A business-cycle model with a modified cash-in-advance feature and government sector: the case of Bulgaria (1999-2018)

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Abstract

We augment an otherwise standard business cycle model with a richer government sector, and add a modified cash in advance (CIA) considerations. In particular, the cash in advance constraint of Cole (2020) is extended to include private investment and government consumption, and allows a proportion of total expenditure to be done using credit. This specification is then calibrated to Bulgarian data after the introduction of the currency board (1999-2018), gives a role to money in accentuating economic fluctuations. In particular, the modified CIA constraint produces a mechanism that allows the framework to reproduce better observed variability and correlations among model variables, and those characterizing the labor market in particular.

Keywords: business cycles, modified cash-in-advance (CIA) constraint, Bulgaria

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1 Introduction and Motivation

It is a well-known fact, *e.g.* Prescott (1986), that the perfectly-competitive (Walrasian) approach to modelling labor markets in real business cycles (RBC) - that is, without money in the setup - does not fit data well, and thus creates a "puzzle" for neoclassical economists. More specifically, in the standard RBC model the fluctuations in employment are due to movements in labor supply. In other words, households increase hours in the face of a raise in the return on labor, the wage, driven by shocks to technology. Instead, if an RBC model is to fit data better along the labor market dimension, even for a small economy like Bulgaria, shocks that work on labor demand and shift it around would be much better candidates to explain the observed fluctuations in the wage rate, aggregate hours and employment.

In order to avoid running into the problem of "observational equivalence," an outcome in which two or more models of substantially different structure may explain equally well certain stylized facts, economists need to justify the inclusion of alternative propagation mechanisms. Therefore, in this paper we base our modeling approach on a particular empirical regularity in Bulgaria, namely that households predominantly use cash for purchases, which is the norm in the period following the introduction of the currency board arrangement (1999-2018). We adopt the approach followed by Cole (2020) to incorporate a modified cash-in-advance (CIA) constraint in RBC models in order to investigate the quantitative effect of money on business cycle fluctuations in aggregate variables in Bulgaria, and whether it is able to address the "labor market puzzle," and validate certain labor market facts, while at the same time retain technology as the only shock process.

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 Setup

There is a representative household, which derives utility out of consumption and leisure. The time available to households can be spent in productive use or as leisure. The households use cash for the majority of their purchases. 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. The monetary authority follows an endogenous money supply rule, and redistributes all seigniorage back to the household. On the production side, there is a representative firm, which hires labor and utilized capital to produce a homogeneous final good, which could be used for consumption, investment, or government purchases.

2.1 Household problem

Each household maximizes expected discounted utility, which is of the form

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \Big\{ \ln c_t - \gamma h_t \Big\}, \tag{1}$$

where E_0 is the expectation operation conditional on information available as of $t = 0$, $0 < \beta < 1$ is the discount factor, c_t is individual household consumption in period t, and h_t are hours worked. Parameters $\gamma > 0$ is the weights attached to disutility of work, where we use aggregation and lotteris as in Hansen (1985) and Rogerson (1988) to convexify a discrete labor supply decision at individual level - work either zero hours or a full-time - to derive the preferences of an aggregate household. In particular, in equilibrium, a households will be chosen for work every period with a probability h_t, which, form the law of large numbers, will also equal the employment rate.

The household starts with a positive endowment of physical capital, k_0, in period 0, which is rented to the firm at the nominal rental rate R_t, that is, before-tax capital income equals $R_t k_t$. Therefore, each household can decide to invest in capital to augment the capital stock, which evolves according to the following law of motion:

$$k_{t+1} = i_t + (1 - \delta) k_t, \tag{2}$$

where $0 < \delta < 1$ is the depreciation rate of physical capital.

In addition to the rental income, the household owns the firm, and thus has a legal claim to the firm's nominal profit, Π_t. Lastly, the household works a certain number of hours, which are remunerated at the spot nominal wage rate W_t, producing a total nominal labor income of $W_t h_t$ in period t.

The budget constraint of the aggregate household, expressed in real terms, is then

$$(1+\tau^c)c_t + k_{t+1} - (1-\delta)k_t + \frac{M_{t+1}}{P_t}\frac{P_{t+1}}{P_{t+1}} = (1-\tau^y)[w_t h_t + r_t k_t] + \frac{M_t}{P_t} + g_t^t + \frac{\Pi_t}{P_t}, \tag{3}$$

where τ^c is the tax rate on final consumption, τ^y is the proportional rate on labor and capital income, P_t is the aggregate price level, i_t^b is the nominal interest rate on bonds. M_t denote the nominal quantities of money holdings in period t. Money stock is treated like a consumption good, it stores wealth over time. That is why real money balances in period t are $m_t = M_t/P_t$ in period $t+1$ only buy M_t/P_{t+1} (next period purchasing power). Similarly, $w_t = W_t/P_t$, and $r_t = R_t/P_t$ are the real wage and the real interest rate.

Real money balances are needed to purchase output, hence the households face the following cash-in-advance constraint

$$\kappa[(1+\tau^c)c_t + k_{t+1} - (1-\delta)k_t + g_t^c] \leq \frac{M_t}{P_t} = m_t, \tag{4}$$

where $0 < \kappa < 1$ reflects the fact that only part of expenditure is done using cash (or deposits, e.g via debit cards).[1]

Next, we set up the Lagrangean of the household's problem:

$$L = E_0 \sum_{t=0}^{\infty} \beta^t \Bigg\{ \ln c_t - \gamma h_t - \lambda_t \Bigg[(1+\tau^c)c_t + k_{t+1} - (1-\delta)k_t + m_{t+1}(1+\pi_{t+1})$$
$$-(1-\tau^y)[w_t h_t + r_t k_t] - m_t - g_t^t - \frac{\Pi_t}{P_t} \Bigg] - \mu_t \Bigg[\kappa[(1+\tau^c)c_t + k_{t+1} - (1-\delta)k_t + g_t^c] - m_t \Bigg] \Bigg\} \tag{5}$$

[1] The rest is implicitly purchased using credit. However, we do not model credit explicitly in the model framework.

The first-order optimality conditions (FOCs) are as follows:

$$c_t \; : \; \frac{1}{c_t} = (1+\tau^c)(\lambda_t + \kappa\mu_t) \tag{6}$$

$$h_t \; : \; \gamma = \lambda_t(1-\tau^y)w_t, \tag{7}$$

$$k_{t+1} \; : \; \lambda_t + \mu_t = \beta E_t \Big[\lambda_{t+1}[1-\delta+(1-\tau^y)r_{t+1}] + \mu_{t+1}\kappa(1-\delta)\Big], \tag{8}$$

$$m_{t+1} \; : \; \lambda_t = \beta E_t \left[\frac{1}{1+\pi_{t+1}}(\lambda_{t+1}+\mu_{t+1})\right], \tag{9}$$

where π_{t+1} is the inflation rate between periods t and $t+1$. Lastly, the boundary (transversality) conditions for capital, and real money balances are as follows:

$$TVC_k \; : \; \lim_{t\to\infty} \beta^t \lambda_t k_{t+1} = 0 \tag{10}$$

$$TVC_m \; : \; \lim_{t\to\infty} \beta^t \lambda_t m_{t+1} = 0 \tag{11}$$

The interpretation of the optimality conditions is standard. In the first, the household equates the marginal utility of consumption, to the VAT adjusted shadow price of wealth and the CIA constraint. The second FOC determines optimal number of hours worked, by balancing at the margin the cost and benefit from working. The remaining equations from the original FOCs are standard: for example, the Euler equation for capital stock describes how capital is allocated across any adjacent periods in order to maximize household's utility. Similarly, the other describes the rule for optimal real money balancess. The transversality conditions (TVCs) for real cash holdings, and physical capital are imposed to rule out explosive solutions.

2.2 Stand-in firm's problem

There is a stand-in firm in the economy, which uses homogeneous capital and labor to produce a final good, which can be used for consumption, investment, or government purchases, through the following production function:

$$y_t = A_t k_t^{\alpha} h_t^{1-\alpha}, \tag{12}$$

where A_t denotes the level of total factor productivity in period t, h_t are total hours used, and α and $1-\alpha$ are the share of capital and labor, respectively. The firm's problem, expressed in real terms, is to

$$\max_{(k_t,h_t)\geq 0} A_t k_t^{\alpha} h_t^{1-\alpha} - r_t k_t - w_t h_t \tag{13}$$

The first-order optimality conditions determining optimal capital, and labor use are

$$k_t \ : \ \alpha \frac{y_t}{k_t} = r_t, \tag{14}$$

$$h_t \ : \ (1-\alpha) \frac{y_t}{h_t} = w_t. \tag{15}$$

Given the results above, it follows that profit is zero in all periods.

2.3 Monetary Authority

In this paper the monetary authority (central bank) supplies the money aggregate, M_t, endogenously. In other words, the money supply will respond to the demand for currency for transaction purposes. All money created (seigniorage) in period t is then distributed to the government, and then to the households in a lump-sum fashion

$$M_{t+1} - M_t = T_t, \tag{16}$$

where T_t is the lump-sum nominal transfer to the household. In the government budget constraint below, we will assume that the central bank distributes the seigniorage to the Ministry of Finance, which in turn passes it to the household as part of the overall government lump-sum transfer, g_t^t.

2.4 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 government purchases and government transfers. The government budget constraint is as follows:

$$\tau^c c_t + \tau^y (w_t h_t + r_t k_t) = g_t^t + g_t^c \tag{17}$$

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.

2.5 Stochastic process

Total factor productivity, A_t, is assumed to follow AR(1) processes in logs, in particular

$$\ln A_{t+1} = (1-\rho_a)\ln A_0 + \rho_a \ln A_t + \epsilon^a_{t+1},$$

where $A_0 > 0$ is steady-state level of the total factor productivity process, $0 < \rho_a < 1$ is the first-order autoregressive persistence parameter and $\epsilon^a_t \sim iidN(0, \sigma^2_a)$ are random shocks to the total factor productivity progress. Hence, the innovations ϵ^a_t represent unexpected changes in the total factor productivity process.

2.6 Dynamic Competitive Equilibrium (DCE)

Given the stochastic process $\{A_t\}_{t=0}^{\infty}$, average tax rates $\{\tau^c, \tau^y\}$, endowments (k_0, m_0), the decentralized dynamic competitive equilibrium is a list of sequences $\{c_t, i_t, k_t, h_t, m_t\}_{t=0}^{\infty}$, a sequence of government purchases and transfers $\{g^c_t, g^t_t\}_{t=0}^{\infty}$, and real input prices $\{w_t, r_t\}_{t=0}^{\infty}$ such that (i) the household maximizes its utility function subject to its budget constraint, and the CIA constraint; (ii) the representative firm maximizes profit; (iii) government budget constraint is balanced in each period; (iv) all markets clear.

3 Data and Model Calibration

To calibrate the model to Bulgarian data, we will focus on the period after the introduction of the currency board (1999-2018). Annual 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, the discount factor, $\beta = 0.982$, as in Vasilev (2017a), is set to match the steady-state capital-to-output ratio in Bulgaria, $k/y = 3.491$. The labor share parameter, $\alpha = 0.429$, was obtained from Vasilev (2017b) as the average value of labor income in aggregate output over the period 1999-2014.

The relative weights attached to the utility out of leisure in the household's utility function, γ, is calibrated to match the fact that in steady-state consumers would supply one-third of their time endowment to working. The CIA parameter $\kappa = 0.85$ is calibrated to match the share of purchases made using cash. In other words, the money in the model corresponds to M2 money aggregate, and $M2/Y = 0.848$ on average over the period 1999-2018. Next, the average depreciation rate of physical capital in Bulgaria, $\delta = 0.05$, was taken from Vasilev (2015). It was estimated as the average depreciation rate over the period 1999-2014. Similarly, the average income tax rate was set to $\tau^y = 0.1$, and the tax rate on consumption is set to its value over the period, $\tau^c = 0.2$. Lastly, as in Vasilev (2017c), the process followed by total factor productivity is estimated from the detrended Solow residual 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.

Table 1: Model Parameters

Parameter	Value	Description	Method
β	0.982	Discount factor	Calibrated
α	0.429	Capital Share	Data average
δ	0.050	Depreciation rate on physical capital	Data average
γ	0.853	Parameter, disutility of work	Calibrated
τ^c	0.200	VAT/consumption tax rate	Data average
τ^y	0.100	Average tax rate on income	Data average
κ	0.850	Share of purchases made using cash	Calibrated
ρ_a	0.701	AR(1) parameter, total factor productivity	Estimated
σ_a	0.044	st.dev, total factor productivity	Estimated

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 reported in Table 2 on the next page. (We approximate the economy around zero inflation.) The model matches consumption-to-output ratio by construction; The investment and government purchases ratios are also closely approximated. 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. Lastly, the after-tax return, net of depreciation, $\tilde{r} = (1 - \tau^y)r - \delta$, is also very closely captured by the model.

Table 2: Data Averages and Long-run Solution

Variable	Description	Data	Model
y	Steady-state output	N/A	0.568
c/y	Consumption-to-output ratio	0.674	0.674
i/y	Investment-to-output ratio	0.201	0.175
g^c/y	Government cons-to-output ratio	0.159	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
$\tilde{r}$	After-tax net return on capital	0.056	0.057

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. 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. Special focus is put on the cyclical behavior of labor market variables.

5.1 Impulse Response Analysis

This subsection documents the impulse responses of model variables to a 1% surprise innovation to technology. The impulse response function (IRFs) are presented in Fig. 1 below. As a result of the one-time unexpected positive shock to total factor productivity, output

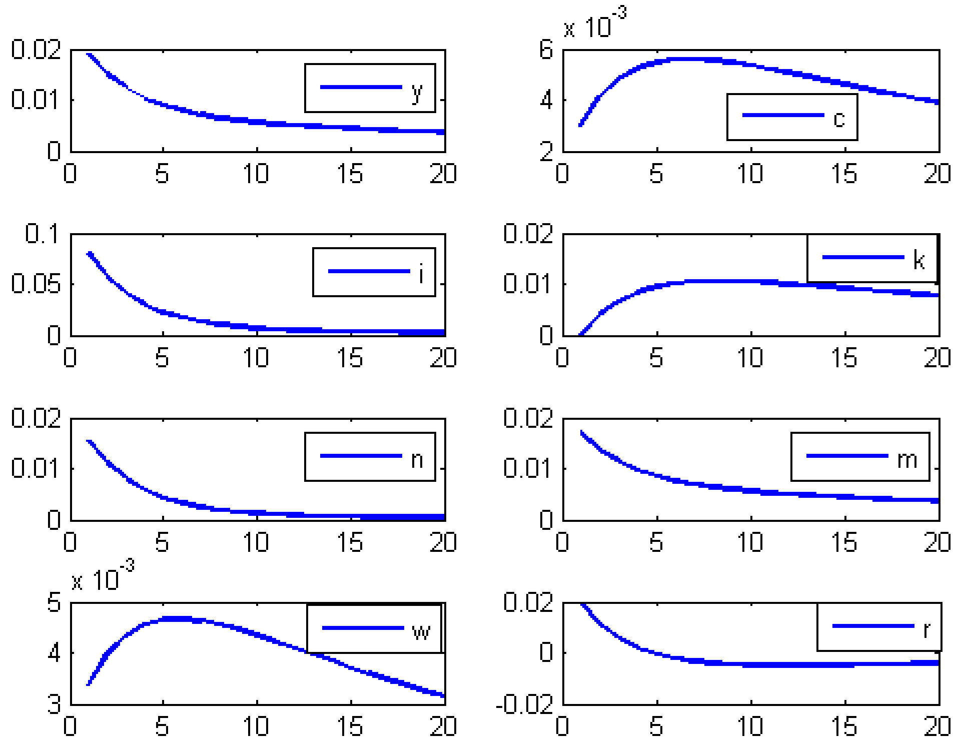

Figure 1: Impulse Responses to a 1% surprise innovation in technology

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 jump 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.

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

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 annual frequency.[2] To minimize the sample error, the simulated moments are averaged out over the computer-generated draws. The model matches quite well the absolute volatility of output. However, the model substantially overestimates the variability in consumption, and investment. This shortcoming of the model could be explained by structural factors in Bulgaria, such as privatization of state assets, and the short annual time series for Bulgaria. In addition, public investment in infrastructure has been also substantial in the last few years due to the EU accession funds. Still, the model is qualitatively consistent with the stylized fact that consumption is less volative than output, and investment is more volatile than output. By construction, government spending in the model varies as much as in data. With respect to the labor market variables, the variability of employment predicted by the model matches that in data, but the variability of wages in the model is lower than that in data.

Next, in terms of contemporaneous correlations, the model slightly over-predicts the procyclicality of the main aggregate variables - consumption and government consumption. This, however, is a common limitation of this class of models. Still, along the labor market dimension, the contemporaneous correlation of employment with output, and unemployment with output, is relatively well-matched. With wages, the model predicts strong cyclicality, while wages in data are acyclical.

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

Table 3: Business Cycle Moments

	Data	Model
σ_y	0.05	0.05
σ_c/σ_y	0.55	0.63
σ_i/σ_y	1.77	3.26
σ_g/σ_y	1.21	1.00
σ_h/σ_y	0.63	0.63
σ_w/σ_y	0.83	0.52
$\sigma_{y/h}/\sigma_y$	0.86	0.52
$corr(c,y)$	0.85	0.62
$corr(i,y)$	0.61	0.78
$corr(g,y)$	0.31	1.00
$corr(h,y)$	0.49	0.77
$corr(w,y)$	-0.01	0.66
$corr(u,y)$	-0.47	-0.77
$corr(h,y/h)$	-0.14	0.34

In the next subsection, 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 against the simulated AFCs and CCFs. Following Canova (2007), this comparison is used as a goodness-of-fit measure. As seen from Table 4 on the next page, the model compares 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.

Table 4: Autocorrelations for Bulgarian data and the model economy

		k			
Method	Statistic	0	1	2	3
Data	$corr(h_t, h_{t-k})$	1.000	0.484	0.009	0.352
Model	$corr(h_t, h_{t-k})$	1.000	0.817	0.628	0.441
	(s.e.)	(0.000)	(0.035)	(0.065)	(0.090)
Data	$corr(y_t, y_{t-k})$	1.000	0.810	0.663	0.479
Model	$corr(y_t, y_{t-k})$	1.000	0.817	0.629	0.444
	(s.e.)	(0.000)	(0.034)	(0.062)	(0.084)
Data	$corr(a_t, a_{t-k})$	1.000	0.702	0.449	0.277
Model	$corr(a_t, a_{t-k})$	1.000	0.817	0.629	0.442
	(s.e.)	(0.000)	(0.033)	(0.064)	(0.091)
Data	$corr(c_t, c_{t-k})$	1.000	0.971	0.952	0.913
Model	$corr(c_t, c_{t-k})$	1.000	0.816	0.631	0.451
	(s.e.)	(0.000)	(0.032)	(0.058)	(0.076)
Data	$corr(i_t, i_{t-k})$	1.000	0.810	0.722	0.594
Model	$corr(i_t, i_{t-k})$	1.000	0.817	0.628	0.441
	(s.e.)	(0.000)	(0.034)	(0.064)	(0.089)
Data	$corr(w_t, w_{t-k})$	1.000	0.760	0.783	0.554
Model	$corr(w_t, w_{t-k})$	1.000	0.816	0.632	0.451
	(s.e.)	(0.000)	(0.033)	(0.057)	(0.075)

The persistence of labor market variables are also well-described by the model dynamics: the ACFs wages are close to the simulated ones until the third lag. Same holds true for output and investment. The ACF for consumption and employment is well-captured only until the first lag. Overall, the model with one-period nominal wage contracts generates the right persistence in model variables, and is able to respond to the criticism in Nelson and Plosser (1992), Cogley and Nason (1995) and Rotemberg and Woodford (1996), who argue that the RBC class of models do not have a strong internal propagation mechanism besides the strong persistence in the TFP process.

Next, as seen from Table 5 on the next page, over the business cycle, in data labor productivity leads employment. The model with CIA constraint, however, cannot account for this fact. In this model, as well 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. Still, the model with a CIA constraint is a clear improvement over the real setup with perfectly-competitive labor market paradigm used in Vasilev (2009).

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	$corr(h_t, (y/h)_{t-k})$	0.010	0.018	0.029	0.341	0.018	0.002	-0.006
	(s.e.)	(0.758)	(0.674)	(0.564)	(0.788)	(0.534)	(0.643)	(0.731)
Data	$corr(h_t, w_{t-k})$	0.355	0.452	0.447	0.328	-0.040	-0.390	-0.57
Model	$corr(h_t, w_{t-k})$	0.010	0.018	0.029	0.341	0.018	0.002	-0.006
	(s.e.)	(0.758)	(0.674)	(0.564)	(0.788)	(0.534)	(0.643)	(0.731)

6 Conclusions

We augment an otherwise standard business cycle model with a richer government sector, and add a modified cash in advance (CIA) considerations. In particular, the cash in advance constraint of Cole (2020) is extended to include private investment and government consumption, and allows a proportion of total expenditure to be done using credit. This specification is then calibrated to Bulgarian data after the introduction of the currency board (1999-2018), gives a role to money in accentuating economic fluctuations. In particular, the modified CIA constraint produces a mechanism that allows the framework to reproduce better observed variability and correlations among model variables, and those characterizing the labor market in particular.

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