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An RBC model with Epstein-Zin (non-expected-utility) recursive preferences: lessons from Bulgaria (1999-2018)

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Abstract

We introduce Epstein-Zin (1989, 1991) preferences into a real-business-cycle (RBC) model with government. We calibrate the model economy to Bulgarian data for the period after the currency board regime (1999-2018). We evaluate the quantitative importance of the presence of "early resolution of uncertainty" motive for the propagation of cyclical fluctuations in Bulgaria. Allowing for Epstein-Zin preferences improves the model performance against data, and in addition this extended setup dominates the standard RBC model framework, *e.g.*, Vasilev (2009).

Keywords: Business fluctuations, Epstein-Zin preferences, Bulgaria

JEL Classification Codes: E32, E22, E37

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1 Introduction and Motivation

Consumer preferences featured by households play a crucial role in an economic model, being an important part of the set of model primitives, which is comprised of preferences, endowments, and technology. As argued in Backus *et al.* (2005), household preferences are "primitives," i.e., they are an unchanging feature of a model in which rational optimizing agents could face a wide range of different circumstances, such as external environments, institutions, or policies. For each scenario, we derive consumers' optimal decision plans from the same underlying preferences. In addition, preferences describe the explicit objective specified in advance which allow us to quantitatively evaluate the welfare effects of different policies or changes in the economic environment.

Furthermore, as pointed in Weil (1990), researchers should distinguish between risk aversion and the households' desire to substitute consumption over time in their models. After all, the two parameters are distinct features of household's preferences, and should be parameterized separately from each other. However, in the usual formulation with time-separable preferences one is reciprocal of the other. This is a problem as in data both a low elasticity of inter-temporal substitution, and low risk aversion have been measured. Lastly, we want to be clear which channel exactly is the quantitatively important mechanism at play when it comes to the effect of macroeconomic policies.

In macroeconomics, the use of *generalized isoelastic utility functions*, which have constant (but unrelated) coefficients of risk aversion and elasticity of intertemporal substitution, have become increasingly popular.¹ In addition, such modelling strategy gives some flexibility to the model as well. Furthermore, those functions feature so-called recursive preferences, which have the following important advantage: that they can be used by researchers who want to focus on the important trade-off between current-period utility and the remaining utility, i.e., the total utility to be derived from all future periods. Since an agent's actions today can affect the evolution of all opportunities in the future, summarizing the future consequences of these actions with a single index, i.e., future utility (or "continuation value"), allows for

¹Note that the elasticity of intertemporal substitution is applicable in the context of deterministic consumption paths only. It is not well-defined in an environment featuring uncertainty.

complex multi-period decision problems to be reduced to a much simpler two-period trade-off is between current utility and a so-called "certainty equivalent" of random future utility, as shown in Epstein and Zin (1989, 1991). Importantly, with those preferences households would like the outcome of an uncertain event (lottery) to be revealed earlier, instead of later.

In this paper we will take these preference considerations seriously, and proceed to quantitatively evaluate the importance of the presence of that so-called "early resolution of uncertainty" motive for the propagation of cyclical fluctuations in Bulgaria. Therefore, we introduce Epstein-Zin (1989, 1991) consumption preferences into a real-business-cycle model with government. We then calibrate the model economy to Bulgarian data for the period after the introduction of the currency board regime (1999-2018). Allowing for Epstein-Zin preferences improves the model performance against data, and in addition this extended setup dominates the standard RBC model framework, *e.g.*, Vasilev (2009).²

The rest of the paper is organized as follows: Section 2 lays down the model framework and defines the decentralized competitive equilibrium concept used, Section 3 outlines the calibration procedure, and Section 4 computes the steady-state model solution. Section 5 extends the analysis by focusing on the general dynamics of model variables, and compares the theoretical moments of model variables against their empirical counterparts. Section 6 concludes.

2 Model Description

There is a stand-in household, which enjoys utility out of consumption and time off-work (leisure). The time endowment can be spent either in productive use or as leisure. Net,

²Following the work of Hall (1997), Nakajima and Rios-Rull (2005) provide a microfoundation for the marginal-rate-of-substitution shift showing that a representative agent model that features such a shock can be viewed as a reduced form of a heterogeneous-agents economy with incomplete markets. On the other hand, Gourio (2012) provides a very appealing microfoundation for the discounting shock as he shows that time varying impatience parameters may be regarded as a reduced form of a model that features a time varying probability of some economic disaster which plays a critical role in the agents (relative) assessment of investment alternatives.

the government taxes final consumption spending, as well as income, in order to finance public consumption spending, and government transfers. On the production side, there is a representative firm, which rents labor and capital to produce output, which could be used for private consumption, investment, or government spending.

2.1 Household

There is a stand-in household, which maximizes its utility function, which features recursive preferences as in Epstein and Zin (1989, 1991) and Weil (1990):

$$V_t = \left[(1 - \beta)[c_t^\nu(1 - h_t)^{1-\nu}]^{\frac{1-\gamma}{\theta}} + \beta[E_t V_{t+1}^{1-\gamma}]^{\frac{1}{\theta}} \right]^{\frac{\theta}{1-\gamma}} \quad (2.1)$$

where

$$\theta = \frac{1 - \gamma}{1 - \frac{1}{\psi}}, \quad (2.2)$$

and V_t is the value function as of period t , $0 < \nu, 1 - \nu < 1$ are the utility weights attached to consumption and leisure, respectively; $[E_t V_{t+1}^{1-\gamma}]^{\frac{1}{\theta}}$ is the *risk-adjusted* expectation operator at of period t , c_t is household's private consumption in period t , h_t are total hours spent working in period t , $0 < \beta < 1$ is the discount factor.³

With Epstein-Zin preferences, the elasticity of intertemporal substitution (EIS), and the coefficient of relative risk aversion (CRRA) are separated. More specifically, $\gamma \geq 0$ is the parameter that controls risk aversion, while $\psi \geq 0$ is the IES.⁴ Note that for values of $\gamma > 1$, and $\psi > 1$, the agent has a preference for "an early resolution of uncertainty" (Kreps and Porteus 1978, Weil 1990).⁵ In other words, the household is averse to volatility in future utility, and more specifically, the recursive utility formulation adds curvature with respect

³Importantly, these preferences are stationary in the sense of Koopmans (1960).

⁴Therefore, this class of preferences responds to Hall's (1988) critique. In contrast, with other functional forms the elasticity of substitution and the coefficient of relative risk aversion are inversely related one another.

⁵Note that, as in Epstein and Zin (1991), early resolution of uncertainty requires

$$1 - \gamma < 1 - \frac{1}{\psi} \quad \text{or} \quad \frac{1}{\psi} < \gamma \quad (2.3)$$

For $\psi, \gamma > 1$ the condition above is satisfied.

to future risks.⁶

The household begins with an initial endowment of physical capital $k_0 > 0$, and has to choose how much to augment it via new investment. The law of motion for physical capital is

$$k_{t+1} = i_t + (1 - \delta)k_t \quad (2.4)$$

and $0 < \delta < 1$ is the period depreciation rate. Next, the real interest rate in the economy is r_t , thus the before-tax capital income generated by a household in period t is $r_t k_t$. In addition to the capital income earned, the household can supply hours to the representative firm at the hourly wage rate of w_t , and earn $w_t h_t$, before taxes, from working. Lastly, the household owns the firm in the economy and receives all the firm's profit, π_t .

Next, the household's problem can be now summarized as

$$\max_{\{c_t, h_t, k_{t+1}\}_{t=0}^{\infty}} V_t = \left[(1 - \beta)[c_t^\nu (1 - h_t)^{1-\nu}]^{\frac{1-\gamma}{\theta}} + \beta[E_t V_{t+1}^{1-\gamma}]^{\frac{1}{\theta}} \right]^{\frac{\theta}{1-\gamma}} \quad (2.5)$$

s.t.

$$(1 + \tau^c)c_t + k_{t+1} - (1 - \delta)k_t = (1 - \tau^y)[w_t h_t + r_t k_t] + g_t^t + \pi_t \quad (2.6)$$

where τ^c is consumption tax, τ^y is the income tax rate ($0 < \tau^c, \tau^y < 1$), and g_t^t are government transfers. The household takes the two tax rates $\{\tau^c, \tau^y\}$, government consumption and transfers, $\{g_t^c, g_t^t\}_{t=0}^{\infty}$, firm's profit $\{\pi_t\}_{t=0}^{\infty}$, the realized technology process $\{A_t\}_{t=0}^{\infty}$, wage and interest rate $\{w_t, r_t\}_{t=0}^{\infty}$, and selects $\{c_t, h_t, k_{t+1}\}_{t=0}^{\infty}$ to maximize its utility subject to the budget constraint.⁷ The constraint optimization problem generates the following optimality

⁶As pointed out in Kaltenbrunner and Lochstoer (2010), investors with Epstein-Zin preferences also demand a premium for holding asserts, which are correlated with shocks to expected consumption growth. When households have preferences for early resolution of uncertainty, these shocks carry a positive price of "long-run risk" (Bansal and Yaron 2004). In applied work, this risk can be potentially defined using shocks to the continuation value, normalized by consumption, via shocks to the wealth-to-consumption ratio, or shocks to the expected future consumption growth.

⁷Note that by choosing k_{t+1} the household implicitly determines investment i_t optimally as well.

conditions:

$$V_t : V_t - \left[(1 - \beta)[c_t^\nu(1 - h_t)^{1-\nu}]^{\frac{1-\gamma}{\theta}} + \beta[E_t V_{t+1}^{1-\gamma}]^{\frac{1}{\theta}} \right]^{\frac{\theta}{1-\gamma}} = 0 \quad (2.7)$$

$$c_t : \nu \left[(1 - \beta)[c_t^\nu(1 - h_t)^{1-\nu}]^{\frac{1-\gamma}{\theta}} + \beta[E_t V_{t+1}^{1-\gamma}]^{\frac{1}{\theta}} \right]^{\frac{\theta}{1-\gamma}-1} \times \\ (1 - \beta)c_t^{\frac{\nu(1-\gamma)}{\theta}-1} (1 - h_t)^{\frac{(1-\nu)(1-\gamma)}{\theta}} = \lambda_t(1 + \tau^c) \quad (2.8)$$

$$h_t : (1 - \nu) \left[(1 - \beta)[c_t^\nu(1 - h_t)^{1-\nu}]^{\frac{1-\gamma}{\theta}} + \beta[E_t V_{t+1}^{1-\gamma}]^{\frac{1}{\theta}} \right]^{\frac{\theta}{1-\gamma}-1} \times \\ (1 - \beta)c_t^{\frac{\nu(1-\gamma)}{\theta}} (1 - h_t)^{\frac{(1-\nu)(1-\gamma)}{\theta}-1} = \lambda_t(1 - \tau^y)w_t \quad (2.9)$$

$$k_{t+1} : \lambda_t = \beta E_t \lambda_{t+1} [1 + (1 - \tau^y)r_{t+1} - \delta] \quad (2.10)$$

$$TVC : \lim_{t \rightarrow \infty} \beta^t \lambda_t k_{t+1} = 0 \quad (2.11)$$

where λ_t denotes the Lagrangean multiplier attached to household's budget constraint in period t . The interpretation of the first-order conditions is as follows: for each household, besides caring for the short-run (period t vs. period $t + 1$ utility), the household cares also for the long run, in the sense that the entire sequence of future consumption and leisure - captured by continuation values - directly affects the state of the economy in period $t + 1$. The second equation dictates that when choosing labor supply optimally, at the margin, each hour spent by the household working balances the benefit from doing so, to the cost, measured in terms of higher disutility. The third equation is the so-called "Euler condition," which describes how the household chooses physical capital over time. The last condition is called the "transversality condition" (TVC): this boundary condition states that at the end of the horizon, the value of physical capital should be zero.

2.2 Firm problem

There is a stand-in firm in the model economy, which produces final aggregate output; The price of output is normalized to unity. The production technology utilizes both physical capital, k_t , and labor hours, h_t , to maximize period profit

$$\Pi_t = A_t k_t^\alpha h_t^{1-\alpha} - r_t k_t - w_t h_t, \quad (2.12)$$

where A_t denotes the level of technology in period t . Since the firm rents the capital and labor from households, the problem of the firm is not really dynamic, but rather a sequence

of static profit maximizing problems. In equilibrium, each input is priced competitively, *i.e.*:

$$k_t : \alpha \frac{y_t}{k_t} = r_t, \quad (2.13)$$

$$h_t : (1 - \alpha) \frac{y_t}{h_t} = w_t. \quad (2.14)$$

In equilibrium, $\pi_t = 0, \forall t$.

2.3 Government

In the model economy, the government is taxing labor and capital income, as well as consumption, in order to finance public consumption, and government transfers. The government budget constraint in period t is:

$$g_t^c + g_t^t = \tau^c c_t + \tau^y [w_t h_t + r_t k_t] \quad (2.15)$$

In the computational analysis that follows, the tax rates and government consumption-to-output ratio would be set to match the average share in data, while government transfers would be adjusting in each period to keep the government budget in balance.

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 $\{k_0\}$, the decentralized dynamic competitive equilibrium is a list of sequences $\{c_t, i_t, k_t, h_t, V_t\}_{t=0}^{\infty}$ for the household, a sequence of government consumption and transfers $\{g_t^c, g_t^t\}_{t=0}^{\infty}$, and wage and interest rate pairs $\{w_t, r_t\}_{t=0}^{\infty}$ such that (i) the household maximizes its utility subject to the budget constraint; (ii) the stand-in firm maximizes total profit; (iii) the government budget is in balance each period; (iv) all (factor and goods) markets clear.

3 Data and Model Calibration

To characterize the business cycle fluctuations in Bulgaria with Epstein-Zin preferences, we will focus on the period after the introduction of the currency board regime (1999-2018). Quarterly data on output, private consumption and investment was collected from

National Statistical Institute (2019) database, while the real interest rate is taken from Bulgarian National Bank Statistical Database (2019). The calibration strategy follows a long-established tradition in modern macroeconomics: first, as in Vasilev (2016), the discount factor, $\beta = 0.982$, is chosen to match the steady-state capital-to-output ratio, $k/y = 13.964$. Next, the labor share parameter, $1 - \alpha = 0.571$, is obtained as the average share of labor income in aggregate output over the period.

Next, the average income tax rate was set to its value in data, $\tau^y = 0.1$, and the consumption tax is set equal to the VAT rate in data, $\tau^c = 0.2$. As in Herberger (2013), the relative risk aversion parameter and the IES are set to $\gamma = 2$ and $\psi = 0.043$, respectively. Next, the relative weight attached to the utility out of consumption in the household's utility function, ν , is calibrated to match that in steady-state consumers would work one-third of the total time available. This is in line with the estimates for Bulgaria (Vasilev 2017a) as well over the period studied. Next, the depreciation rate, $\delta = 0.013$, was estimated as the average quarterly depreciation rate over the period 1999-2014. Finally, the process followed by TFP is estimated from the detrended Solow residuals by running an AR(1) regression. Table 1 below summarizes the model parameters used in the paper.

Table 1: Model Parameters

Parameter	Value	Description	Method
β	0.982	Discount factor	Calibrated
α	0.429	Capital Share	Data average
γ	2.000	Relative risk aversion parameter	Set
ψ	0.043	Intertemporal elasticity of substitution	Set
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

4 Steady-State

Conditional on the the values of model parameters, the steady-state equilibrium can be solved for, and the so-called "big ratios" can be compared to their averages in Bulgarian data. The results are presented in Table 2 below. Note that the steady-state level of output was normalized to one, which greatly simplified the estimation. Next, the model economy matches consumption-to-output and government purchases ratios in data by construction; The investment ratio is also closely approximated by the model. The shares of income are also identical to those in data, which is an artifact of the Cobb-Douglas assumptions imposed on functional form of the aggregate production function; Finally, the after-tax return is also relatively well-captured by the model.

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

5 Out of steady-state model dynamics

The model does not possess a closed-form (analytical) solution in the general case; thus, we need to solve the model numerically via log-linearization, which produces a first-order system of stochastic difference equations, which is easier to work with. Next, we study the dynamic behavior of model variables to a one-time shock to the TFP process; then we proceed to simulate the model to compare theoretical moments of the model variables against their

empirical counterparts.

5.1 Impulse Response Analysis

This subsection computes the responses of model variables to a 1% surprise innovation to the TFP process. The impulse response functions (IRFs) are presented in Fig. 1 below.

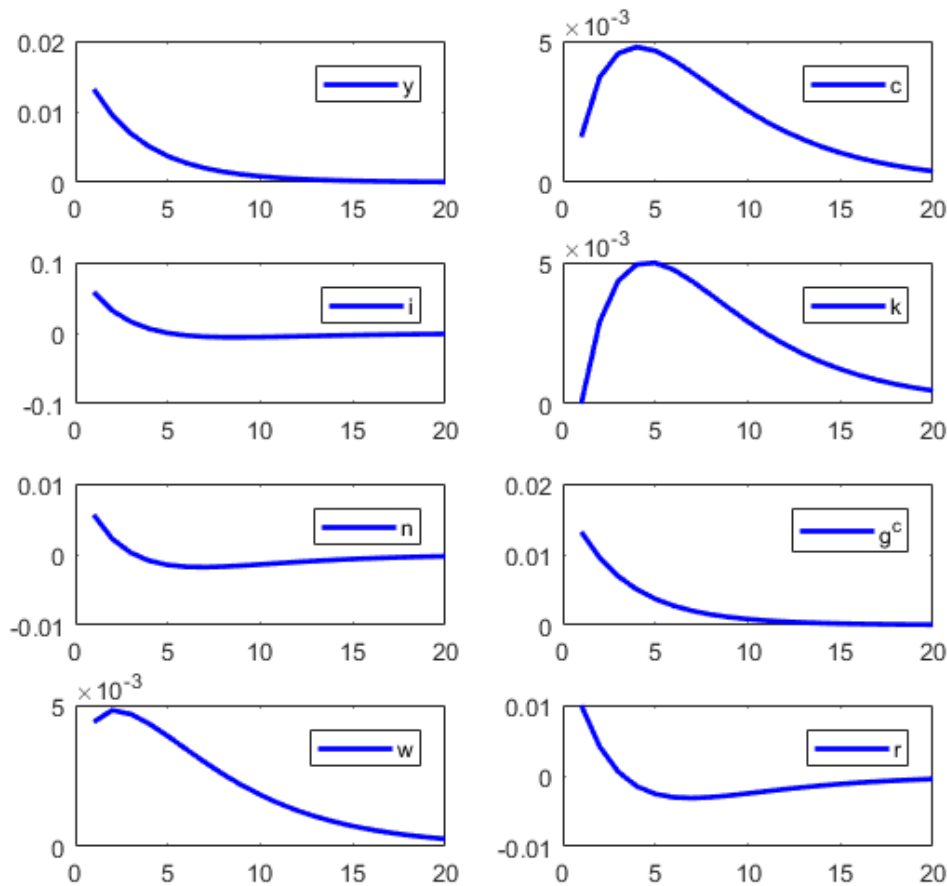


Figure 1: Impulse Responses to a 1% surprise innovation in technology

As a result of the unexpected positive shock to TFP, output directly increases upon impact. This expands the uses of output - consumption, investment and government consumption, which also increase contemporaneously. In addition, the increase in overall productivity increases the after-tax return on labor and capital. The household respond to the incentives

contained in prices and starts investing, and working more. In turn, the increase in capital stock then feeds back in output through the production function channel. In the labor market, the increase in total hours also increases output indirectly. Over time, as capital stock increases, its after-tax marginal product starts to fall, and households have fewer incentives to save. In turn, capital eventually returns to its old steady-state, exhibiting a hump-shaped dynamics over its transition path. The rest of the model variables also return to their old steady-state values, but in a monotone fashion, as the effect of the technology shock dies out.

5.2 Simulation and moment-matching

Following Vasilev (2017b), we simulate the model 10,000 times for the length of the data horizon. Both empirical and model simulated data is detrended via the same method - the Hodrick-Prescott (1980) filter. Table 3 below compares 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. Similar to Vasilev (2016, 2017b, 2017c), the model matches the absolute volatility of output; by construction, government consumption in the model varies as much as output. However, the model with Epstein-Zin preferences significantly overestimates the variability in consumption, and to a certain extent the volatility in investment. Still, the setup is in line with the stylized fact that consumption is smoother than output, while investment is varies more than output.

Looking at the labor market variables, the variability of employment in the model is lower than that in data, but the variability of wages is approximately the same as in data, which is an implicit confirmation that the perfectly-competitive assumption, e.g. as the one used in Vasilev (2009), does not fit the observed dynamics of employment. Next, in terms of correlations with output, the model generally over-predicts the pro-cyclicality of the major variables: investment, and government consumption; This, however, is a common limitation of this whole class of RBC models. In addition, the contemporaneous correlation of employment with output, is poorly matched: the model predicts strong cyclicalities, while wages in

Table 3: Business Cycle Moments

	Data	Model
σ_y	0.05	0.05
σ_c/σ_y	0.55	0.97
σ_i/σ_y	1.77	2.22
σ_g/σ_y	1.21	1.00
σ_h/σ_y	0.63	0.28
σ_w/σ_y	0.83	0.81
$\sigma_{y/h}/\sigma_y$	0.86	0.81
$corr(c, y)$	0.85	0.83
$corr(i, y)$	0.61	0.76
$corr(g, y)$	0.31	1.00
$corr(h, y)$	0.49	0.25
$corr(w, y)$	-0.01	0.95

data are acyclical.⁸ In the next subsection, we proceed to investigate the dynamic correlation between labor market variables and output; In addition, the autocorrelation functions (ACFs) of empirical data, are compared to the theoretical ones.

5.3 Auto- and cross-correlation

This subsection discusses the auto-(ACFs) and cross-correlation functions (CCFs) of the major model variables against the predicted ones from the model. The coefficients of the ACFs and CCFs are presented in Table 4 below.

⁸This shortcoming is well-known in the literature and an artifact of model assumption that the wage is equal to the labor productivity in the model.

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	0.953	0.894	0.826
	(s.e.)	(0.000)	(0.029)	(0.056)	(0.082)
Data	$corr(n_t, n_{t-k})$	1.000	0.484	0.009	0.352
Model	$corr(n_t, n_{t-k})$	1.000	0.953	0.894	0.826
	(s.e.)	(0.000)	(0.029)	(0.056)	(0.082)
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	0.902	0.840
	(s.e.)	(0.000)	(0.026)	(0.051)	(0.074)
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	0.901	0.838
	(s.e.)	(0.000)	(0.027)	(0.052)	(0.075)
Data	$corr(c_t, c_{t-k})$	1.000	0.971	0.952	0.913
Model	$corr(c_t, c_{t-k})$	1.000	0.959	0.909	0.851
	(s.e.)	(0.000)	(0.025)	(0.069)	(0.089)
Data	$corr(i_t, i_{t-k})$	1.000	0.810	0.722	0.594
Model	$corr(i_t, i_{t-k})$	1.000	0.949	0.886	0.812
	(s.e.)	(0.000)	(0.031)	(0.058)	(0.084)
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	0.901	0.849
	(s.e.)	(0.000)	(0.025)	(0.047)	(0.069)

The model ACFs compares relatively well vis-a-vis the observed ones: in particular, the 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 within the bands; The persistence of hours and wages is also well-described by the model. Overall, the model with Epstein-Zin preferences still generates too much persistence in output and both employment and unemployment, and is also a subject to the criticism raised in

Nelson and Plosser (1992), Cogley and Nason (1995) and Rotemberg and Woodford (1996b) - namely, that the RBC models lack a strong internal propagation mechanism (besides the strong persistence in the exogenous TFP process). Finally, as seen from Table 5 below, over the business cycle, in data labor productivity/wages leads employment. The model with Epstein-Zin preferences cannot produce such an effect - the effect between employment and labor productivity in the model 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	$corr(n_t, (y/n)_{t-k})$	0.022	0.010	-0.001	-0.516	-0.191	-0.170	-0.149
	(s.e.)	(0.329)	(0.285)	(0.233)	(0.288)	(0.288)	(0.225)	(0.261)
Data	$corr(n_t, w_{t-k})$	0.355	0.452	0.447	0.328	-0.040	-0.390	-0.57
Model	$corr(n_t, w_{t-k})$	0.022	0.010	-0.001	-0.516	-0.191	-0.170	-0.149
	(s.e.)	(0.329)	(0.285)	(0.233)	(0.288)	(0.288)	(0.225)	(0.261)

6 Conclusions

We introduce Epstein-Zin (1989, 1991) preferences into a real-business-cycle (RBC) model with government. We calibrate the model economy to Bulgarian data for the period after the currency board regime (1999-2018). We evaluate the quantitative importance of the presence of "early resolution of uncertainty" motive for the propagation of cyclical fluctuations in Bulgaria. Allowing for Epstein-Zin preferences improves the model performance against data, and in addition this extended setup dominates the standard RBC model framework, e.g., Vasilev (2009).

References

Andreasen, M. (2012, July). On the effects of rare disasters and uncertainty shocks for risk premia in non-linear dsge models. *Review of Economic Dynamics* 15(3), 295316.

Backus, D. K., B. R. Routledge, and S. E. Zin (2008). "Recursive preferences," in S. N. Durlauf and L. E. Blume (Eds.), *The New Palgrave Dictionary of Economics Online* 2nd ed. Palgrave Macmillan.

Bansal, R. and A. Yaron (2004). "Risks for the Long Run: A Potential Resolution of Asset Pricing Puzzles," *Journal of Finance* 59: 1481-509.

Bulgarian National Bank. 2019. Bulgarian National Bank Statistics. Available on-line at www.bnb.bg. Accessed on Dec. 21, 2019.

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

Epstein, L. and Zin, S. (1989) "Substitution, Risk Aversion, and the Temporal Behavior of Consumption and Asset Returns: A Theoretical Framework," *Econometrica* 57: 937-69.

Epstein, L. and Zin, S. (1991) "Substitution, Risk Aversion, and the Temporal Behavior of Consumption and Asset Returns: An Empirical Analysis," *Journal of Political Economy* 99(2): 263-286.

Gourio, F. (2012). "Disaster risk and business cycles," *American Economic Review* 102(6), 2734-66.

Gourio, F. (2013). "Credit risk and disaster risk." *American Economic Journal* 5(3), 134.

Hall, R. E. (1988). "Intertemporal substitution in consumption," *Journal of Political Economy* 96, 339-357.

Hall, R. E. (1988). "Macroeconomic Fluctuations and the Allocation of Time," *Journal of Labor Economics*, vol. 15(1), pages 223-250.

Heiberger, C. (2017) "Asset Prices, Epstein Zin Utility, and Endogenous Economic Disasters," Unpublished Dissertation, University of Augsburg, Germany.

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

Kaltenbrunner, G. and L. A. Lochstoer (2010). "Long-run risk through consumption smoothing," *Review of Financial Studies* 23(8), 3190-3224.

Koopmans, T. (1960) "Stationary Ordinal Utility and Impatience," *Econometrica*, XXVIII, 287-309.

Kreps, D. and Porteus, E. (1978) "Temporal Resolution of Uncertainty and Dynamic Choice Theory," *Econometrica* 46: 185-200.

Kreps, D. and Porteus, E. (1979a) "Dynamic Choice Theory and Dynamic Programming," *Econometrica* XLVII, 91-100.

Kreps, D. and Porteus, E. (1979b) "Temporal von Neumann-Morgenstern and Induced Preferences," *Journal of Economic Theory* XX, 81-109.

Nakajima, M. and J.-V. Rios-Rull (2005) "Default and Aggregate Fluctuations in Storage Economies," in *Frontiers in Applied General Equilibrium Modelling: in Honor of Herbert Scarf*, T. Kehoe, T.N. Srinivasan, and J. Whalley (eds.), Cambridge University Press, UK.

National Statistical Institute. 2019. Aggregate Statistical Indicators. Available on-line at www.nsi.bg. Accessed on Dec. 21, 2019.

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

view, 86: 71-89.

Rudebusch, G. D. and E. T. Swanson (2012). "The bond premium in a DSGE model with long-run real and nominal risks," *American Economic Journal: Macroeconomics* 4, 105143.

van Binsbergen, J. H., J. Fernandez-Villaverde, R. S. Koijen, and J. F. Rubio-Ramrez (2012). "The term structure of interest rates in a DSGE model with recursive preferences." *Journal of Monetary Economics* 59(7), 634648.

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. (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 an 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. (2015c) "Modeling Real Private Consumption Expenditure in Bulgaria after the Currency Board Implementation (1997-2005)," *Zagreb International Review of Economics and Business*, vol. 18(1), pages 81-89.

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.

Weil, P. (1990). "Nonexpected utility in macroeconomics," *The Quarterly Journal of Economics* 105(1), 2942.