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Are Habits Important for the Propagation of Business Cycle Fluctuations in Bulgaria?

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Abstract

We introduce internal consumption habits into a real-business-cycle setup augmented with a detailed government sector. We calibrate the model to Bulgarian data for the period following the introduction of the currency board arrangement (1999-2016). We investigate the quantitative importance of the presence of internal consumption habits motive for the propagation cyclical fluctuations in Bulgaria. Allowing for habits in consumption improves the model performance against data, and in addition this extended setup dominates the standard RBC model framework without habits, *e.g.*, Vasilev (2009).

Keywords: Business fluctuations, consumption habits, Bulgaria

JEL Classification Codes: E32, E22, E37

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1 Introduction and Motivation

In aggregate data, private consumption generally varies less than output for most of the developed economies. This behavior is also observed in new EU member states: Private final consumption of households in Bulgaria varies twice less than output in Bulgaria in the period after the introduction of the currency board arrangement.[1] These stylized facts can be rationalized by rational individuals, who optimize their consumption level inter-temporally (over time). The standard Real-Business-Cycle model, however, when calibrated to Bulgarian data, *e.g.* Vasilev (2009), overpredicts consumption volatility, when only technology shocks are present in the model. Introducing taxation and government spending does not solve this puzzle. One reason for the failure of the model along the consumption dimension is that there could be some motive at play that generates extreme consumption smoothing, which - while quantitatively important - is not present in the standard setup.

One reason for the failure of the model along the consumption dimension is that there is some motive that generates extreme consumption smoothing, which is not present in the standard setup. One way to improve the model is to include habits in consumption. As pointed out by Campbell and Cochrane (1999), habits are a fundamental concept in human psychology. Smets and Wouters (2003) also include habits in their large-scale macroeconomic model, and found that feature generated a better fit and improved the forecasting properties of the model. Simialrly, Buriel at al. (2010) include consumption habits in their model for the Spanish economy. Boldrin *et al.* (2001) match in addition addition some financial dimensions, such as asset prices.[2] Given that the stock market in Bulgaria is not well-developed, we will not pursue that dimension in our study. For a review of the literature on habit formation, the interested reader is referred to Deaton (1992).

More specifically, lagged consumption will be introduced into the model through the house-

[1]A currency board arrangement is an extreme form of fixed exchange rate, where 1 Bulgarian lev (BGN) was fixed to 1 Deutsche Mark (DM), and with the introduction of the Euro, to the Euro, at the rate 1 Euro = 1.95582 BGN. The period after the introduction of the currency board arrangement in Bulgaria was chosen as that was a period of macroeconomic stability.

[2]For example, Constantinides (1990) shows that the inclusion of consumption habits can quantitatively help to resolve the so-called "equity premium puzzle."

hold's utility function: the household will not want its current consumption to deviate from the past. With this extension, the utility function is no longer time-separable, which increases consumption persistence. Such an adjustment cost in consumption may help the model quantitatively to decrease consumption volatility, as adjustment will be done via capital accumulation (saving) and investment. In addition, consumption habits could be thought of capturing deviations from the permanent income-life cycle hypothesis, which were also documented empirically for Bulgaria (Vasilev 2015c). In Bulgaria, (at least some) households behave in a myopic way, with current consumption tracking (showing "excess sensitivity" to) current income, instead of permanent income.

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 and leisure. The time available to households can be spent in productive use or as leisure. The government taxes consumption spending and levies a common tax on all income, 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 homogenous final good, which could be used for consumption, investment, or government purchases.

2.1 Household

There is a representative household, which maximizes its expected utility function, which features time-nonseparability in consumption, as in Duesenberry (1949):[3]

$$\max E_0 \sum_{t=0}^{\infty} \left\{ \ln(c_t - \phi c_{t-1}) + \gamma \ln(1 - h_t) \right\} \tag{2.1}$$

where E_0 denotes household's expectations as of period 0, c_t denotes household's private consumption in period t, $0 < \phi < 1$ measures the degree of habit presistence, 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.[4]

The household starts with an initial stock of physical capital $k_0 > 0$, and has to decide how much to add to it in the form of new investment. The law of motion for physical capital is

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

and $0 < \delta < 1$ is the depreciation rate. 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

$$\max E_0 \sum_{t=0}^{\infty} \left\{ \ln(c_t - \phi c_{t-1}) + \gamma \ln(1 - h_t) \right\} \tag{2.3}$$

s.t.

$$(1 + \tau^c)c_t + k_{t+1} - (1 - \delta)k_t = (1 - \tau^y)[w_t h_t + r_t k_t] + g_t^t + \pi_t \tag{2.4}$$

[3]Similar specifications are also used in Pollak (1970) and Abel (1990).

[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.

where τ^c is the tax on consumption, τ^y is the proportional income tax rate ($0 < \tau^c, \tau^y < 1$), levied on both labor and capital income, and g_t^t denotes government transfers. The household takes the two tax rates $\{\tau^c, \tau^y\}$, 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 $\{c_t, h_t, k_{t+1}\}_{t=0}^{\infty}$ to maximize its utility subject to the budget constraint.[5] The constraint optimization problem generates the following optimality conditions:

$$c_t : \frac{1}{c_t - \phi c_{t-1}} - \frac{\beta\phi}{c_{t+1} - \phi c_t} = \lambda_t(1 + \tau^c) \tag{2.5}$$

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

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

$$TVC : \lim_{t\to\infty} \beta^t \lambda_t k_{t+1} = 0 \tag{2.8}$$

where λ_t is the Lagrangean 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 (taking into consideration the effect of habits) equals the marginal utility of wealth, corrected for the consumption tax rate. 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 last condition is called the "transversality condition" (TVC): it states that at the end of the horizon, the value of physical 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 both physical capital, k_t, and labor hours, h_t, to maximize static profit

$$\Pi_t = A_t k_t^{\alpha} h_t^{1-\alpha} - r_t k_t - w_t h_t, \tag{2.9}$$

[5]Note that by choosing k_{t+1} the household is implicitly setting investment i_t optimally.

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.*:

$$k_t \; : \; \alpha \frac{y_t}{k_t} = r_t, \tag{2.10}$$

$$h_t \; : \; (1-\alpha) \frac{y_t}{h_t} = w_t. \tag{2.11}$$

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, in order to finance spending on wasteful government purchases, and government transfers. The government budget constraint is as follows:

$$g_t^c + g_t^t = \tau^c c_t + \tau^y [w_t h_t + r_t k_t] \tag{2.12}$$

Tax rates and government consumption-to-output ratio would be chosen to match the average share in data, and 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 process followed by technology $\{A_t\}_{t=0}^{\infty}$ average tax rates $\{\tau^c, \tau^y\}$, initial capital stock $\{k_0\}$, lagged consumption $\{c_{-1}\}$, the decentralized dynamic competitive equilibrium is a list of sequences $\{c_t, i_t, k_t, h_t\}_{t=0}^{\infty}$ 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.

3 Data and Model Calibration

To characterize business cycle fluctuations with an endogenous depreciation rate in Bulgaria, we will focus on the period following the introduction of the currency board (1999-2016). Quarterly data on output, consumption and investment was collected from National Statistical Institute (2017), while the real interest rate is taken from Bulgarian National Bank Statistical Database (2017). 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. 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 1999-2016. This value is slightly higher as compared to other studies on developed economies, due to the overaccumulation 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 tax rate on consumption is set to its value over the period, $\tau^c = 0.2$. As in Torres (2013), the habit persistence parameter was set to $\phi = 0.8$. 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. Net, the steady-state depreciation rate of physical capital in Bulgaria, $\delta = 0.013$, was taken from Vasilev (2016). It was estimated as the average quarterly depreciation rate over the period 1999-2014. Finally, the processes followed by TFP processes and energy prices, are estimated from the detrended series by running an AR(1) regression and saving the residuals. Table 1 below summarizes the values of all model parameters used in the paper.

4 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

Table 1: Model Parameters

Parameter	Value	Description	Method
β	0.982	Discount factor	Calibrated
α	0.429	Capital Share	Data average
$1-\alpha$	0.571	Labor Share	Calibrated
γ	0.873	Relative weight attached to leisure	Calibrated
δ	0.013	Depreciation rate on physical capital	Data average
ϕ	0.800	Habit persistence parameter	Set
τ^y	0.100	Average tax rate on income	Data average
τ^c	0.200	VAT/consumption tax rate	Data average
ρ_a	0.701	AR(1) persistence coefficient, TFP process	Estimated
σ_a	0.044	st. error, TFP process	Estimated

reported in Table 2 below. 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 consumption-to-output and government purchases ratios by construction; The investment ratios are also closely approximated, despite the closed-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. 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.

5 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.

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	0.674
i/y	Investment-to-output ratio	0.201	0.175
k/y	Capital-to-output ratio	13.96	13.96
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

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.

5.1 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 and on the next page.[6] 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 used of output - consumption, investment, energy use and government consumption also increase contemporaneously. With habits in consumption, the response in consumption is smoothed ("excess smoothness" in consumption), while the response in investment is increased. This "excess sensitivity" in investment behavior is due to the fact that with smooth consumption, the adjustment happens with saving (physical capital accumulation). Capital becomes more volatile, and exhibits a hump-shaped behavior.

[6] As a robustness check, we also perform simulations for the case when consumption habits are external. Results are reported in the Appendix, and are generally worse than the case of internal habits presented in this paper.

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. Lastly, the utilization rate increases as well, following the increase in the return on capital, but this also increases the endogenous depreciation rate. 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.

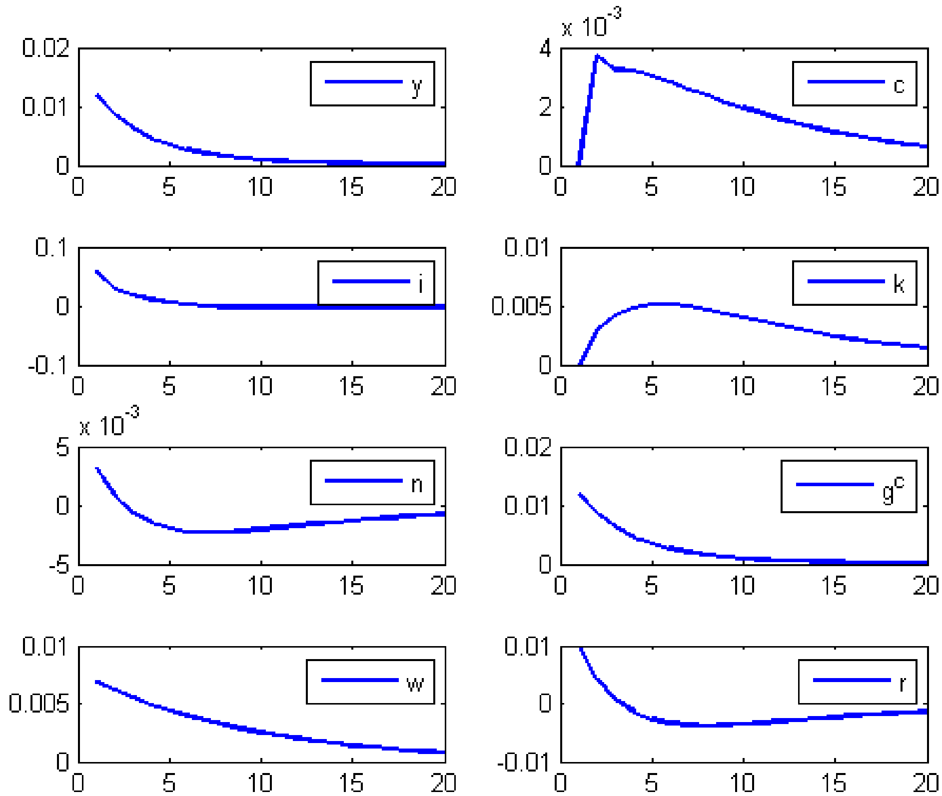

Figure 1: Impulse Responses to a 1% surprise innovation in technology

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.

5.2 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.[7] To minimize the sample error, the simulated moments are averaged out over the computer-generated draws. As in Vasilev (2016, 2017b, 2017c), the model matches quite well the absolute volatility of output and investment. By construction, government consumption in the model varies as much as output. However, the model with consumption habits in this paper still overestimates the variability in consumption, but volatility is lower that that in a model without habits ($\phi = 0$).[8] In addition, the model is qualitatively consistent with the stylized fact that consumption generally varies less than output, while investment is more volatile than output. Note that investment variability is larger when compared to the setup without habits ("benchmark model") in consumption, while consumption volatility is lower.

With respect to the labor market variables, the variability of employment predicted by the model is lower than that in data, but the variability of wages in the model is higher than that in data. This 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. Next, in terms of contemporaneous correlations, the 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 models. However, along the labor market dimension, the contemporaneous

[7]The model-predicted 95 % confidence intervals are available upon request.

[8]Increasing habit persistence to $\phi = 0.9$ (and even to $\phi = 0.95$, or $\phi = 0.99$) only slightly decreases consumption volatility, but also increases investment, wage and employment volatility.

Table 3: Business Cycle Moments

	Data	Model (with habits)	Benchmark model (w/o habits)
σ_y	0.05	0.05	0.05
σ_c/σ_y	0.55	0.71	0.84
σ_i/σ_y	1.77	2.79	2.36
σ_g/σ_y	1.21	1.00	1.00
σ_h/σ_y	0.63	0.54	0.29
σ_w/σ_y	0.83	1.12	0.81
$\sigma_{y/h}/\sigma_y$	0.86	1.12	0.81
$corr(c, y)$	0.85	0.85	0.89
$corr(i, y)$	0.61	0.87	0.80
$corr(g, y)$	0.31	1.00	1.00
$corr(h, y)$	0.49	0.53	0.33
$corr(w, y)$	-0.01	0.94	0.96

correlation of employment with output, and unemployment with output, is relatively well-matched. With respect to wages, the model 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.

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.

5.3 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. For the sake of brevity, we present only results for the model with consumption habits. 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	$corr(u_t, u_{t-k})$	1.000	0.765	0.552	0.553
Model	$corr(u_t, u_{t-k})$	1.000	0.957	0.906	0.849
	(s.e.)	(0.000)	(0.027)	(0.052)	(0.075)
Data	$corr(n_t, n_{t-k})$	1.000	0.484	0.009	0.352
Model	$corr(n_t, n_{t-k})$	1.000	0.957	0.906	0.849
	(s.e.)	(0.000)	(0.027)	(0.052)	(0.075)
Data	$corr(y_t, y_{t-k})$	1.000	0.810	0.663	0.479
Model	$corr(y_t, y_{t-k})$	1.000	0.955	0.901	0.840
	(s.e.)	(0.000)	(0.028)	(0.055)	(0.079)
Data	$corr(a_t, a_{t-k})$	1.000	0.702	0.449	0.277
Model	$corr(a_t, a_{t-k})$	1.000	0.954	0.900	0.836
	(s.e.)	(0.000)	(0.0269	(0.055)	(0.080)
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	0.908	0.851
	(s.e.)	(0.000)	(0.026)	(0.051)	(0.074)
Data	$corr(i_t, i_{t-k})$	1.000	0.810	0.722	0.594
Model	$corr(i_t, i_{t-k})$	1.000	0.952	0.892	0.821
	(s.e.)	(0.000)	(0.030)	(0.057)	(0.082)
Data	$corr(w_t, w_{t-k})$	1.000	0.760	0.783	0.554
Model	$corr(w_t, w_{t-k})$	1.000	0.957	0.907	0.850
	(s.e.)	(0.000)	(0.026)	(0.051)	(0.075)

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. Overall, the model with habits in consumption generates too much persistence in output and both employment and unemployment, 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 modelled in the Walrasian market-clearing spirit, and output and unemployment persistence is low.

Next, as seen from Table 5 below, over the business cycle, in data labor productivity leads employment. The model, 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	$corr(n_t, (y/n)_{t-k})$	-0.342	-0.363	-0.187	-0.144	0.475	0.470	0.346
Model	$corr(n_t, (y/n)_{t-k})$	-0.014	-0.029	-0.051	-0.771	-0.294	-0.247	-0.208
	(s.e.)	(0.338)	(0.293)	(0.239)	(0.194)	(0.250)	(0.293)	(0.332)
Data	$corr(n_t, w_{t-k})$	0.355	0.452	0.447	0.328	-0.040	-0.390	-0.57
Model	$corr(n_t, w_{t-k})$	-0.014	-0.029	-0.051	-0.771	-0.294	-0.247	-0.208
	(s.e.)	(0.338)	(0.293)	(0.239)	(0.194)	(0.250)	(0.293)	(0.332)

6 Conclusions

We introduce internal consumption habits into a real-business-cycle setup augmented with a detailed government sector. We calibrate the model to Bulgarian data for the period following the introduction of the currency board arrangement (1999-2016). We investigate the quantitative importance of the presence of internal consumption habits motive for the propagation cyclical fluctuations in Bulgaria. Allowing for habits in consumption improves the model performance against data, and in addition this extended setup dominates the standard RBC model framework without habits, *e.g.*, Vasilev (2009).

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Appendix: External habits extension

In contrast to internal habits, external habits are with reference to the past aggregate consumption a la "keeing up with the Joneses (Abel 1990). This only slightly will modify the consumer problem, without affecting either the firm's problem, or the government budget constraint.[9] The representative household now maximizes

$$\max E_0 \sum_{t=0}^{\infty} \left\{ \ln(c_t - \phi C_{t-1}) + \gamma \ln(1 - h_t) \right\} \tag{6.1}$$

where E_0 denotes household's expectations as of period 0, c_t denotes household's private consumption in period t, $0 < \phi < 1$ measures the degree of habit presistence, 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 C_t denotes aggregate consumption in period t. Everything else is stnadard. The household's problem is modified to

$$\max E_0 \sum_{t=0}^{\infty} \left\{ \ln(c_t - \phi C_{t-1}) + \gamma \ln(1 - h_t) \right\} \tag{6.2}$$

s.t.

$$(1 + \tau^c)c_t + k_{t+1} - (1 - \delta)k_t = (1 - \tau^y)[w_t h_t + r_t k_t] + g_t^t + \pi_t \tag{6.3}$$

The constraint optimization problem generates the following optimality conditions:

$$c_t \quad : \quad \frac{1}{c_t - \phi C_{t-1}} = \lambda_t(1 + \tau^c) \tag{6.4}$$

$$h_t \quad : \quad \frac{\gamma}{1 - h_t} = \lambda_t(1 - \tau^y)w_t \tag{6.5}$$

$$k_{t+1} \quad : \quad \lambda_t = \beta E_t \lambda_{t+1}[1 + (1 - \tau^y)r_{t+1} - \delta] \tag{6.6}$$

$$TVC \quad : \quad \lim_{t \to \infty} \beta^t \lambda_t k_{t+1} = 0 \tag{6.7}$$

As seen from above, the only optimality condition that changes is the one for consumption.

We also need to impose that in equilibrium, $c_t = C_t$. After log-linearization, we obtain

$$\hat{\lambda}_t + \frac{1}{1 - \phi}\hat{c}_t - \frac{\phi}{1 - \phi}\hat{c}_{t-1} = 0 \tag{6.8}$$

[9] In addition, the calibration and the steady-state are identical.

When $\phi = 0$, we are back in the no-habits case. Also notice the difference from the "internal habits" case:

$$\hat{\lambda}_t = \frac{\phi\beta}{1-\phi(1+\beta)+\beta\phi^2}\hat{c}_{t+1} - \frac{1+\phi\beta}{1-\phi(1+\beta)+\beta\phi^2}\hat{c}_t + \frac{\phi}{1-\phi(1+\beta)+\beta\phi^2}\hat{c}_{t-1} \tag{6.9}$$

In other words, with internal habits, the consumption smoothing motive is stronger than in the case of external habits. Indeed, consumption response in the impulse responses reported in Fig. 2 below is (a bit) more volatile.

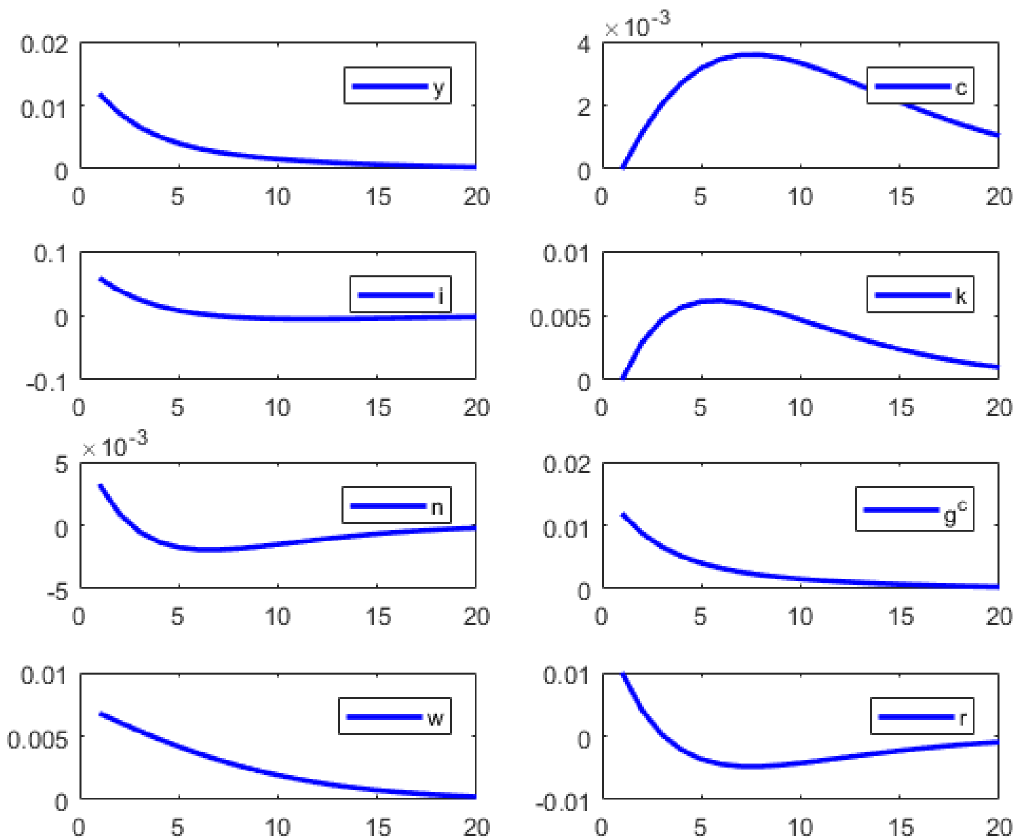

Figure 2: Impulse Responses to a 1% surprise innovation in technology

We can see this increase in consumption volatility in the second moments reported in Table 6 above. However, the increase in consumption variability works in the opposite direction with respect to matching data. On the other hand, investment volatility is lower, and closer to the observed one. Employment volatility is also lower, and twice lower than that in data,

Table 6: Business Cycle Moments

	Data	Internal habits	External habits
σ_y	0.05	0.05	0.05
σ_c/σ_y	0.55	0.71	0.84
σ_i/σ_y	1.77	2.79	2.21
σ_g/σ_y	1.21	1.00	1.00
σ_h/σ_y	0.63	0.54	0.31
σ_w/σ_y	0.83	1.12	0.88
$\sigma_{y/h}/\sigma_y$	0.86	1.12	0.88
$corr(c, y)$	0.85	0.85	0.78
$corr(i, y)$	0.61	0.87	0.75
$corr(g, y)$	0.31	1.00	1.00
$corr(h, y)$	0.49	0.53	0.69
$corr(w, y)$	-0.01	0.94	0.99
$corr(h, y/h)$	-0.14	-0.78	-0.77

while wage volatility is also lower, but much closer to data. Contemporaneous correlations are generally worse than in the case with internal habits. Lastly, auto-and cross-correlations (not reported) are virtually unchanged, except for consumption and investment, where the change is minute - by one-two units in the third digit after the decimal point.