Aleksandar Zdravkov Vasilev
University of Lincoln, UK
Lincoln International Business School
Accountancy, Finance and Economics Department
avasilev@ lincoln.ac.uk
orcid.org/0000-0002-3956-6314

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How Quantitatively Important are the Shocks to the Time Endowment for Business Cycle Fluctuations? Lessons Learnt From Bulgaria (1999-2018)

Qual a Importância Quantitativa dos Choques na Dotação de Tempo para as Flutuações nos Ciclos Económicos? Lições da Bulgária no Período 1999-2018

Aleksandar Vasilev

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ABSTRACT
Shocks to time endowment are 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 total time available to households is investigated for the magnitude of cyclical fluctuations in Bulgaria. Although hours worked became more volatile, and wages a bit smoother, the quantitative effect of such a shock is found to be small, and thus not very important for the propagation of business cycle fluctuations.
Keywords: Business cycles; time endowment shocks; Bulgaria.

JEL Classification*:* E24; E32.

1. Introduction and motivation

It is a well-known fact, e.g. Prescott (1986), that the aggregate fluctuations produced by the standard real-business-cycle (RBC) model are entirely driven by highly-persistent innovations to the total factor productivity part of the aggregate production functions (and labeled as "technological shocks"). One way to improve the standard RBC model is to add additional shocks. In this paper we will focus on a disturbance that affects the total time available to the representative household. Such a stochastic process will affect labor supply, which in interaction with the other major variables in the model, could produce interesting additional effects. This example is considered graphically only in Gillman (2010) as a shift of a stochastic labor supply curve. In this paper, we add value to the graphical analysis by performing a careful quantitative analysis using a micro-founded general-equilibrium model.

In the model setup in this paper, the shock to the time endowment could be interpreted in a similar fashion to a preference shock a la Bencivenga (1992). The process is also akin to a home-production technology shock (Benhabib et al. 1991), or some time-saving technology, which decreases cleaning time, or the time needed to prepare and cook food. Yet another interpretation is a cut to non-work hours, such as transportation or commuting costs incurred to reach the workplace. Alternatively, higher time endowment could be a result of a healthier lifestyle, which cuts out the time lost from taking smoking breaks, and potentially more sick days being taken. Finally, it might be a result of the new normal, and in particular "working from home" practice, where everything is available at one's fingertips, and there is no need to travel (and even to groom) to perform certain office tasks. We can go even further and speculate about demographic changes in the labor supply, like allowing individuals between 16-18 to work freely, or increasing the retirement age.

We do not aim to provide a detailed literature review here, as we will be staying agnostic regarding the true cause of the change in the time endowment; i.e, we are not going to explicitly model those in this paper, beyond the exogenous shock to time. Still, the major idea is taken seriously, and this paper incorporates shocks to the household's time endowment 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 an interesting testing case for the theory. The paper then proceeds to quantitatively evaluate the effect of such an additional stochastic process as a tool for business cycle transmission. This is the first study on the issue using modern macroeconomic modelling techniques, and thus an important contribution to the field. Unfortunately, despite making hours worked more volatile, and wages a bit smoother, he quantitative effect of such a shock is found to be small, and thus not very important cause behind the propagation of business cycle fluctuations in Bulgaria over the period 1999-2018.

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 household, which derives utility out of consumption and leisure. The time available to households can be spent in productive use or as leisure. The time endowment is subject to a stochastic shock. 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

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \{ lnc_t + y\ln (n_t - h_t) \}, \tag{2.1}$$

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. The endowment, n_t will be assumed to be time-varying, and will take an average value of unity.

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

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \{ lnc_t + y\ln (n_t - h_t) \}, \tag{2.3}$$

s.t

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

where $\{\tau^c, \tau^y\}$ are the ta rates on consumption and income, respectively, and g_t^t denotes government transfers. The household takes fiscal policy instruments as given, as well as the prices, and chooses consumption, capital and hours sequences that maximize its utility s.t the period budget constraint.

The first-order optimality conditions are as follows:

$$c_t\text{: } \frac{1}{c_t} = \lambda_t(1 + \tau^c) \tag{2.5}$$

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

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

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

where λ_t is the Lagrangean multiplier attached to households budget constraint in period t. The interpretation of the fir st-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. 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. Note that this equation also captures the varying nature of the time endowment. The third equation is "the so-called "Euler condition," which describes how the household chooses to allocate physical capital over time. The last condition is called the "transversality condition" (TVC): it states that at the end of the horizon, the value of physical capital should be zero.

2.2. Firm problem

There is a representative firm in the economy, which produces a homogeneous final product, y_t. 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.:

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

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

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:

$$g_t^c + g_t^t = \tau^c c_t + \tau^y[r_t k_t + w_t h_t + \pi_t] \qquad (2.12)$$

In the model, consumption tax rate, income tax rate and government consumption-to-output ratio would be chosen to match the average share in data, while government transfers would be determined residually in each period so that the government budget is always balanced.

2.4. Dynamic competitive equilibrium (DCE)

For a given process followed by technology and time endowment $\{A_t, n_t\}_0^\infty$, tax schedules $\{\tau^c, \tau^y\}_0^\infty$ and initial capital stock $\{k_0\}$ the decentralized dynamic competitive equilibrium is a list of sequences $\{c_t, h_t, k_{t+1}\}_0^\infty$ for the household, a sequence of government purchases and transfers $\{g_t^c, g_t^t\}_0^\infty$, and input prices $\{w_t, r_t\}_0^\infty$ such that (i) the household maximizes its utility function subject to its budget constraint; (ii) the representative firm maximizes profit; (iii) government budget is balanced in each period; (iv) all markets clear.

3. **Data and model calibration**

To characterize business cycle fluctuations 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 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 overaccumulation of physical capital, which was part of the ideology of the totalitarian regime, which was in place until 1989. Next, the average labor and capital income tax rate was set to $\tau^y = 0.1$. 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, the moments of the time shock process will be set the same. 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
$1-\alpha$	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
ρ_t	0.701	AR(1) persistence coefficient, time shock process	Set
σ_a	0.044	st. error, TFP process	Estimated
σ_t	0.044	st. error, time shock process	Set

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 below. The steady-state level of output was normalized to unity (hence the level of technology A differs from one, which is usually the normalization done in other studies), which greatly simplified the computations. Next, the model matches consumption-to-output and government purchases ratios by construction; The investment ratios are also closely approximated, despite the closed-economy assumption and the absence of foreign trade sector. The shares of income are also identical to those in data, which is an artifact of the assumptions imposed on functional form of the aggregate production function. The after-tax return, where $\tilde{r} = (1-\tau^y)r-\delta$ 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
gc/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
r^{-}	After-tax net return on capital	0.014	0.016

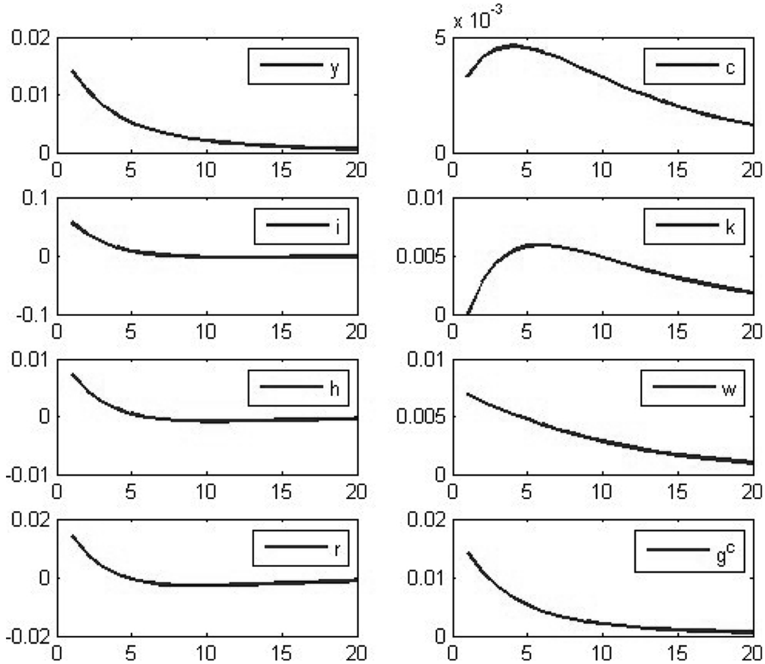
5. Out of steady-state model dynamics

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.

This subsection documents the impulse responses of model variables to a 1% surprise innovation to technology and time. The impulse response functions (IRFs) are presented in Fig. 1 and Fig. 2, 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.

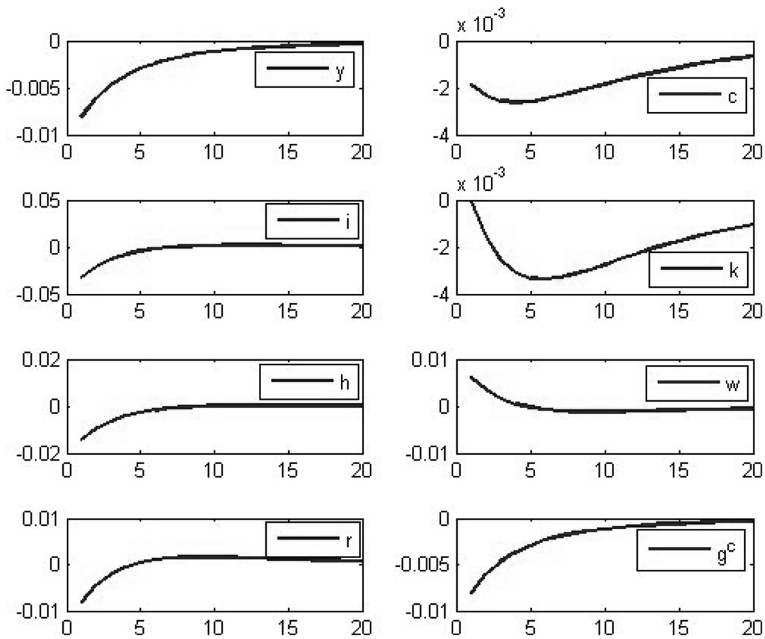
Figure 1: Impulse Responses to a 1% surprise innovation in technology



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.

In the case of the shock to time endowment, despite being significant, the effect is quite short-lived. A positive and unexpected increase in time endowment relaxes the time constraint, and makes hours less valuable at the margin. That is why, upon impact of the shock, hours worked fall, which directly affects output. As a result of the reduction in labor supply, marginal productivity of labor increases, and wages go up. Next, due to the fact that capital and labor are complements in the production function, investment also falls, and interest rates as well. This decrease in capital over the transition path negatively impacts output in an indirect manner. As the shock dies out, the variables return to their old steady-states in a monotone fashion, with the exception of consumption and capital, which follow hump-shaped dynamics.

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



5.1. 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 "Model" is the case with both shocks at work, as well as the scenario when one process is turned off. In addition, to minimize the sample error, the simulated moments are averaged out over the computer-generated draws. As in Vasilev (2016, 2017b, 2017c), all models match quite well the absolute volatility of output. By construction, government consumption in the model varies as much as output. In addition, the predicted consumption and investment volatilies are 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 time hocks produces smoother wage series (but the effect is quite small), and more volatile hours worked series, where the latter effect is quite substantial, and perfectly matches the volatility in data.

Table 3: Business Cycle Moments

	Data	Model (both shocks)	Model (TFP (shocks only)	Model (time (shocks only)
σy	0.05	0.05	0.05	0.05
$\sigma c/\sigma y$	0.55	0.81	0.82	0.82
$\sigma i/\sigma y$	1.77	2.37	2.35	2.35
$\sigma g/\sigma y$	1.21	1.00	1.00	1.00
$\sigma h/\sigma y$	0.63	0.63	0.28	1.16
$\sigma w/\sigma y$	0.83	0.78	0.86	0.44
$\sigma y/h/\sigma y$	0.86	0.78	0.86	0.44
corr(c, y)	0.85	0.89	0.90	0.90
corr(i, y)	0.61	0.83	0.83	0.83
corr(g, y)	0.31	1.00	1.00	1.00
corr(h, y)	0.49	0.58	0.59	0.92
corr(w, y)	-0.01	0.71	0.96	-0.17

With respect to the labor market variables, with only TFP at play, the variability of employment predicted by the model is lower than that in data, but the variability of wages in the model is very close to that in data. This is yet another confirmation that the perfectly-competitive assumption, e.g. Vasilev (2009), as well as the benchmark calibration here, does not describe very well the dynamics of labor market variables. Next, in terms of contemporaneous correlations, the model systematically over-predicts the pro-cyclicality of the main aggregate variables – consumption, investment, and government consumption. This, however, is a common limitation of this class of models, and the presence of time shocks does not help much. Along the labor market dimension, the contemporaneous correlation of employment with output is too high. With respect to wages, the model predicts strong cyclicality, while wages in data are acyclical. This shortcoming is well-known in the literature and an artifact of the wage being equal to the labor productivity in the model.

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

5.2. Auto-and cross-correlation

This subsection discusses the auto-(ACFs) and cross-correlation functions (CCFs) of the major model variables. The coefficients empirical ACFs and CCFs at different leads and lags are presented in Table 4 below against the averaged simulated AFCs and CCFs. For the sake of brevity, only the results for the setup with both shocks at play is reported.

As seen from Table 4 on the previous page, 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 time shocks generates too much persistence in output and employment, and is subject to the criticism in Nelson and Plosser (1982), Cogley and Nason (1995) and Rotemberg and Woodford (1996b), who argue that the RBC class of models do not have a strong internal propagation mechanism besides the strong persistence in the TFP process. In those models, e.g. Vasilev (2009), and in the current one, labor market is modelled in the Walrasian market-clearing spirit, and output and unemployment persistence is low.

Next, as seen from Table 5 below, over the business cycle, in data labor productivity leads employment. The model, however, cannot account for this fact. As in the standard RBC model a technology shock can be regarded as a factor shifting the labor demand curve, while holding the labor supply curve constant. The shocks to the labor supply does not help much. Therefore, the overall effect between employment and labor productivity is only a contemporaneous one.

Table 4: Autocorrelations for Bulgarian data and the model economy

		k			
Method	Statistic	0	1	2	3
Data	$corr(n_t, n_{t-k})$	1.000	0.484	0.009	0.352
Model	$corr(n_t, n_{t-k})$	1.000	0.955	0.899	0.834
	(s.e.)	(0.000)	(0.028)	(0.053)	(0.078)
Data	$corr(y_t, y_{t-k})$	1.000	0.810	0.663	0.479
Model	$corr(y_t, y_{t-k})$	1.000	0.956	0.903	0.843
	(s.e.)	(0.000)	(0.027)	(0.053)	(0.076)
Data	$corr(a_t, a_{t-k})$	1.000	0.702	0.449	0.277
Model	$corr(a_t, a_{t-k})$	1.000	0.954	0.900	0.836
	(s.e.)	(0.000)	(0.028)	(0.054)	(0.078)
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)	(0.048)	(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	0.828
	(s.e.)	(0.000)	(0.029)	(0.056)	(0.081)
Data	$corr(w_t, w_{t-k})$	1.000	0.760	0.783	0.554
Model	$corr(w_t, w_{t-k})$	1.000	0.956	0.905	0.846
	(s.e.)	(0.000)	(0.026)	(0.051)	(0.074)

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	$corr(h_t,(y/h)_{t-k})$	0.022	0.019	0.012	-0.011	0.058	-0.076	-0.087
	(s.e.)	(0.337)	(0.297)	(0.252)	(0.506)	(0.271)	(0.291)	(0.320)
Data	$corr(h_t, w_{t-k})$	0.355	0.452	0.447	0.328	-0.040	-0.390	-0.57
Model	$corr(h_t, w_{t-k})$	0.022	0.019	0.012	-0.011	0.058	-0.076	-0.087
	(s.e.)	(0.337)	(0.297)	(0.252)	(0.506)	(0.271)	(0.291)	(0.320)

6. **Conclusions**

Shocks to time endowment are 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 total time available to households is investigated for the magnitude of cyclical fluctuations in Bulgaria. Despite making hours worked more volatile, and wages a bit smoother, he quantitative effect of such a shock is found to be small, and thus not very important for the propagation of business cycle fluctuations.

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