BEP 01-2021 January 2021

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

ISSN: 2367-7082

BEP
Bulgarian Economic Papers

Can Shocks to Risk Aversion Explain Business Cycle Fluctuations in Bulgaria (1999-2018)?

Aleksandar Vasilev

BEP 01-2021
Publication: January 2020

Online: http://www.bep.bg
Contact for submissions and requests: bep@feb.uni-sofia.bg

Can shocks to risk aversion explain business cycle fluctuations in Bulgaria (1999-2018)?

Aleksandar Vasilev[*]

January 17, 2021

Abstract

Stochastic risk aversion is introduced 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 shocks to risk aversion is investigated for the propagation of cyclical fluctuations in Bulgaria. In particular, allowing for a stochastic risk aversion in the setup improves the model fit vis-a-vis data by increases variability of employment and decreasing the variability of investment. However, those improvements are at the cost of decreasing the volatility of investment and wages.

Keywords: business cycles, stochastic risk aversion, Bulgaria

JEL Classification Codes: E24, E32

---

[*] Lecturer, Lincoln International Business School, UK. E-mail for correspondence: AVasilev@lincoln.ac.uk.

1 Introduction and Motivation

The standard real-business-cycle (RBC) model was introduced in modern quantitative dynamic macroeconomics as a modeling tool that allows researchers to create artificial economies, which approximate those of existing countries along important aggregate dimensions, and use those simulated environments to generate artificial, or model-predicted time series, which are then compared to the properties of empirical (observed) time series. In this way the models could be interpreted as disciplined data-generating mechanisms for data matching akin to the general method of moments (GMM) in econometrics. Alternatively, those simulated data series could be interpreted as a maximum likelihood estimation (MLE), investigating how likely is that the observed time series were produced by the theoretical model. In addition, and in important contrast to ad hoc dynamic econometric models (e.g., Vector-Auto-Regressions, or VARs) used in time series analysis, the important transmission mechanisms (based on inter- and intra-temporal optimality principles) in these theoretical model economies are explicit, as those setups are based on micro-foundations, so macroeconomic researchers could gain a deeper insight about how the real economy works. Finally, those model economies could be used for computational experiments, which could produce quantitative assessments of policies and reforms that are not yet implemented. This is again a strong advantage to econometric estimation, which is not useful in such contexts.

The technical procedure used in the quantitative theoretical macroeconomic literature to assign values of the parameters in the model is called *calibration*. In contrast to what many applied researchers think/believe, calibration is not done in an arbitrary fashion; In particular, calibration is preferred to estimation in cases when we already have data for certain parameters, or we have a *target from data* that we need to match in the model, which will constrain the calibration procedure and determine (”identify” in econometric language) the value of that parameter. In addition, calibration is preferred in cases when we do not have information on the parameter, and want to investigate how the model predictions change when the parameter changes over a certain (plausible) range, *i.e*, how robust is the model to slight changes in certain parameters. Then, after calibrating all model parameters, we can proceed to simulate the model to produce artificial time series.

With regard to the individual variability of the parameter estimates above, the question ”why just settle for a particular point estimate?” may be raised. In particular, the core of the criticism raised by some economists is that by giving up the variability in the parameter (or parameters), researchers are giving up information, which might be potentially useful.[1] We can thus argue that holding the risk aversion parameter fixed over the cycle might lead researchers to wrong conclusions. We thus allow the risk aversion parameter to vary in order to evaluate the importance of the information contained in the variability of the parameter.[2] It is thus plausible to assume that household's risk aversion can change over the business cycle. In the model setup, the risk aversion parameter shows up in the marginal rate of substitution for the household, which determines how consumption and labor supply decisions are chosen in each period, so a shock to the risk aversion parameter in turn will affect wages, interest rates, and thus production, investment, and capital accumulation decisions as well.Therefore, allowing for a stochastic risk aversion in the theoretical setup can generate additional interesting interactions among model variables.

This proposal is taken seriously, and this paper incorporates a stochastic risk aversion parameter in an otherwise standard real-business-cycle (RBC) model with a detailed government sector. The model is calibrated for Bulgaria in the period 1999-2018, as Bulgaria provides a good testing case for the theory.[3] The paper then proceeds to quantitatively evaluate the effect of such a stochasticity as a mechanism of business cycle propagation. This is the first study on the issue using modern macroeconomic modeling techniques, and thus an important

---

[1] As pointed out in Vasilev (2020), an alternative approach in macroeconomic modeling is to estimate those RBC models using techniques based on Bayesian statistical approach. In particular, those researchers take each parameter to follow a distribution, and thus, in addition to the mean, also take into consideration the standard deviation of the distribution.

[2] Parkin (1988) uses such a technique (which he refers to as ”strip mining”) as a test whether RBC model parameters are structural. Similarly, for Bulgaria Vasilev (2020) studies the effect of a stochastic capital share, Vasilev (2019a) studies the effect of a stochastic leisure preference parameter, while Vasilev (2019b) investigates the quantitative effect of an endogenously determined depreciation rate.

[3] Before the introduction of proportional income taxation of 10 percent in 2008, Bulgaria operated a progressive income taxation regime during the period 1993-2007 with the same effective rate. In addition, the corporate income tax rate has been reduced, in several steps, to a proportional rate of 10 percent in 2007 as well, to avoid incentives to move earnings across the income categories.

contribution to the field. Unfortunately, for reasonable degree of risk aversion variability, the quantitative effects are tiny. In particular, allowing for a stochastic risk aversion in the setup improves the model fit vis-a-vis data by increases variability of employment and decreasing the variability of investment. However, those improvements are at the cost of decreasing the volatility of investment and wages. The small effect of the risk aversion stochasticity can be viewed as a validation of the robustness of the standard real business cycle model.

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, levies a common proportional ("flat") tax on labor and capital 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 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

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

where E_0 denotes household's expectations as of period 0, c_t denotes household's private consumption in period t, 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 $\sigma_t > 0$ is the time-varying risk aversion parameter.[4,5]

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

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

s.t.

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

where where τ^c is the tax on consumption, τ^y is the proportional income tax rate on labor ($0 < \tau^c, \tau^y < 1$), and g_t^t denotes government transfers. The household takes the tax rates $\{\tau^c, \tau^y\}_{t=0}^{\infty}$, government spending categories, $\{g_t^c, g_t^t\}_{t=0}^{\infty}$, profit $\{\pi_t\}_{t=0}^{\infty}$, the realized technology process $\{A_t\}_{t=0}^{\infty}$, the risk-aversion process $\{\sigma_t\}_{t=0}^{\infty}$, 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.[6] The first-order

---

[4] The last parameter is also the inverse of the inter-temporal elasticity of substitution between consumption in period t, and consumption in period $t+1$.

[5] 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.

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

optimality conditions as as follows:

$$\begin{aligned}
c_t &: \; E_t\left[\frac{1}{c_t^{\sigma_t}}\right] = \lambda_t(1+\tau^c) && (2.5)\\
h_t &: \; \frac{\gamma}{1-h_t} = \lambda_t(1-\tau^l)w_t && (2.6)\\
k_{t+1} &: \; \lambda_t = \beta E_t\lambda_{t+1}\Bigg[1+[1-\tau^y]r_{t+1}-\delta\Bigg] && (2.7)\\
TVC &: \; \lim_{t\to\infty}\beta^t\lambda_t k_{t+1} = 0 && (2.8)
\end{aligned}$$

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; Note that the presence of a stochastic risk aversion parameter will play an important role in this equation. 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. Again, there is a direct link between the shadow value λ and the stochastic risk aversion via the first optimality condition. 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

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

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:

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

Income and consumption tax rates 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 $\{A_t, \sigma_t\}_{t=0}^{\infty}$ tax schedules $\{\tau^c, \tau^y\}_{t=0}^{\infty}$, and initial capital stock $\{k_0\}$, 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.

Data and Model Calibration

To characterize business cycle fluctuations in Bulgaria, we will focus on the period following the introduction of the currency board (1999-2018). Quarterly data on output, consumption and investment was collected from National Statistical Institute (2020), while the real interest rate is taken from Bulgarian National Bank Statistical Database (2020). 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 steady-state risk parameter value was set to $\sigma = 2$, which is a typical value in the literature.[7] 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, $\tau^c = 0.2$.

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. Next, the 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 process followed by the TFP process is estimated from the detrended series by running an AR(1) regression and saving the residuals. Due to the lack of data, we use the same parameters for the risk aversion process. Table 1 below summarizes the values of all model parameters used in the paper.

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

---

[7] Experimenting with a wider range of values, *i.e.*, $\sigma \in [1, 3]$ did not affect the results from the paper in any major way.

Table 1: Model Parameters

Parameter	Value	Description	Method
β	0.982	Discount factor	Calibrated
σ	2.000	Risk aversion	Set
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
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
ρ_s	0.701	AR(1) persistence coefficient, risk aversion	Set
σ_s	0.044	st. error, risk aversion	Set

are 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. The stochastic risk aversion plays no role in the steady-state computation. 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.

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

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 and Fig. 2 for the technology and the risk aversion shocks, respectively. 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.

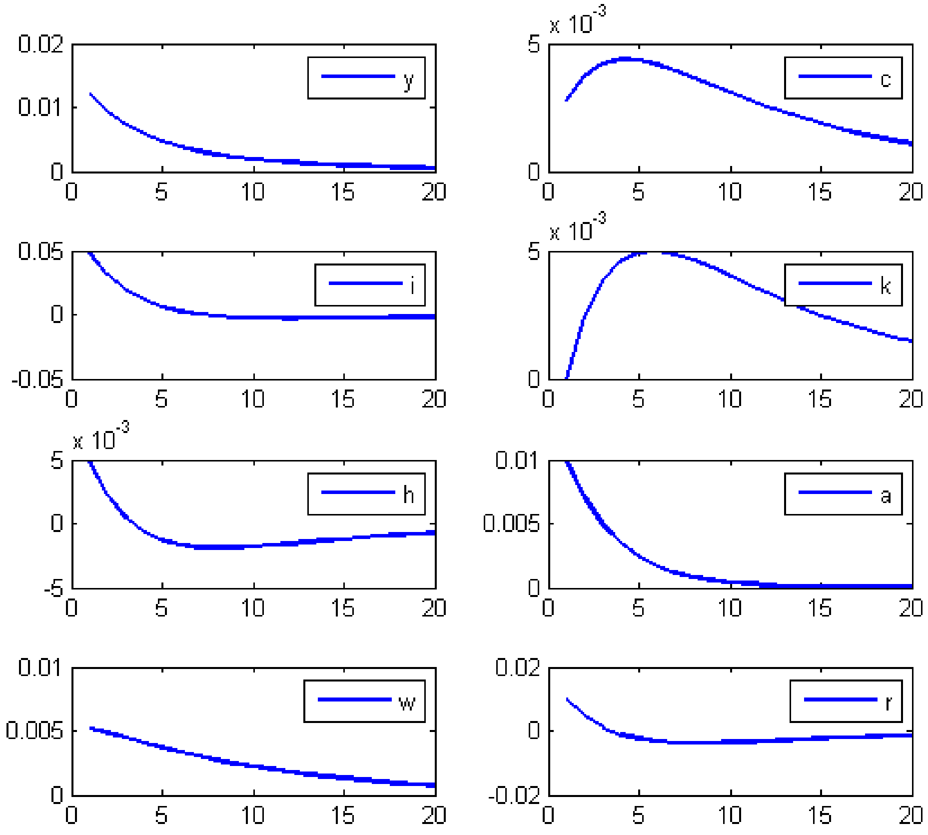

Figure 1: Impulse Responses to a 1% surprise innovation in technology

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.

The second shock is a one-time innovation to the risk aversion parameter. The results are summarized in Fig. 2 below.

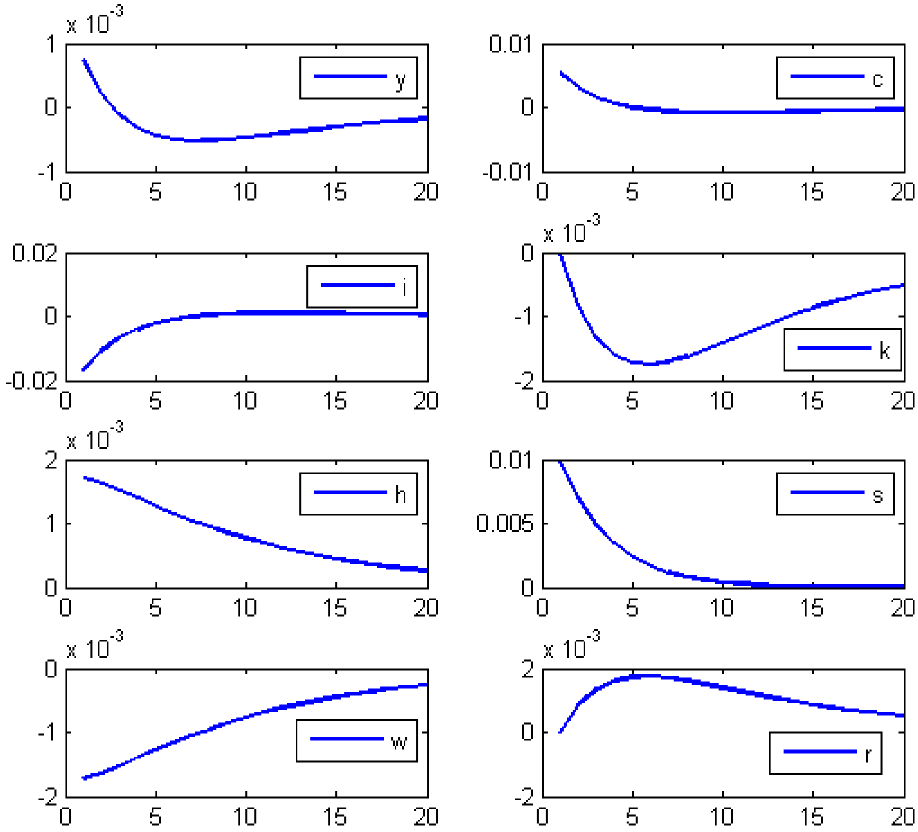

Figure 2: Impulse Responses to a 1% surprise innovation in technology (flat capital tax case)

Overall, the effect of this shock is quite small, so changes in risk aversion are unlikely candidates for business cycle propagators. In particular, upon impact of the shock, the marginal utility of consumption (the shadow price) decreases, which is why we see that consumption has increased. Investment decreases, capital accumulation drops. Next, from the marginal rate of substitution equation, it follows that hours worked have to increase, which simultaneously decreases the wage rate. The increase in hours worked increases directly output, and indirectly the marginal productivity of capital, due to the complementarity between labor and capital in the Cobb-Douglas production function; in turn, the interest rate increased.

We see this in the Euler equation, which is disturbed, as the shadow prices in both period t and $t+1$ are disturbed. To preserve the balance, the interest rate in period $t+1$ needs to increase; this is because now the consumer values consumption today more relative to consumption tomorrow, which discourages investment, and thus capital stock decreases relative to its steady state. Overall, the effect of the shock to risk aversion is very short-lived, and variables return quickly to their old steady-states.

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 the case with both shocks, and risk aversion-, and technology shocks only, respectively. 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 and investment. By construction, government consumption in the model varies as much as output. In addition, the predicted consumption and investment volatilies are too high. Still, the model is qualitatively consistent with the stylized fact that consumption generally varies less than output, while investment is more volatile than output. The model with both shocks produces more volatile consumption and employment, and smoother investment series, relative to a setup with technology shocks only, but the quantitative effect is rather small. Overall, the two models are almost indistinguishable from one another.

With respect to the labor market variables, the variability of employment and wages predicted by the model with both shocks 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. Next, in terms of contemporaneous correlations, the model systematically over-predicts the pro-cyclicality of the main aggregate variables - consumption, investment, and government

Table 3: Business Cycle Moments

	Data	Both Shocks	Risk shocks only	Technology Shocks only
σ_y	0.05	0.05	0.05	0.05
σ_c/σ_y	0.55	0.89	2.24	0.82
σ_i/σ_y	1.77	2.32	7.74	2.35
σ_g/σ_y	1.21	1.00	1.00	1.00
σ_h/σ_y	0.63	0.44	2.59	0.28
σ_w/σ_y	0.83	0.78	2.59	0.86
$\sigma_{y/h}/\sigma_y$	0.86	0.78	2.59	0.86
$corr(c, y)$	0.85	0.87	0.46	0.90
$corr(i, y)$	0.61	0.74	0.08	0.83
$corr(g, y)$	0.31	1.00	1.00	1.00
$corr(h, y)$	0.49	0.33	0.79	0.59
$corr(w, y)$	-0.01	0.92	0.79	0.96

consumption. This, however, is a common limitation of this class of models. Along the labor market dimension, the contemporaneous correlation of employment with output is too low. 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.

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.[8] For the sake of brevity, we only present the case with both shocks.

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	0.956	0.904	0.843
	(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	0.956	0.904	0.843
	(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	0.957	0.903	0.843
	(s.e.)	(0.000)	(0.025)	(0.049)	(0.071)
Data	$corr(a_t, a_{t-k})$	1.000	0.702	0.449	0.277
Model	$corr(a_t, a_{t-k})$	1.000	0.955	0.901	0.837
	(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	0.908	0.851
	(s.e.)	(0.000)	(0.025)	(0.040)	(0.070)
Data	$corr(i_t, i_{t-k})$	1.000	0.810	0.722	0.594
Model	$corr(i_t, i_{t-k})$	1.000	0.953	0.895	0.827
	(s.e.)	(0.000)	(0.029)	(0.055)	(0.080)
Data	$corr(w_t, w_{t-k})$	1.000	0.760	0.783	0.554
Model	$corr(w_t, w_{t-k})$	1.000	0.959	0.909	0.853
	(s.e.)	(0.000)	(0.024)	(0.047)	(0.069)

---

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

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 both technological shocks and stochastic risk aversion 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 modeled 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	$corr(h_t, (y/h)_{t-k})$	-0.342	-0.363	-0.187	-0.144	0.475	0.470	0.346
Model	$corr(h_t, (y/h)_{t-k})$	-0.01	-0.024	-0.042	-0.620	-0.400	-0.359	-0.316
	(s.e.)	(0.342)	(0.299)	(0.247)	(0.307)	(0.278)	(0.308)	(0.341)
Data	$corr(h_t, w_{t-k})$	0.355	0.452	0.447	0.328	-0.040	-0.390	-0.57
Model	$corr(h_t, w_{t-k})$	-0.01	-0.024	-0.042	-0.620	-0.400	-0.359	-0.316
	(s.e.)	(0.342)	(0.299)	(0.247)	(0.307)	(0.278)	(0.308)	(0.341)

Conclusions

Stochastic risk aversion is introduced 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 shocks to risk aversion is investigated for the propagation of cyclical fluctuations in Bulgaria. In particular, allowing for a stochastic risk aversion in the setup improves the model fit vis-a-vis data by increases variability of employment and decreasing the variability of investment. However, those improvements are at the cost of decreasing the volatility of investment and wages.

References

Baxter, Marianne and Robert King. 1993. "Fiscal policy in general equilibrium," *American Economic Review* 83: 315-334.

Bulgarian National Bank. 2020. Bulgarian National Bank Statistics. Available on-line at www.bnb.bg. Accessed on April 21, 2020.

Canova, Fabio. 2007. *Methods for Applied Macroeconomic Research.* Princeton University Press: Princeton, NJ.

Cogley, Timothy and James Nason. 1995. "Output dynamics in Real-Business-Cycles," *American Economic Review* 85(3): 492-511.

Di Nola, A., Kocharkov, G., and Vasilev, A. (2019) "Envelope wages, Hidden Production, and Labor Productivity," *B.E. Journal of Macroeconomics (Advances)*, 19(2), pp.1-30.

Hodrick, Robert and Edward Prescott. 1980. "Post-war US business cycles: An empirical investigation." *Unpublished manuscript* (Carnegie-Mellon University, Pittsburgh, PA).

National Statistical Institute. 2020. Aggregate Statistical Indicators. Available on-line at www.nsi.bg. Accessed on April 21, 2020.

Parkin, M. (1988). "A method for determining whether parameters in aggregative models are structural." *Carnegie-Rochester Conference on Public Policy*, 29, 215252.

Rotemberg, Julio and Michael Woodford. 1996b. "Real-Business-Cycle Models and the Forecastable Movements in Output, Hours, and Consumption," *American Economic Review*, 86: 71-89.

Vasilev, A. (2020) "A Real-business-cycle Model with a Stochastic Capital Share: Lessons for Bulgaria (19992018)," *Margin: The Journal of Applied Economic Research* 14(1): 107121.

Vasilev, A. (2019a). "How important are consumer confidence shocks for the propagation of business cycles in Bulgaria?" (LEAF Working Papers). Lincoln, UK: University of Lincoln.

Vasilev, A. (2019b). "The role of endogenous capital depreciation rate for business cycle dynamics: lessons from Bulgaria (1999-2018)." Lincoln, UK: Mimeo, University of Lincoln.

Vasilev, A. (2017a) "Business Cycle Accounting: Bulgaria after the introduction of the currency board arrangement (1999-2014), *European Journal of Comparative Economics*, 14(2): 197-219.

Vasilev, A. (2017b) "A Real-Business-Cycle model with efficiency wages and a government sector: the case of Bulgaria," *Central European Journal of Economics and Econometrics*, 9(4): 359-377.

Vasilev, A. (2017c) "A Real-Business-Cycle model with reciprocity in labor relations and fiscal policy: the case of Bulgaria," *Bulgarian Economic Papers* BEP 03-2017, Center for Economic Theories and Policies, Sofia University St. Kliment Ohridski, Faculty of Economics and Business Administration, Sofia, Bulgaria.

Vasilev, A. (2017d) "VAT Evasion in Bulgaria: A General-Equilibrium Approach," *Review of Economics and Institutions*, 8(2): 2-17.

Vasilev, A. (2017e). "Progressive taxation and (in)stability in an exogenous growth model with an informal sector," *Journal of Economics and Econometrics* 60(2): 1-13.

Vasilev, A. (2016a). "Progressive taxation and (in)stability in an endogenous growth model with human capital accumulation," *Journal of Economics and Econometrics* 59(2): 1-15.

Vasilev, A. (2016) "Search and matching frictions and business cycle fluctuations in Bulgaria," *Bulgarian Economic Papers* BEP 03-2016, Center for Economic Theories and Policies, Sofia University St. Kliment Ohridski, Faculty of Economics and Business Administration, Sofia, Bulgaria.

Vasilev, A. (2015a) "Welfare effects of flat income tax reform: the case of Bulgaria," *Eastern European Economics* 53(2): 205-220.

Vasilev, A. (2015b) "Welfare gains from the adoption of proportional taxation in a general-equilibrium model with a grey economy: the case of Bulgaria's 2008 flat tax reform," *Economic Change and Restructuring*, 48(2): 169-185.

Vasilev, A. (2009) "Business cycles in Bulgaria and the Baltic countries: an RBC approach," *International Journal of Computational Economics and Econometrics*, 1(2): 148-170.