Center for
Economic Theories and Policies
Sofia University St. Kliment Ohridski
Faculty of Economics and Business Administration

ISSN: 2367-7082

Bulgarian Economic Papers

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Aleksandar Vasilev

BEP 01-2026
Publication: January 2026

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Abstract

Housing stock, and the accumulation of utility-enhancing housing capital are introduced as an additional mechanism into a real-business-cycle setup augmented with a detailed government sector. The model is calibrated to Bulgarian data for the period following the introduction of the currency board arrangement (1999-2024). The quantitative importance of the presence of housing capital accumulation is investigated for the propagation of cyclical fluctuations in Bulgaria. In particular, allowing for housing considerations in the setup improves the model fit vis-a-vis data by increasing the variability of employment and decreasing the variability of consumption and investment. However, those improvements are at the cost of decreasing the volatility of wages. The model severely over-predicts variability of housing investment, and wrongly concludes that it is counter-cyclical. Still, the model with housing is a clear improvement relative to the standard RBC setup.

Keywords: business cycles, housing, Bulgaria

JEL Classification Codes: E24, E32

*Researcher, Faculty of Economics and Business Administration, Sofia University, Bulgaria. E-mail for correspondence: alvasilev@yahoo.com

1 Introduction and Motivation

The standard real-business-cycle (RBC) model, e.g. Prescott (1986), and Kydland and Prescott (1990), is known to exhibit several shortcomings, especially along the labor market dimension. One of the reasons behind these "failures" is the assumption of perfectly-competitive labor markets, which might be too restrictive at an aggregate economic level. Another possibility is that potentially an important ingredient is missing from the model, or that the assumption of a homogeneous aggregate capital is too restrictive. One such possible missing link is housing - after all, economists distinguish between productive capital, or machinery used as a capital input in the production of consumption goods, and other (residential) capital, which provides consumption-type services. Before the financial crisis/real estate crisis, housing was rarely in the focus of economics, and macroeconomics in particular.[1] It was a topic dealt mostly by urban economists and those specializing in regional economics.

Housing entered macroeconomic models in the mid-2000s, more than two decades after Kydland and Prescott (1982) first quantitative micro-founded model: Davis and Heathcore (2005), and later, Kydland at al. (2016) are the first to include housing, and investigate housing dynamics over the US cycle using a dynamic general equilibrium model.[2] The difficulty is that housing is discrete, and heterogeneous, while the representative agent setup required a very stylized modelling shortcut. Thus, we use a simplified version of their approach here: The main focus falls on the real side of the housing issue - the provision of shelter and protection of elements, which is a major determinant of living standards.[3] The setup introduces housing considerations in a tractable way, so that some novel and interesting insights can

[1] After the crisis, macroeconomists started paying more attention to the problem with collateralization, the corporate finance problem, and more generally, the link between real and financial side of the economy.

[2] Further papers with co-authors, e.g., Garriga et al. (2017, 2021), followed to introduce financial frictions in the mortgage markets within a New-Keynesian model with sticky prices and monopolistic competition to study monetary policy effects. In contrast, in this paper we keep the model real, and abstract away from nominal frictions. Furthermore, Bulgaria is operating under a currency board, so it does not have an independent monetary policy.

[3] The model presented in this paper is thus equivalent to a setup with perfect credit (mortgage) markets - mortgages; it is isomorphic to a model where households are owning a building society mutual. After all, in general equilibrium, someone owns banks and financial institutions. Since it is a representative agent model, the setup will abstract away from inequality issues.

still be drawn and seen analytically. To keep matters as simple as possible, the model does not distinguish between owning and lending, or between land and structures; these are all lumped together to keep the analysis tractable. In the model setup, the presence of housing serves two roles: first, as a utility component, and then as a type of capital, which can be accumulated by the household - introduces several new margins of adjustment: first, the representative agent would balance between consumption and housing, as well as between labor supply and housing, as the household derives utility out of leisure. Second, the agent balances between the dynamic paths of accumulation of physical and housing capital. The distinction is that housing capital is assumed to be non-marketable, i.e, it is assumed that housing is providing non-tradable housing services. In this sense, the return on housing is in terms of marginal utility out of enjoying housing services, net of depreciation and taxes, while the return on physical capital is its marginal product, net od taxes and depreciation. The presence of housing in turn will affect wages, interest rates, and thus production, investment, and physical capital accumulation decisions as well (which is the main propagation channel in the model).Therefore, allowing for housing considerations in the theoretical setup can generate additional interesting interactions among model variables.

This proposal is taken seriously, and this paper incorporates housing capital in an otherwise standard real-business-cycle (RBC) model with a detailed government sector. The model is calibrated for Bulgaria in the period 1999-2024, as Bulgaria provides a good testing case for the theory. The paper then proceeds to quantitatively evaluate the effect of such an additional mechanism of business cycle propagation. This is the first study on the issue using modern macroeconomic modeling techniques, and thus an important contribution to the field. In particular, allowing for housing considerations in the setup improves the model fit vis-a-vis data by increasing the variability of employment and decreasing the variability of consumption and investment. However, those improvements are at the cost of decreasing the volatility of wages. The model severely over-predicts variability of housing investment, and wrongly concludes that it is counter-cyclical. Still, the model with housing is a clear improvement relative to the standard RBC setup.

The rest of the paper is organized as follows: Section 2 describes the model framework and describes the decentralized competitive equilibrium system, Section 3 discusses the calibration procedure, and Section 4 presents the steady-state model solution. Sections 5 proceeds with the out-of-steady-state dynamics of model variables, and compared the simulated second moments of theoretical variables against their empirical counterparts. Section 6 concludes the paper.

2 Model Description

There is a representative households which derives utility out of consumption, housing capital, and leisure. The time available to households can be spent in productive use or as leisure. The government taxes consumption spending, levies a common proportional ("flat") tax on labor and capital income, as well as a tax on housing, in order to finance wasteful purchases of government consumption goods, and government transfers. On the production side, there is a representative firm, which hires labor and capital to produce a homogeneous final good, which could be used for consumption, investment, or government purchases.

2.1 Households

There is a representative household, which maximizes its expected utility function

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \Big\{ \ln c_t + \psi \ln d_t + \gamma \ln(1 - h_t) \Big\} \tag{2.1}$$

where E_0 denotes household's expectations as of period 0, c_t denotes household's private consumption in period t, d_t is the amount of housing capital/stock, h_t are hours worked in period t, $0 < \beta < 1$ is the discount factor, $0 < \gamma < 1$ is the relative weight that the household attaches to leisure, and $\psi_t > 0$ is the utility weight (relative to consumption) attached to housing.[4]

The household starts with an initial stock of physical capital $k_0 > 0$, as well as an ini-

[4]This utility function is equivalent to a specification with a separable term containing government consumption, e.g. Baxter and King (1993). Since in this paper we focus on the exogenous (observed) policies, and the household takes government spending as given, the presence of such a term is irrelevant. For the sake of brevity, we skip this term in the utility representation above.

tial stock of housing capital $d_0 > 0$, and has to decide how much to add to each type of capital in the form of new investment. The law of motion for physical capital is

$$k_{t+1} = i_t^k + (1 - \delta^k)k_t \tag{2.2}$$

and $0 < \delta^k < 1$ is the depreciation rate on physical capital.

Similarly, the law of motion for housing capital is

$$d_{t+1} = i_t^d + (1 - \delta^d)d_t \tag{2.3}$$

and $0 < \delta^d < 1$ is the depreciation rate of housing capital. Housing capital is assumed to be non-tradable; that corresponds to the assumption that people buy a house to live in it, and not as a re-sellable asset. While being a bit of an extreme assumption, it simplifies the model a lot, without compromising on the economics behind the model.

Next, the real interest rate is r_t, hence the before-tax capital income of the household in period t equals $r_t k_t$. In addition to capital income, the household can generate labor income. Hours supplied to the representative firm are rewarded at the hourly wage rate of w_t, so pre-tax labor income equals $w_t h_t$. Lastly, the household owns the firm in the economy and has a legal claim on all the firm's profit, π_t.

Next, the household's problem can be now simplified to

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \ln c_t + \psi \ln d_t + \gamma \ln(1 - h_t) \right\} \tag{2.4}$$

s.t.

$$(1 + \tau^c)c_t + k_{t+1} - (1 - \delta^k)k_t + d_{t+1} - (1 - \delta^d)d_t + \tau^d d_t = (1 - \tau^y)[r_t k_t + \pi_t + w_t h_t] + g_t^t, \tag{2.5}$$

where τ^c is the tax on consumption, τ^y is the proportional income tax rate on labor, and τ^d is the housing tax ($0 < \tau^c, \tau^y, \tau^d < 1$), and g_t^t denotes government transfers. The household takes all tax rates $\{\tau^c, \tau^y, \tau^d\}$, government spending categories, $\{g_t^c, g_t^t\}_{t=0}^{\infty}$, profit $\{\pi_t\}_{t=0}^{\infty}$, the realized technology process $\{A_t\}_{t=0}^{\infty}$, prices $\{w_t, r_t\}_{t=0}^{\infty}$, and chooses $\{c_t, h_t, d_{t+1},$

$k_{t+1}\}_{t=0}^{\infty}$ to maximize its utility subject to the budget constraint.[5] The first-order optimality conditions as as follows:

$$c_t \quad : \quad \frac{1}{c_t} = \lambda_t(1+\tau^c)$$

$$h_t \quad : \quad \frac{\gamma}{1-h_t} = \lambda_t(1-\tau^l)w_t \tag{2.6}$$

$$k_{t+1} \quad : \quad \lambda_t = \beta E_t \lambda_{t+1}\Big[1+[1-\tau^y]r_{t+1}-\delta^k\Big] \tag{2.7}$$

$$d_{t+1} \quad : \quad \beta E_t \frac{\psi}{d_{t+1}} - \lambda_t + \beta E_t \lambda_{t+1}(1-\delta^d) - \beta E_t \lambda_{t+1}\tau^d = 0 \tag{2.8}$$

$$TVC_k \quad : \quad \lim_{t\to\infty} \beta^t \lambda_t k_{t+1} = 0 \tag{2.9}$$

$$TVC_d \quad : \quad \lim_{t\to\infty} \beta^t \lambda_t d_{t+1} = 0 \tag{2.10}$$

where λ_t is the Lagrangian multiplier attached to household's budget constraint in period t. The interpretation of the first-order conditions above is as follows: the first one states that for each household, the marginal utility of consumption equals the marginal utility of wealth, corrected for the consumption tax rate. Next, the second equation states that when choosing labor supply optimally, at the margin, each hour spent by the household working for the firm should balance the benefit from doing so in terms of additional income generates, and the cost measured in terms of lower utility of leisure. The third equation is the so-called "Euler condition," which describes how the household chooses to allocate physical capital over time. The optimality condition for housing capital is the novelty of the model. Being a dynamic variable, optimal allocation of housing over time is similar in spirit to the asset equation for physical capital; hence, we call it the "housing-Euler equation." The last two conditions are called the "transversality" conditions (TVCs): those boundary conditions state that at the end of the optimization horizon, the value of both physical and housing capital should be zero.

2.2 Firm problem

There is a representative firm in the economy, which produces a homogeneous product. The price of output is normalized to unity. The production technology is Cobb-Douglas and uses

[5] Note that by choosing k_{t+1} and d_{t+1}, the household is implicitly setting the respective investment levels i_t^k and i_t^d optimally.

both physical capital, k_t, and labor hours, h_t, to maximize static profit

$$\Pi_t = A_t k_t^{\alpha} h_t^{1-\alpha} - r_t k_t - w_t h_t, \tag{2.11}$$

where A_t denotes the level of technology in period t. Since the firm rents the capital from households, the problem of the firm is a sequence of static profit maximizing problems. In equilibrium, there are no profits, and each input is priced according to its marginal product, *i.e.*:

$$k_t \;:\; \alpha \frac{y_t}{k_t} = r_t, \tag{2.12}$$

$$h_t \;:\; (1-\alpha) \frac{y_t}{h_t} = w_t. \tag{2.13}$$

In equilibrium, given that the inputs of production are paid their marginal products, $\pi_t = 0$, $\forall t$.

2.3 Government

In the model setup, the government is levying taxes on labor and capital income, as well as consumption and housing capital stock, in order to finance spending on wasteful government purchases, and government transfers. The government budget constraint is as follows:

$$g_t^c + g_t^t = \tau^c c_t + \tau^y [w_t h_t + r_t k_t + \pi_t] + \tau^d d_t \tag{2.14}$$

Income and consumption tax rates, property tax revenue to output, and government consumption-to-output ratio would be chosen to match the average share in data. Finally, government transfers would be determined residually in each period so that the government budget is always balanced.

2.4 Dynamic Competitive Equilibrium (DCE)

For a given processes followed by technology $\{A_t\}_{t=0}^{\infty}$ tax schedules $\{\tau^c, \tau^y, \tau^d\}_{t=0}^{\infty}$, and initial capital stocks $\{k_0, d_0]\}$, the decentralized dynamic competitive equilibrium is a list of sequences $\{c_t, i_t^k, i_t^d, k_t, d_t, h_t\}_{t=0}^{\infty}$ for the household, a sequence of government purchases and transfers $\{g_t^c, g_t^t\}_{t=0}^{\infty}$, and input prices $\{w_t, r_t\}_{t=0}^{\infty}$ such that (i) the household maximizes its utility function subject to its budget constraint; (ii) the representative firm maximizes profit; (iii) government budget is balanced in each period; (iv) all markets clear.

Data and Model Calibration

To characterize business cycle fluctuations in Bulgaria, we will focus on the period following the introduction of the currency board (1999-2024). Quarterly data on output, consumption and investment was collected from National Statistical Institute (2025), while the real interest rate is taken from Bulgarian National Bank Statistical Database (2025). The calibration strategy described in this section follows a long-established tradition in modern macroeconomics: first, as in Vasilev (2016), the discount factor, $\beta = 0.982$, is set to match the steady-state capital-to-output ratio in Bulgaria, $k/y = 13.964$, in the steady-state Euler equation. Next, the labor share parameter, $1 - \alpha = 0.571$, is obtained as in Vasilev (2017d), and equals the average value of labor income in aggregate output over the period 1999-2018. This value is slightly higher as compared to other studies on developed economies, due to the over-accumulation of physical capital, which was part of the ideology of the totalitarian regime, which was in place until 1989. Next, the average income tax rate was set to $\tau^y = 0.1$. This is the average effective tax rate on income between 1999-2007, when Bulgaria used progressive income taxation, and equal to the proportional income tax rate introduced as of 2008. Similarly, the average tax rate on consumption is set to its value over the period, $\tau^c = 0.2$. The tax rate on housing, $\tau^d = 0.003$ was set to approximate the average effective property and inheritance levies.

Next, the relative weight attached to the utility out of leisure in the household's utility function, γ, is calibrated to match that in steady-state consumers would supply one-third of their time endowment to working. This is in line with the estimates for Bulgaria (Vasilev 2017a) as well over the period studied. The utility weight attached to housing, ψ, was similarly calibrated from the household's housing dynamic optimality condition Note that this utility weight is relative to the consumption utility component. Proceeding with technology parameters, the depreciation rate of physical capital in Bulgaria, $\delta = 0.013$, was taken from Vasilev (2018). It was estimated as the average quarterly depreciation rate over the period 1999-2014. The corresponding one for housing was computed to be $\delta^d = 0.04$ per quarter. Together with the data on average construction-to-output ratio, $i^d/y = 0.056$, this was used to determine the steady state housing stock to output, d/y.[6] Finally, the process followed by the TFP process is estimated from the detrended series by running an AR(1) regression and saving the residuals. Table 1 on the next page summarizes the values of all model parameters used in the paper, and the method used to determine their values.

Table 1: Model Parameters

Parameter	Value	Description	Method
β	0.982	Discount factor	Calibrated
α	0.429	Capital Share	Data average
ψ	0.489	Relative weight attached to housing	Calibrated
γ	0.121	Relative weight attached to leisure	Calibrated
δ^k	0.013	Depreciation rate on physical capital	Data average
δ^d	0.003	Depreciation rate on housing capital	Data average
τ^y	0.100	Average tax rate on income	Data average
τ^c	0.200	VAT/consumption tax rate	Data average
τ^d	0.003	Average tax rate on housing stock	Data average
ρ_a	0.701	AR(1) persistence coefficient, TFP process	Estimated
σ_a	0.044	st. error, TFP process	Estimated

3 Steady-State

Once the values of model parameters were obtained, the steady-state equilibrium system solved, the "big ratios" can be compared to their averages in Bulgarian data. The results are reported in Table 2 on the next page. The steady-state level of output was normalized to unity (hence the level of technology A differs from one, which is usually the normalization done in other studies), which greatly simplified the computations. Next, the model matches well consumption-to-output ratio, and by construction matches exactly government purchases ratios; The investment ratios are also closely approximated, despite the closed-

[6] The obtained value is not far off from the value of housing stock to output, where the value of housing was computed by multiplying the overall area of dwellings times the housing price index, where both series are from NSI (2025).

economy assumption and the absence of foreign trade sector. The shares of income are also identical to those in data, which is an artifact of the assumptions imposed on functional form of the aggregate production function. The after-tax return, where $\bar{r} = (1 - \tau^y)r - \delta$ is also relatively well-captured by the model. For housing, we can compute the corresponding implicit return (as housing capital is assumed to be non- tradable) from the no-arbitrage condition between physical and housing capital. Lastly, given the absence of debt, and the fact that transfers were chosen residually to balance the government budget constraint, the result along this dimension is understandably not so close to the average ratio in data.

Table 2: Data Averages and Long-run Solution

Variable	Description	Data	Model
y	Steady-state output	N/A	1.000
c/y	Consumption-to-output ratio	0.648	0.620
i^k/y	Investment-to-output ratio	0.201	0.175
i^d/y	Housing investment-to-output ratio	0.056	0.056
k/y	Capital-to-output ratio	13.96	13.96
h/y	Housing capital-to-output ratio	17.24	17.24
g^c/y	Government consumption-to-output ratio	0.151	0.151
wh/y	Labor income-to-output ratio	0.571	0.571
rk/y	Capital income-to-output ratio	0.429	0.429
h	Share of time spent working	0.333	0.333
$\bar{r}$	After-tax net return on capital	0.014	0.016

4 Out of steady-state model dynamics

Since the model does not have an analytical solution for the equilibrium behavior of variables outside their steady-state values, we need to solve the model numerically. This is done by log-linearizing the original equilibrium (non-linear) system of equations around the steady-state. This transformation produces a first-order system of stochastic difference equations. First, we study the dynamic behavior of model variables to an isolated shock to the total factor productivity process, and then we fully simulate the model to compare how the second moments of the model perform when compared against their empirical counterparts.

4.1 Impulse Response Analysis

This subsection documents the impulse responses of model variables to a 1% surprise innovation to technology. The impulse response functions (IRFs) are presented in Fig. 1 for the technology shock.

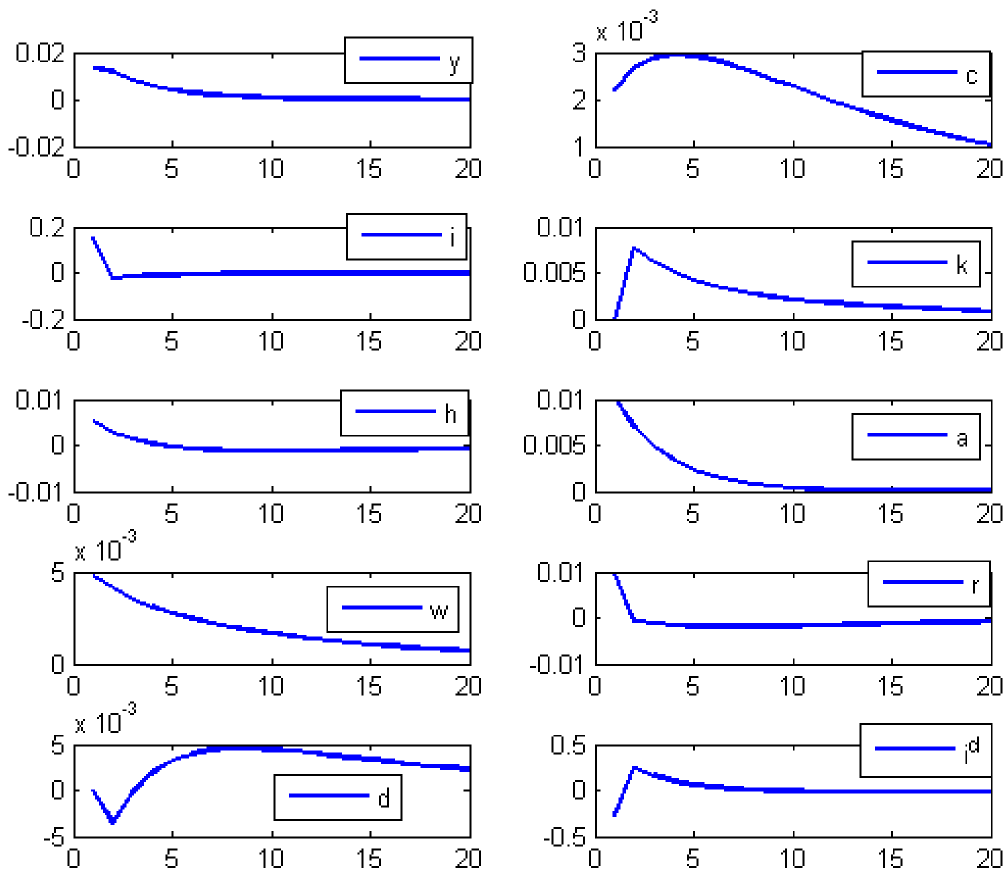

Figure 1: Impulse Responses to a 1% surprise innovation in technology

As a result of the one-time unexpected positive shock to total factor productivity, output increases upon impact. This expands the availability of resources in the economy, so uses of output - consumption, investment, and government consumption - also increase contemporaneously.

At the same time, the increase in productivity increases the after-tax return on the two factors of production, labor and capital. The representative households then respond to the incentives contained in prices and start accumulating capital, and supplies more hours worked. In turn, the increase in capital input feeds back in output through the production function and that further adds to the positive effect of the technology shock. In the labor market, the wage rate increases, and the household increases its hours worked. In turn, the increase in total hours further increases output, again indirectly.

The housing channel is secondary in the model. Investment in housing is an alternative methods of capital accumulation, which brings direct utility benefits, as compared to the indirect effect of capital, which brings additional capital income, which can in turn be spent on consumption and leisure. The model generates a housing investment puzzle - after a positive technology shock, investment in housing drops, but over time investment tends to co-move with output. This short-coming of the model is most probably due to the absence of any investment adjustment costs, and the lack of time-to-build delays in the housing capital production. Still, this simple mechanism is quite good at capturing housing dynamics at medium-term frequencies.

Over time, as capital is being accumulated, its after-tax marginal product starts to decrease, which lowers the households' incentives to save. As a result, physical capital stock eventually returns to its steady-state, and exhibits a hump-shaped dynamics over its transition path. The rest of the model variables return to their old steady-states in a monotone fashion as the effect of the one-time surprise innovation in technology dies out.

4.2 Simulation and moment-matching

As in Vasilev (2017b), we will now simulate the model 10,000 times for the length of the data horizon. Both empirical and model simulated data is detrended using the Hodrick-Prescott (1980) filter. Table 3 on the next page summarizes the second moments of data (relative volatilities to output, and contemporaneous correlations with output) versus the same moments computed from the model-simulated data at quarterly frequency. The results presented are evaluated against the benchmark RBC setup without housing. In addition, to minimize the sample error, the simulated moments are averaged out over the computer-generated draws. As in Vasilev (2016, 2017b, 2017c), both models match quite well the absolute volatility of output. By construction, government consumption in the model varies as much as output. In addition, the predicted consumption and investment volatilies are a bit too high. Both models are qualitatively consistent with the stylized fact that consumption generally varies less than output, while investment is more volatile than output; in addition, the model with housing is closer to data along those dimensions. The model with housing produces less volatile consumption and employment, and smoother investment series, relative to the standard RBC setup. The model with housing generates a sensible figure for the relative volatility of the housing stock to output, but the volatility of investment in housing is much higher than the variability in construction to output, which was taken as a proxy. One explanation for the observed mismatch is that construction is mostly about net creation of housing, and does not take into consideration the "upkeep" spending on existing dwellings. Thus, the failure along this dimension could be due to the housing mechanism introduced in the model being too simple, and missing some interesting patterns.

With respect to the labor market variables, the variability of employment and wages predicted by the model with housing is lower than that in data, which is yet another confirmation that the perfectly-competitive assumption, e.g. Vasilev (2009), as well as the benchmark calibration here, does not describe very well the dynamics of labor market variables. Still, hours very a bit more in the model with housing. Variability of wages is better captured by the standard RBC model. This could be attributed to the fact that we do not model the housing production function, and do not introduce construction labor, which will introduce a new trade-off with the sectoral labor supply choice.

Next, in terms of contemporaneous correlations, the standard model systematically over-predicts the pro-cyclicality of the main aggregate variables - consumption, investment, and government consumption. This, however, is a common limitation of this class of RBC models.When housing is added, the correlations move closer to their empirical counterparts. In

Table 3: Business Cycle Moments

	Data	Benchmark RBC	RBC with housing
σ_y	0.05	0.05	0.05
σ_c/σ_y	0.55	0.82	0.68
σ_i/σ_y	1.77	2.35	2.01
σ_{i^d}/σ_y	0.84	-	8.09
σ_d/σ_y	0.82	-	1.06
σ_g/σ_y	1.21	1.00	1.00
σ_h/σ_y	0.63	0.28	0.32
σ_w/σ_y	0.83	0.86	0.63
$\sigma_{y/h}/\sigma_y$	0.86	0.86	0.63
$corr(c, y)$	0.85	0.90	0.71
$corr(i, y)$	0.61	0.83	0.71
$corr(i^d, y)$	-0.97	-	0.87
$corr(d, y)$	0.99	-	0.34
$corr(g, y)$	0.31	1.00	1.00
$corr(h, y)$	0.49	0.59	0.29
$corr(w, y)$	-0.01	0.96	0.86

addition, the model with housing captures the pro-cyclicality of the housing stock, but over-predicts its magnitude: while housing is only moderately pro-cyclical, the model predicts an almost perfect pro-cyclicality. At the same time, the model predicts negative correlation between housing investment and output. Those outcomes could be due to the perfect substitutability between physical and housing capital in the resource constraint. If a wedge is introduced, that could help the model do better. Some investment adjustment costs, like "time to build", could address the correlation puzzle. As we saw in the impulse responses section, after the first 2 periods, housing investment and output move together.

Along the labor market dimension, the contemporaneous correlation of employment with output is a bit too low, with the standard RBC model being closer to data. With respect to wages, both models predicts strong cyclicality, while wages in data are acyclical. This shortcoming is well-known in the literature and an artifact of the wage being equal to the labor productivity in the model. Still, the model with housing is able to lower a bit the correlation between wages and output in the right direction.

In the next subsection, as in Vasilev (2016), we investigate the dynamic correlation between labor market variables at different leads and lags, thus evaluating how well the model matches the phase dynamics among variables. In addition, the autocorrelation functions (ACFs) of empirical data, obtained from an unrestricted VAR(1) are put under scrutiny and compared and contrasted to the simulated counterparts generated from the model.

4.3 Auto- and cross-correlation

This subsection discusses the auto-(ACFs) and cross-correlation functions (CCFs) of the major model variables. The coefficients empirical ACFs and CCFs at different leads and lags are presented in Table 4 below against the averaged simulated AFCs and CCFs firm the model with housing.[7] As seen from Table 4 above, the model compares relatively well vis-a-vis data. Empirical ACFs for output and investment are slightly outside the confidence band predicted by the model, while the ACFs for total factor productivity and household consumption are well-approximated by the model. The persistence of labor market variables are also relatively well-described by the model dynamics.

[7]Following Canova (2007), this is used as a goodness-of-fit measure.

Table 4: Autocorrelations for Bulgarian data and the model economy

		k			
Method	Statistic	0	1	2	3
Data	$corr(n_t, n_{t-k})$	1.000	0.484	0.009	0.352
Model	$corr(n_t, n_{t-k})$	1.000	0.954	0.897	0.832
	(s.e.)	(0.000)	(0.028)	(0.054)	(0.079)
Data	$corr(y_t, y_{t-k})$	1.000	0.810	0.663	0.479
Model	$corr(y_t, y_{t-k})$	1.000	0.956	0.902	0.840
	(s.e.)	(0.000)	(0.020)	(0.053)	(0.077)
Data	$corr(a_t, a_{t-k})$	1.000	0.702	0.449	0.277
Model	$corr(a_t, a_{t-k})$	1.000	0.959	0.902	0.840
	(s.e.)	(0.000)	(0.027)	(0.053)	(0.077)
Data	$corr(c_t, c_{t-k})$	1.000	0.971	0.952	0.913
Model	$corr(c_t, c_{t-k})$	1.000	0.958	0.909	0.855
	(s.e.)	(0.000)	(0.024)	(0.046)	(0.067)
Data	$corr(i_t, i_{t-k})$	1.000	0.810	0.722	0.594
Model	$corr(i_t, i_{t-k})$	1.000	0.943	0.878	0.798
	(s.e.)	(0.000)	(0.034)	(0.064)	(0.091)
Data	$corr(w_t, w_{t-k})$	1.000	0.760	0.783	0.554
Model	$corr(w_t, w_{t-k})$	1.000	0.958	0.908	0.852
	(s.e.)	(0.000)	(0.025)	(0.048)	(0.070)
Data	$corr(i^d_t, i^d_{t-k})$	1.000	0.861	0.717	0.552
Model	$corr(i^d_t, i^d_{t-k})$	1.000	0.948	0.886	0.813
	(s.e.)	(0.000)	(0.032)	(0.060)	(0.086)
Data	$corr(d_t, d_{t-k})$	1.000	0.848	0.698	0.552
Model	$corr(d_t, d_{t-k})$	1.000	0.958	0.909	0.853
	(s.e.)	(0.000)	(0.024)	(0.047)	(0.068)

Overall, the model with housing generates too much persistence in output and employment, and is subject to the criticism in Nelson and Plosser (1992), Cogley and Nason (1995) and

Rotemberg and Woodford (1996b), who argue that the RBC class of models do not have a strong internal propagation mechanism besides the strong persistence in the TFP process. In those models, e.g. Vasilev (2009), and in the current one, labor market is modeled in the Walrasian market-clearing spirit, and output and employment persistence is low.

Along the housing dimension, which is the extension in this RBC setup, the model with housing capital generates too much persistence in the housing stock and investment in housing capital. Next, as seen from Table 5 below, over the business cycle, in data labor productivity leads employment. The model with housing, however, cannot account for this fact. As in the standard RBC model a technology shock can be regarded as a factor shifting the labor demand curve, while holding the labor supply curve constant. Therefore, the effect between employment and labor productivity is only a contemporaneous one.

Table 5: Dynamic correlations for Bulgarian data and the model economy

		k						
Method	Statistic	-3	-2	-1	0	1	2	3
Data	$corr(h_t, (y/h)_{t-k})$	-0.342	-0.363	-0.187	-0.144	0.475	0.470	0.346
Model	$corr(h_t, (y/h)_{t-k})$	0.016	0.014	0.009	-0.183	-0.087	-0.008	-0.087
	(s.e.)	(0.333)	(0.290)	(0.238)	(0.355)	(0.232)	(0.273)	(0.311)
Data	$corr(h_t, w_{t-k})$	0.355	0.452	0.447	0.328	-0.040	-0.390	-0.57
Model	$corr(h_t, w_{t-k})$	0.016	0.014	0.009	-0.183	-0.087	-0.008	-0.087
	(s.e.)	(0.333)	(0.290)	(0.238)	(0.355)	(0.232)	(0.273)	(0.311)

Conclusions

Housing capital and accumulation of utility-enhancing housing capital are introduced as an additional mechanism into a real-business-cycle setup augmented with a detailed government sector. The model is calibrated to Bulgarian data for the period following the introduction of the currency board arrangement (1999-2018). The quantitative importance of the presence of housing capital is investigated for the propagation of cyclical fluctuations in Bulgaria.

In particular, allowing for housing considerations in the setup improves the model fit vis-a-vis data by increasing the variability of employment and decreasing the variability of consumption and investment. However, those improvements are at the cost of decreasing the volatility of wages. The model severely over-predicts variability of housing investment, and wrongly concludes that it is counter-cyclical. However, this is likely to be due to the absence of "time-to-build" investment adjustment costs. Overall, the model with housing is a clear improvement relative to the standard RBC setup.

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