.0101	1.3331	0.9483	1.1717	1.3456	8.49	9.7505	-6.1268
15	0.0671	0.0101	1.3331	0.9483	1.1717	1.3456	8.4901	9.7505	-6.1268
16	0.0671	0.0101	1.3331	0.9483	1.1717	1.3456	8.4901	9.7505	-6.1267
17	0.0671	0.0101	1.3331	0.9482	1.1717	1.3455	8.4902	9.7505	-6.1267
18	0.0671	0.0101	1.3331	0.9482	1.1716	1.3455	8.4902	9.7505	-6.1267
19	0.0671	0.0101	1.3331	0.9482	1.1716	1.3455	8.4902	9.7505	-6.1266
20	0.0671	0.0101	1.3331	0.9482	1.1716	1.3455	8.4903	9.7505	-6.1266
21	0.0671	0.0101	1.3331	0.9482	1.1716	1.3455	8.4903	9.7505	-6.1266
22	0.0671	0.0101	1.3331	0.9482	1.1716	1.3455	8.4903	9.7504	-6.1266
23	0.0671	0.0101	1.3331	0.9482	1.1716	1.3455	8.4903	9.7504	-6.1265
24	0.0671	0.0101	1.3331	0.9482	1.1716	1.3455	8.4903	9.7504	-6.1265
25	0.0671	0.0101	1.3331	0.9482	1.1716	1.3455	8.4903	9.7504	-6.1265

Table 6: One-period one percentage increase in productivity: Evolution of aggregate variables and welfare

Period	Var. u_u	Var. V_u	Var. u_c	Var. V_c	Var. c	Var. h	Var. k	Var. V
1	-0.866	-86.6307	-0.9954	-99.4879	3.8628	27.9894	9.6806	-272.7494
2	-0.8661	-86.631	-0.9951	-99.4874	3.863	27.9896	9.6819	-272.7494
3	-0.8661	-86.6312	-0.995	-99.4872	3.8631	27.9898	9.682	-272.7496
4	-0.8662	-86.6314	-0.9949	-99.4871	3.8631	27.99	9.6819	-272.7499
5	-0.8662	-86.6316	-0.9949	-99.4871	3.8631	27.9902	9.6815	-272.7502
6	-0.8662	-86.6317	-0.9949	-99.4871	3.863	27.9904	9.6812	-272.7505
7	-0.8662	-86.6318	-0.9948	-99.4871	3.863	27.9905	9.6809	-272.7508
8	-0.8662	-86.632	-0.9948	-99.4871	3.863	27.9906	9.6805	-272.751
9	-0.8662	-86.6321	-0.9948	-99.4872	3.8629	27.9907	9.6802	-272.7513
10	-0.8662	-86.6322	-0.9948	-99.4872	3.8629	27.9908	9.68	-272.7516
11	-0.8662	-86.6323	-0.9948	-99.4873	3.8629	27.9909	9.6797	-272.7518
12	-0.8662	-86.6324	-0.9948	-99.4873	3.8629	27.991	9.6795	-272.752
13	-0.8662	-86.6325	-0.9948	-99.4873	3.8628	27.991	9.6792	-272.7523
14	-0.8662	-86.6325	-0.9948	-99.4874	3.8628	27.9911	9.679	-272.7525
15	-0.8663	-86.6326	-0.9948	-99.4874	3.8628	27.9911	9.6788	-272.7527
16	-0.8663	-86.6327	-0.9948	-99.4875	3.8628	27.9912	9.6786	-272.7529
17	-0.8663	-86.6328	-0.9948	-99.4875	3.8627	27.9912	9.6785	-272.753
18	-0.8663	-86.6328	-0.9948	-99.4876	3.8627	27.9912	9.6783	-272.7532
19	-0.8663	-86.6329	-0.9948	-99.4876	3.8627	27.9912	9.6782	-272.7534
20	-0.8663	-86.6329	-0.9948	-99.4876	3.8627	27.9912	9.6781	-272.7535
21	-0.8663	-86.633	-0.9948	-99.4877	3.8627	27.9912	9.6779	-272.7537
22	-0.8663	-86.633	-0.9948	-99.4877	3.8627	27.9912	9.6778	-272.7538
23	-0.8663	-86.6331	-0.9948	-99.4877	3.8626	27.9912	9.6777	-272.7539
24	-0.8663	-86.6331	-0.9948	-99.4878	3.8626	27.9912	9.6776	-272.754
25	-0.8663	-86.6332	-0.9948	-99.4878	3.8626	27.9911	9.6775	-272.7542

Table 7: The US economy case, subperiod 1992-2000: Evolution of prices and individual allocations

Period	Var.	Var.	Var.	Var.	Var.	Var.	Var.	Var.	Var.
	r	ir	w	q	c_c	c_u	h_c	h_u	b_c
1	0.0671	0.0685	1.3309	0.9524	1.2512	1.3582	8.7637	9.6206	-6.5154
2	0.0676	0.1281	1.3349	0.9571	1.1059	1.3663	6.7787	10.6169	-5.2833
3	0.0678	0.1092	1.3443	0.9588	0.9727	1.3746	6.745	10.6398	-5.5528
4	0.0678	-0.0639	1.3534	0.9606	1.1595	1.3668	8.2418	9.8959	-6.476
5	0.0677	0.064	1.3578	0.9621	1.064	1.3719	7.4019	10.3228	-5.8694
6	0.0678	-0.0039	1.3673	0.963	1.1495	1.3694	7.8911	10.0816	-6.1761
7	0.0678	0.0152	1.3749	0.9639	1.123	1.3704	8.337	9.8658	-6.5455
8	0.0677	0.0321	1.3822	0.9644	1.1188	1.3714	7.9909	10.0412	-6.2429
9	0.0677	0.0042	1.3946	0.9656	1.1214	1.3712	8.5219	9.7831	-6.6032
10	0.0658	0.0095	1.3664	0.9667	1.1408	1.3704	7.3669	10.3678	-5.413
11	0.0652	0.0092	1.3552	0.9666	1.1523	1.3691	7.6896	10.2131	-5.6558
12	0.065	0.0088	1.3506	0.9658	1.1602	1.3677	7.9122	10.1079	-5.8186
13	0.065	0.0086	1.3483	0.9649	1.1658	1.3663	8.0712	10.0339	-5.9312
14	0.0651	0.0086	1.347	0.9637	1.1697	1.365	8.187	9.9808	-6.0103
15	0.0652	0.0086	1.346	0.9626	1.1724	1.3637	8.2725	9.9424	-6.0662
16	0.0653	0.0086	1.3451	0.9614	1.1742	1.3626	8.3359	9.9143	-6.1054
17	0.0655	0.0086	1.3443	0.9602	1.1754	1.3615	8.3833	9.8938	-6.1328
18	0.0656	0.0087	1.3436	0.9591	1.1762	1.3604	8.4189	9.8787	-6.1515
19	0.0657	0.0088	1.3428	0.9581	1.1766	1.3595	8.4457	9.8675	-6.1641
20	0.0658	0.0088	1.3422	0.9571	1.1769	1.3586	8.466	9.8591	-6.1722
....	....	....	....	....	....	....	....	....	....
85	0.0671	0.0101	1.3332	0.9474	1.172	1.346	8.5052	9.7682	-6.1317
86	0.0671	0.0101	1.3332	0.9474	1.172	1.346	8.5047	9.7676	-6.1315
87	0.0671	0.0101	1.3332	0.9474	1.172	1.346	8.5043	9.7671	-6.1314
88	0.0671	0.0101	1.3332	0.9474	1.172	1.3459	8.5039	9.7666	-6.1312
89	0.0671	0.0101	1.3332	0.9475	1.1719	1.3459	8.5035	9.7661	-6.131
90	0.0671	0.0101	1.3332	0.9475	1.1719	1.3459	8.5031	9.7656	-6.1309
91	0.0671	0.0101	1.3332	0.9475	1.1719	1.3459	8.5028	9.7652	-6.1307
92	0.0671	0.0101	1.3332	0.9475	1.1719	1.3459	8.5024	9.7647	-6.1306
93	0.0671	0.0101	1.3332	0.9475	1.1719	1.3459	8.502	9.7643	-6.1304
94	0.0671	0.0101	1.3332	0.9475	1.1719	1.3458	8.5017	9.7638	-6.1303
95	0.0671	0.0101	1.3332	0.9476	1.1719	1.3458	8.5014	9.7634	-6.1302
96	0.0671	0.0101	1.3332	0.9476	1.1719	1.3458	8.501	9.763	-6.13
97	0.0671	0.0101	1.3332	0.9476	1.1719	1.3458	8.5007	9.7626	-6.1299
98	0.0671	0.0101	1.3332	0.9476	1.1719	1.3458	8.5004	9.7623	-6.1298
99	0.0671	0.0101	1.3332	0.9476	1.1718	1.3458	8.5001	9.7619	-6.1297
100	0.0671	0.0101	1.3332	0.9476	1.1718	1.3458	8.4998	9.7615	-6.1296

Table 8: The US economy case, subperiod 1992-2000: Evolution of the aggregate variables and welfare

Period	Var. u_u	Var. V_u	Var. u_c	Var. V_c	Var. c	Var. h	Var. k	Var. V
1	-0.8637	-86.3871	-0.9525	-99.5397	3.9677	28.0048	9.6089	-272.3138
2	-0.844	-86.271	-1.0717	-99.9144	3.8384	28.0126	9.6238	-272.4565
3	-0.8394	-86.1673	-1.1716	-100.1279	3.722	28.0247	9.7156	-272.4625
4	-0.853	-86.3246	-1.0094	-99.6514	3.8932	28.0337	9.7328	-272.3006
5	-0.8446	-86.2589	-1.0914	-99.8031	3.8078	28.0476	9.8	-272.3209
6	-0.8495	-86.3277	-1.0247	-99.6244	3.8883	28.0544	9.8441	-272.2797
7	-0.8513	-86.3305	-1.0332	-99.5998	3.8637	28.0686	9.9104	-272.2608
8	-0.8488	-86.3344	-1.0451	-99.6123	3.8617	28.0733	9.9933	-272.2811
9	-0.852	-86.3585	-1.0319	-99.5261	3.8638	28.0882	10.0909	-272.243
10	-0.8455	-86.3694	-1.0392	-99.4935	3.8816	28.1025	10.1141	-272.2323
11	-0.848	-86.3874	-1.0241	-99.4507	3.8905	28.1158	10.1083	-272.2255
12	-0.8499	-86.4033	-1.0138	-99.4219	3.8957	28.128	10.0911	-272.2284
13	-0.8515	-86.4174	-1.0066	-99.4027	3.8985	28.1389	10.0696	-272.2375
14	-0.8529	-86.43	-1.0016	-99.3904	3.8997	28.1487	10.0467	-272.2505
15	-0.854	-86.4415	-0.9981	-99.3828	3.8999	28.1572	10.0237	-272.2659
16	-0.855	-86.452	-0.9956	-99.3787	3.8994	28.1646	10.0013	-272.2827
17	-0.8558	-86.4616	-0.9939	-99.377	3.8984	28.1709	9.9798	-272.3002
18	-0.8566	-86.4705	-0.9927	-99.3769	3.897	28.1763	9.9594	-272.3178
19	-0.8572	-86.4787	-0.992	-99.378	3.8956	28.1807	9.9401	-272.3353
20	-0.8578	-86.4863	-0.9915	-99.3799	3.894	28.1842	9.922	-272.3525
...	....	....	....	....	....	....	....	....
85	-0.8658	-86.6205	-0.9943	-99.4747	3.864	28.0415	9.6823	-272.7157
86	-0.8658	-86.6209	-0.9944	-99.4751	3.8639	28.04	9.6821	-272.7169
87	-0.8658	-86.6213	-0.9944	-99.4755	3.8639	28.0385	9.6818	-272.7181
88	-0.8658	-86.6217	-0.9944	-99.4759	3.8638	28.0371	9.6816	-272.7193
89	-0.8659	-86.6221	-0.9944	-99.4763	3.8638	28.0357	9.6814	-272.7204
90	-0.8659	-86.6224	-0.9944	-99.4767	3.8637	28.0344	9.6812	-272.7215
91	-0.8659	-86.6228	-0.9944	-99.477	3.8637	28.0331	9.6811	-272.7226
92	-0.8659	-86.6231	-0.9944	-99.4774	3.8637	28.0318	9.6809	-272.7236
93	-0.8659	-86.6234	-0.9945	-99.4777	3.8636	28.0306	9.6807	-272.7246
94	-0.8659	-86.6238	-0.9945	-99.478	3.8636	28.0294	9.6806	-272.7256
95	-0.8659	-86.6241	-0.9945	-99.4784	3.8635	28.0282	9.6804	-272.7265
96	-0.866	-86.6244	-0.9945	-99.4787	3.8635	28.0271	9.6803	-272.7274
97	-0.866	-86.6247	-0.9945	-99.479	3.8635	28.026	9.6801	-272.7283
98	-0.866	-86.625	-0.9945	-99.4792	3.8634	28.0249	9.68	-272.7292
99	-0.866	-86.6252	-0.9945	-99.4795	3.8634	28.0239	9.6799	-272.73
100	-0.866	-86.6255	-0.9945	-99.4798	3.8634	28.0229	9.6797	-272.7308

Table 9: The US economy case, subperiod 2003-2009: Evolution of prices and individual allocations

Period	Var.	Var.	Var.	Var.	Var.	Var.	Var.	Var.	Var.
	r	ir	w	q	c_c	c_u	h_c	h_u	b_c
1	0.0675	0.0626	1.3412	0.9533	1.187	1.3551	8.2322	9.8862	-6.2142
2	0.0678	0.2792	1.3546	0.9588	0.8687	1.3757	1.5042	13.2538	-1.0918
3	0.0676	-0.1013	1.3662	0.9632	1.1609	1.3668	6.9411	10.5453	-5.1893
4	0.0677	0.0832	1.3762	0.9656	1.0723	1.3727	5.8187	11.1096	-4.4403
5	0.0674	0.0471	1.3847	0.9641	1.0519	1.3758	6.9246	10.5615	-5.4169
6	0.0669	0.027	1.3898	0.9683	1.1123	1.375	6.711	10.6791	-5.1662
7	0.066	0.0126	1.3786	0.9721	1.1526	1.3743	6.4388	10.8245	-4.778
8	0.065	0.0119	1.3613	0.9714	1.1606	1.3729	7.8552	10.1249	-6.0904
9	0.0648	0.0089	1.3542	0.9701	1.1669	1.3713	8.0607	10.0298	-6.2454
10	0.0648	0.0086	1.3509	0.9685	1.1708	1.3698	8.193	9.9705	-6.3397
11	0.0649	0.0085	1.349	0.9669	1.1733	1.3683	8.2822	9.932	-6.3988
12	0.065	0.0085	1.3477	0.9653	1.1748	1.3668	8.3441	9.9063	-6.4363
13	0.0651	0.0085	1.3466	0.9637	1.1756	1.3655	8.388	9.8889	-6.4598
14	0.0653	0.0085	1.3456	0.9623	1.176	1.3643	8.4197	9.8769	-6.4741
15	0.0654	0.0086	1.3447	0.9609	1.1762	1.3631	8.4428	9.8687	-6.4824
16	0.0655	0.0087	1.3439	0.9596	1.1761	1.3621	8.46	9.8628	-6.4865
17	0.0656	0.0087	1.3431	0.9585	1.176	1.3611	8.4728	9.8586	-6.4879
18	0.0657	0.0088	1.3424	0.9574	1.1757	1.3602	8.4826	9.8555	-6.4875
19	0.0658	0.0089	1.3418	0.9564	1.1755	1.3593	8.4902	9.8531	-6.486
20	0.0659	0.009	1.3411	0.9554	1.1752	1.3585	8.4961	9.8511	-6.4838
....	....	....	....	....	....	....	....	....	....
85	0.0671	0.0101	1.3332	0.9474	1.1694	1.3473	8.4859	9.7772	-6.4153
86	0.0671	0.0101	1.3332	0.9474	1.1694	1.3473	8.4854	9.7767	-6.4152
87	0.0671	0.0101	1.3332	0.9474	1.1693	1.3472	8.485	9.7762	-6.415
88	0.0671	0.0101	1.3332	0.9474	1.1693	1.3472	8.4846	9.7757	-6.4148
89	0.0671	0.0101	1.3332	0.9475	1.1693	1.3472	8.4842	9.7752	-6.4146
90	0.0671	0.0101	1.3332	0.9475	1.1693	1.3472	8.4839	9.7747	-6.4145
91	0.0671	0.0101	1.3332	0.9475	1.1693	1.3472	8.4835	9.7743	-6.4143
92	0.0671	0.0101	1.3332	0.9475	1.1693	1.3472	8.4831	9.7738	-6.4142
93	0.0671	0.0101	1.3332	0.9475	1.1693	1.3472	8.4828	9.7734	-6.414
94	0.0671	0.0101	1.3332	0.9475	1.1693	1.3471	8.4825	9.773	-6.4139
95	0.0671	0.0101	1.3332	0.9476	1.1693	1.3471	8.4821	9.7726	-6.4138
96	0.0671	0.0101	1.3332	0.9476	1.1692	1.3471	8.4818	9.7722	-6.4136
97	0.0671	0.0101	1.3332	0.9476	1.1692	1.3471	8.4815	9.7718	-6.4135
98	0.0671	0.0101	1.3332	0.9476	1.1692	1.3471	8.4812	9.7714	-6.4134
99	0.0671	0.0101	1.3332	0.9476	1.1692	1.3471	8.4809	9.7711	-6.4133
100	0.0671	0.0101	1.3331	0.9477	1.1692	1.3471	8.4806	9.7707	-6.4132

Table 10: The US economy case, subperiod 2003-2009: Evolution of aggregate variables and welfare

Period	Var. u_u	Var. V_u	Var. u_c	Var. V_c	Var. c	Var. h	Var. k	Var. V
1	-0.863	-86.4041	-1.0205	-99.5833	3.8971	28.0046	9.667	-272.3916
2	-0.8066	-86.0992	-1.3476	-100.415	3.6202	28.0117	9.8331	-272.6133
3	-0.8489	-86.2976	-1.0578	-99.6826	3.8946	28.0318	9.8636	-272.2778
4	-0.8343	-86.2253	-1.1155	-99.8678	3.8177	28.038	9.9589	-272.3183
5	-0.8418	-86.2114	-1.1297	-99.9032	3.8035	28.0476	10.0723	-272.3259
6	-0.8395	-86.2445	-1.0744	-99.7383	3.8623	28.0691	10.1521	-272.2273
7	-0.8397	-86.2686	-1.0575	-99.6676	3.9011	28.0878	10.1839	-272.2047
8	-0.847	-86.2914	-1.0148	-99.6081	3.9064	28.105	10.1756	-272.1909
9	-0.849	-86.3072	-1.0062	-99.5902	3.9095	28.1203	10.1524	-272.2046
10	-0.8505	-86.3213	-1.0008	-99.5805	3.9103	28.134	10.1243	-272.2231
11	-0.8517	-86.334	-0.9973	-99.5759	3.9098	28.1461	10.0953	-272.244
12	-0.8528	-86.3457	-0.9951	-99.5746	3.9085	28.1566	10.067	-272.266
13	-0.8537	-86.3564	-0.9937	-99.5755	3.9067	28.1658	10.04	-272.2882
14	-0.8545	-86.3663	-0.9928	-99.5777	3.9046	28.1736	10.0146	-272.3102
15	-0.8552	-86.3755	-0.9923	-99.5807	3.9025	28.1802	9.9907	-272.3317
16	-0.8559	-86.3841	-0.9921	-99.5843	3.9003	28.1856	9.9684	-272.3525
17	-0.8564	-86.3921	-0.992	-99.5882	3.8981	28.1901	9.9477	-272.3724
18	-0.857	-86.3996	-0.992	-99.5922	3.896	28.1937	9.9285	-272.3915
19	-0.8575	-86.4067	-0.9921	-99.5962	3.8941	28.1964	9.9106	-272.4096
20	-0.8579	-86.4134	-0.9922	-99.6002	3.8922	28.1983	9.894	-272.4269
....	....	....	....	....	....	....	....	....
85	-0.865	-86.5368	-0.9966	-99.6975	3.8639	28.0402	9.682	-272.7712
86	-0.865	-86.5372	-0.9966	-99.6979	3.8639	28.0388	9.6818	-272.7724
87	-0.865	-86.5376	-0.9966	-99.6983	3.8638	28.0373	9.6816	-272.7736
88	-0.865	-86.538	-0.9966	-99.6987	3.8638	28.036	9.6814	-272.7747
89	-0.865	-86.5384	-0.9966	-99.699	3.8637	28.0346	9.6812	-272.7758
90	-0.865	-86.5387	-0.9967	-99.6994	3.8637	28.0333	9.681	-272.7769
91	-0.8651	-86.5391	-0.9967	-99.6997	3.8637	28.032	9.6808	-272.7779
92	-0.8651	-86.5394	-0.9967	-99.7001	3.8636	28.0308	9.6807	-272.7789
93	-0.8651	-86.5397	-0.9967	-99.7004	3.8636	28.0296	9.6805	-272.7799
94	-0.8651	-86.54	-0.9967	-99.7007	3.8635	28.0284	9.6804	-272.7808
95	-0.8651	-86.5403	-0.9967	-99.701	3.8635	28.0273	9.6802	-272.7817
96	-0.8651	-86.5406	-0.9967	-99.7013	3.8635	28.0261	9.6801	-272.7826
97	-0.8651	-86.5409	-0.9967	-99.7016	3.8634	28.0251	9.68	-272.7834
98	-0.8651	-86.5412	-0.9968	-99.7019	3.8634	28.024	9.6798	-272.7843
99	-0.8652	-86.5415	-0.9968	-99.7021	3.8634	28.023	9.6797	-272.7851
100	-0.8652	-86.5417	-0.9968	-99.7024	3.8634	28.022	9.6796	-272.7859

Table 11: The comparison of the present value of household allocations, aggregate variables and welfare resulting from actual transition with the present value of the those resulting from the situation with unchanged steady state

Var.	Actual transition	Unchanged steady state	Actual transition	Unchanged steady state
	One-period increase in LTV		One-period increase in productivity	
c_u	84.441	84.441	84.446	84.441
c_c	73.532	73.532	73.534	73.532
h_u	580.187	580.199	580.292	580.199
h_c	505.253	505.236	505.208	505.236
u_u	-54.373	-54.371	-54.369	-54.371
u_c	-62.438	-62.442	-62.4418	-62.442
V_u	-5437.401	-5437.39	-5437.34	-5437.39
V_c	-6244.14	-6244.183	-6244.178	-6244.183
c	242.417	242.417	242.429	242.417
h	1756.674	1665.36	1665.828	1665.36
V	-17118.991	-17118.993	-17118.833	-17118.993
	US case, 1992-2000 subperiod		US case, 2003-2009 subperiod	
c_u	84.972	84.441	84.975	84.525
c_c	73.121	73.532	72.940	73.368
h_u	590.042	580.199	595.067	580.762
h_c	500.027	505.236	490.664	504.109
u_u	-53.994	-54.371	-53.907	-54.321
u_c	-62.908	-62.442	-63.286	-62.581
V_u	-5430.45	-5437.39	-5425.82	-5432.13
V_c	-6249.203	-6244.183	-6263.35	-6358.14
c	243.066	242.417	243	242.417
h	1680.112	1665.36	1680.799	1665.64
V	-17104.232	-17118.993	-17107.3	-17122.4