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Abstract

Financial openness 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 (1999-2020). The quantitative importance of financial openness is investigated for the stabilization of cyclical fluctuations in Bulgaria. The computational experiment performed in this paper reveals that greater financial openness increases the impact of technology shocks on output, investment, consumption, labor hours, and net exports. This amplification effect is due to the following mechanism: openness provides a cheap access to foreign funds. Unfortunately, the new results come at odds with a major empirical observation, i.e. that consumption and net exports strongly pro-cyclical; the model, however, produces a countercyclical consumption, as well as net exports. Thus, such a setup is not yet ready to be used for policy analysis.

Keywords: business cycles, progressive capital taxation, Bulgaria

JEL Classification Codes: E24, E32

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1 Introduction and Motivation

In this paper, aggregate fluctuations and propagation mechanisms under varying degrees of financial openness are analyzed for a small open economy, such as Bulgaria. Using a DSGE framework with financial intermediation (foreign-owned banks) and foreign borrowing (from the headquarters, i.e. "the mother-bank"), we investigate the importance of increased financial openness for the propagation of the technology shocks in the economy. The model is calibrated for Bulgaria in the period 1999-2020, as Bulgaria provides a good testing case for the theory, being a relatively financially under-developed emerging economy, and the poorest member state in the EU.

The novel framework in this paper examines financial liberalization by taking into consideration certain realistic aspects of Bulgarian economy, such as the important information asymmetries and financial frictions: In particular, the presence of asymmetric information in the economy and the uncertainty in the entrepreneurial production process itself (as proxied by the probability of success for a project) necessitate the existence of financial intermediation, or banking, in our artificial economy.[1] In turn, the assumed Holmstrom-Tirole (1997) uncertainty in production utilized in the model framework in this paper also drives other model ingredients; in particular, this type of informational friction requires firms to pledge certain amount of collateral upon borrowing, where physical capital stock serving as both asset collateral and a factor of production.[2]

The computational experiment performed in this paper reveals that greater financial openness increases the impact of technology shocks on the main macroeconomic variables: output, investment, consumption, labor hours, and net exports. This amplification effect is due to the following mechanism: that openness provides a cheap access to foreign funds, which are then extended as credit to local entrepreneurs. Unfortunately, the new results come at odds with a major empirical observation, i.e. that consumption and net exports are strongly

[1] If the entrepreneurs are "start-ups", then the financial intermediation could be thought of as being so-called "business angels," or "venture capitalists" (VCs), as long as they can raise funds from abroad, and thus not necessarily traditional banks.

[2] In this sense, the modeling of the physical capital (land) is akin to Kiyotaki and Moore (1997).

pro-cyclical; the model, however, produces a countercyclical consumption and net exports. Thus, such a setup is not ready to be used for policy analysis.

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 presents the impulse response functions of model variables to an unanticipated technology shock. Section 6 concludes the paper.

2 Model Setup

The model is a relatively standard RBC model; More specifically, the setup follows that in Cakici (2012): the openness will be driven only by the use of foreign deposits by the financial intermediaries.[3] On top of that, the model features other financial frictions, such as informational frictions (asymmetric information in terms of project selection, and project's success rate), and uncertainty in the production process at microeconomic, or project-, level.

There is a representative household, entrepreneurs/firms, financial intermediaries (banks), and implicitly - a financial regulator.[4] All decisions are assumed to be made after the aggregate technology shock is realized. For the stock variables, we use the notion of allocation at the end of the period, e.g., K_t denotes *end-of-period* capital stock. The infinitely-lived household owns the financial intermediaries, and maximizes discounted utility over consumption and leisure. The household also decides how much to deposit in the financial intermediaries in the form of deposits. At the beginning of each period, households receive their previous-period deposits plus interest, and make current-period deposits at the financial intermediaries.

On the firm side, those are simply technologies used by entrepreneurs, who have a finite, but

[3] In reality, those correspond to the financial inflows (KI), and the net exports (NX) are the opposite of the capital flows, as $KI + NX = 0$.

[4] The financial regulator will only have a passive role, captured by the financial openness parameter.

uncertain (stochastic) lifespan. Every period, a certain proportion of entrepreneurs receives a "signal of death", and leaves the economy; simultaneously, the same proportion of entrants, or new-born entrepreneurs, enters the economy, and starts producing. Entrepreneurs maximize profit in each period, using capital, labor, and loans from the financial intermediaries. At the beginning of every period, the surviving entrepreneurs pay back the loans they owe the financial intermediaries, plus the interest, and roll over the loans (borrow again) for the current period. The loans are used to hire labor and capital as productive inputs.

The new entrants are assumed to bring some initial wealth with them; this is the Holmstrom and Tirole (1997) type of uncertainty. Entrepreneurs have two types of available projects to produce a homogeneous final good (which can be used for consumption, investment, or government spending), both of which are subject to idiosyncratic shock process. In particular, there is positive return in the case of success and zero return in the case of a failure. The projects differ in their success probabilities, p^H for a "good" project, and p^L for a "bad" project, $p^H > p^L$. There is a private benefit that the bad project yields in the case of a success, which creates a positive demand for those types of projects in equilibrium. In the case of a success of a "good" project, there are no private gains. It will be assumed that the outcomes of the projects are directly observable/verifiable by the financial intermediaries, but the particular project choices of the entrepreneurs are not.[5] Next, foreign lenders will be assumed to supply foreign deposits in a perfectly elastic way (large agents) - at the constant, world interest rate - which is lower than the domestic rate (lower risk).

Finally, the financial intermediaries (foreign banks) are assumed to maximize the discounted value of dividends, which is then distributed back to the representative household. The financial intermediaries collect both domestic and foreign deposits to extend loans to the firms. In case of successful project, the financial intermediary gains a positive net return; in case of a failure, the financial intermediary is able to grab a proportion of the firm's assets (capital). The intermediaries are constrained in their holdings of foreign deposits by a financial regulator, who would be only present in the model via the upper bound on the share of

[5]From the law of large numbers, it follows that even though each project is stochastic, the aggregate return will be deterministic, and not in expected terms.

financial deposits held as the liabilities by the intermediary. This share would act as a proxy of financial openness. In particular, in a financially underdeveloped economy, the bank will ask the headquarters to extend some reserves (at a cost), which will be then channeled in the form of loans to domestic firms. Given that the reserves are obtained at some reserve cost, it is equivalent to thinking about those as "foreign deposits". In case when the projects fail, the collateral is liquidated and domestic and foreign deposit holders are paid with these funds.

2.1 Households

There is a representative household, which maximizes its expected utility function

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \Big\{ \ln C_t + \gamma \ln(1 - H_t) \Big\} \tag{2.1}$$

whereE_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 household starts with an initial stock of domestic deposits, $DD_0 > 0$, and has to decide how much to add, or withdraw, where the law of motion of domestic deposits is

$$DD_{t+1} = I_t^d + DD_t R_{H,t}, \tag{2.2}$$

where I_t^d is financial investment in deposits in period t, and $R_{H,t}$ is the deposit rate. We will also assume that $DD_t \geq 0$, $\forall t$. Furthermore, the household receives dividends from firms' profit, B_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 $w_t H_t$. Next, the household's problem can be now simplified to

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \Big\{ \ln C_t + \gamma \ln(1 - H_t) \Big\} \tag{2.3}$$

s.t.

$$(1 + \tau^c) C_t + DD_t = (1 - \tau^y)[w_t H_t + DD_{t-1} R_{H,t} + B_t] + G_t^t, \tag{2.4}$$

where where τ^c is the tax on consumption, τ^y is the income tax rate ($0 < \tau^c, \tau^y < 1$), and G_t^t denotes government transfers. The household takes the tax rates $\{\tau^c, \tau^y\}$, government spending categories, $\{G_t^c, G_t^t\}_{t=0}^{\infty}$, profit $\{B_t\}_{t=0}^{\infty}$, the realized technology process $\{A_t\}_{t=0}^{\infty}$, prices $\{w_t, R_{H,t}\}_{t=0}^{\infty}$, and chooses $\{C_t, H_t, DD_t\}_{t=0}^{\infty}$ to maximize its utility subject to the budget constraint.[6] The first-order optimality conditions are as follows:

$$C_t \;:\; \frac{1}{C_t} = \Lambda_t(1+\tau^c) \tag{2.5}$$

$$H_t \;:\; \frac{\gamma}{1-H_t} = \Lambda_t(1-\tau^y)w_t \tag{2.6}$$

$$DD_t \;:\; \Lambda_t = \beta E_t \Lambda_{t+1}[1-\tau^y]r_t^h \tag{2.7}$$

$$TVC \;:\; \lim_{t\to\infty} \beta^t \Lambda_t DD_t = 0, \tag{2.8}$$

where Λ_t is the Lagrangean multiplier attached to household's budget constraint in period t. The interpretation of the first-order conditions above is as follows: the first one states that for each household, the marginal utility of consumption equals the marginal utility of wealth, corrected for the consumption tax rate. The second equation states that when choosing labor supply optimally, at the margin, each hour spent by the household working for the firm should balance the benefit from doing so in terms of additional income generates, and the cost measured in terms of lower utility of leisure. The third equation is the so-called deposit "Euler condition," which describes how the household chooses to allocate its deposits over time. The last condition is called the "transversality condition" (TVC): it states that at the end of the horizon, the value of deposits, measured in terms of consumption they could purchase, should be zero.

2.2 Firms

The model in this part follows closely Cakici (2012). There is a unit mass of entrepreneurs in the economy that runs the firms. Each period, a constant share π of those entrepreneurs perish, and an equal share of new-born entrepreneurs enters the market. At micro level, this means that each entrepreneur faces a stochastic probability of death in each period. This modelling approach with a stochastic death/birth rate is imposed in order to prevent the entrepreneurs from accumulating too much profit, as that would invalidate the assumption

[6] Note that by choosing DD_t the household is implicitly setting investment I_t^d optimally.

of the borrowing constraints faced by firms. In addition, in this paper the households are not able to observe profit levels, as there will be certain informational asymmetries (about the profitability of the projects) present in the model setup.

With probability i, each entrepreneur receives a signal in each period whether or not s/he will die at the end of the period. Those who are above to die, consume everything what is left of their wealth at the end of the period, after paying off their debts.[7] The new entrants bring along some initial wealth, which could be thought as being inherited from the entrepreneurs who died in the previous period. The wealth will be used as capital for production. The capital stock is purchased from the financial intermediaries (which receive capital stock as repayment of loans in the case of failure of the firms' projects).

Entrepreneurs thus maximize profit, by taking into account this stochastic probability of death. In addition, there is uncertainty involved in the production process of the firm, resulting from the fact that the entrepreneurs have a choice between two available projects to pursue to produce; both of the projects are subject to idiosyncratic risk. More specifically, the two projects differ in their probabilities of success and the benefits that are accrued to the entrepreneur; in particular, there is positive output in the case of success, and no output in the case of a failure. The probabilities of success of a "good" and "bad" project are denoted by p^H and p^L, respectively, where $0 < p^L < p^H < 1$. The entrepreneur obtains PB amount of benefit/return (expressed per capital stock) in case of a "bad" project; there is no such benefit in case of a success on a "good" project. The projects' expected payoffs are as follows. In case of a "good" project:

$$p^H[Y_t - R_{Ft}L_t] + (1 - p^H)[0 - \mu(1 - \delta)K_{t-1}]. \tag{2.9}$$

In case of a "bad" project:

$$p^L[Y_t - R_{Ft}L_t] + (1 - p^L)[0 - \mu(1 - \delta)K_{t-1}] + PB * K_t, \tag{2.10}$$

where L_t represents loans (firm's borrowing from financial intermediaries) at a gross interest rate of R_{Ft}. Parameter μ measures the fraction of the capital stock that firms have to hand

[7] This requirement - to pay off debts - is assumed to be specified in the loan contract between the firm and the financial intermediary (banks); otherwise, there will be no protection for financial intermediaries against the stochastic death probability faced by entrepreneurs.

over to financial intermediaries in the case of bankruptcy (failure of the projects).[8]

The production function available to each firm is

$$Y_t = A_t K_{t-1}^{\alpha} N_t^{1-\alpha}, \tag{2.11}$$

where we assume that the capital takes one period to become productive (time to be installed). N_t is the amount of the labor input hired by each firm. Finally, A_t denotes the level of technology at time t, which is assumed to follow an AR(1) process.

Next, the capital accumulation process, as well as firm's profit, will be decomposed for the case of each contingency. As in Cakici (2012), let F_t^s and K_t^s (F_t^f and K_t^f, respectively) denote the profit and capital stock accumulated in the case of success (failure) of the project. Then, aggregate profit and capital stock are given as[9]

$$F(t) = F_t^s p^H + F_t^f (1 - p^H) \tag{2.12}$$

and

$$K_t = K_t^s p^H (1 - \pi) + K_t^f (1 - p^H). \tag{2.13}$$

The profits made in the case of a successful project, are reinvested as physical capital, and thus transferred to the next period, and are given by the following equation:

$$F_t^s = Y_t - \pi R_{Ft} L_t - (1 - \pi) R_{F,t-1} L_{t-1}. \tag{2.14}$$

The corresponding capital stock in the case when projects are successful, is

$$K_t^s = F_t^s + (1 - \delta) K_{t-1}. \tag{2.15}$$

where $0 < \delta < 1$ is the depreciation rate of capital. In case of failure, there is no output realized. In turn, profits are negative, and equal to part of the undepreciatiated capital left behind:

$$F_t^f = -\mu (1 - \delta) K_{t-1}, \tag{2.16}$$

[8] Alternatively, that is the share that firms leave behind with limited commitment, when the projects do not turn out to be profitable.

[9] Notice that following the law of large numbers, even though at micro level the outcome is stochastic, the aggregate outcomes will be deterministic.

while the capital stock in case of failure is

$$K_t^f = F_t^f + (1-\delta)K_{t-1} = (1-\mu)(1-\delta)K_{t-1}; \tag{2.17}$$

More specifically, in case of a failure, there is disinvestment, and debt is rolled over. At macro level, the law of motion for aggregate physical capital is then

$$K_t = p^H[\pi\mu(1-\delta)K_{t-1} + (1-\pi)(I_t + (1-\delta)K_{t-1})] + (1-p^H)(1-\mu)(1-\delta)K_{t-1}. \tag{2.18}$$

In particular, K_t is the aggregate physical capital to become productive at $t+1$. In addition, $\pi\mu(1-\delta)K_{t-1}$ is the capital stock held by the newly-born entrepreneurs. Next, the second term in the firs bracket is the capital stock carried over by the successful entrepreneurs that continue to produce, net of depreciation, $(1-\delta)K_{t-1}$, plus the new investment, I_t. The last expression on the right side is the capital of unsuccessful entrepreneurs that realize losses in the previous period. Total profit in each period is given by

$$F_t = p^H Y_t - p^H \pi R_{Ft} L_t - p^H(1-\pi)R_{F,t-1}L_{t-1} - (1-p^H)\mu(1-\delta)K_{t-1}. \tag{2.19}$$

More specifically, with probability p^H the firm is able to make use of the loans it borrows from the FI to hire N_t amount of hours, which it can use with the capital stock it already has, K_{t-1}, in order to produce output, Y_t. The entrepreneur then makes an interest payment to the FI for the loans at the loan rate R_{Ft}. In the case of failure, there is no output produced, and the entrepreneur has to disinvest and transfer a certain amount of capital (net of depreciation rate) to pledge as collateral to the FI, in order to borrow from the FI.

Entrepreneurs' profit maximization problem above is subject to the wage borrowing constraint, or

$$w_t N_t \leq L_t. \tag{2.20}$$

Given the informational asymmetries in the model means that there is also an incentive-compatibility constrain, so that the entrepreneur decides to choose the good project:

$$Y_t - R_{Ft}L_t \geq \frac{PB.K_t}{p^H - p^L} \tag{2.21}$$

This constraint also gives the borrowing constraint of the firm

$$R_{Ft}L_t \leq Y_t - \frac{PB.K_t}{p^H - p^L} \tag{2.22}$$

and the loan demand(as the constraint will bind in equilibrium)

$$L_t^d = \frac{Y_t - \frac{PB.K_t}{p^H - p^L}}{R_{Ft}} \tag{2.23}$$

The loan supply will be defined by the outside option of financial intermediaries. In particular, the financial intermediary will continue to loan to the firms as long that produces a return higher than alternative investments in financial assets in the model economy, i.e. the return on loans should exceed that of deposits, or

$$p^H R_{Ft} + (1 - p^H)\frac{\mu(1-\delta)K_{t-1}}{L_t} \geq R_{Ht} \tag{2.24}$$

The equation above implicitly defines the loan supply, L_t^s schedule.

2.3 Financial intermediaries (FIs)

The FIs maximize the expected discounted stream of dividents they pay to households. FIs receive deposits from households, DD_t, and deposit from foreign investors, FD_t. (or funding from the mother-bank) FIs then use both types of funds to disperse loans to firms. According to the loan contract between the FIs and the firms, FIs obtain a net return of $R_{Ft} - 1$ in the case of a successful outcome of the firms' project, and a share μ of the capital stock in the case of failure. FIs are allowed to hold no more than a certain fraction of their total deposits in the form of foreign deposits. (capital controls?) - there is an upper limit on the fraction of foreign deposits over total deposit liabilities of the FIs; this is taken in the paper to represent the degree of financial openness in the economy (financial liberalization, foreign credit bias - if there is insufficient saving domestically due to low incomes in Bulgaria?)

The objective of the representative financial intermediary is to maximize the expected discounted stream of dividends:[10]

$$E_0 \sum_{t=0}^{\infty} \beta^{t+1} \frac{B_t}{C_{t+1}} \tag{2.25}$$

subject to the budget constraint

$$B_t \leq [p^H \pi R_{Ft} L_t + p^H(1-\pi)R_{F,t-1}L_{t-1} + (1-p^H)\mu(1-\delta)K_{t-1}] - R_{H,t-1}DD_{t-1} - R^* FD_{t-1}, \tag{2.26}$$

[10]The value of dividends is in terms of consumption of the private good. Alternatively, the firm is discounting using a so-called stochastic discount kernel.

where $FD_t \geq 0$ are the foreign deposits collected by the FIs. [11,12]

The second constraint is the balance sheet constraint, and requires that

$$D_t \leq L_t, \tag{2.27}$$

i.e., the liabilities of the FI (deposits) are less than the value of the assets (loans), where

$$D_t = DD_t + FD_t \tag{2.28}$$

and

$$FD_t = \psi D_t \tag{2.29}$$

$$DD_t = (1 - \psi) D_t, \tag{2.30}$$

where $0 < \psi < 1$ reflects the degree of financial openness (where higher levels of ψ imply more financial openness/liberalization), and is assumed to be under the control of the financial regulator, which here is set exogenously.

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

$$G_t^c + G_t^t = \tau^c C_t + \tau^y [w_t H_t + R_{H,t} DD_{t-1} + B_t] \tag{2.31}$$

Consumption- and income tax rate 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.

[11] The present value of dividends is discounted by a stochastic kernel, i.e., the marginal utility of consumption due to the fact that the FI is owned by the households and that an extra unit of dividends is valued by households to the extent that it is used to finance future consumption.

[12] Current-period deposit holdings and loans cancel out in the budget constraint.

2.5 Dynamic Competitive Equilibrium (DCE)

For a given process followed by technology $\{A_t\}_{t=0}^{\infty}$ tax schedules $\{\tau^c, \tau^y\}$, and initial conditions for capital and deposits $\{K_{-1}, DD_{-1}\}$, the decentralized dynamic competitive equilibrium is a list of sequences $\{C_t, K_t, DD_t, H_t\}_{t=0}^{\infty}$ for the household, a sequence of government purchases and transfers $\{G_t^c, G_t^t\}_{t=0}^{\infty}$, and input prices $\{w_t, R_{H,t}, R_{F,t}\}_{t=0}^{\infty}$ such that (i) the household maximizes its utility function subject to its budget constraint; (ii) the entrepreneurs maximize profit; (iii) each financial intermediary maximizes profit; (iv) government budget is balanced in each period; (v) 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 (1999-2020). Quarterly data on output, consumption and investment was collected from National Statistical Institute (2021), while the real interest rate is taken from Bulgarian National Bank Statistical Database (2021). The calibration strategy described in this section follows a long-established tradition in modern macroeconomics: first, as in Vasilev (2015b), 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 (2015a), and equals the average value of labor income in aggregate output over the period 1999-2020. 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. Next, the steady-state depreciation rate of physical capital in Bulgaria, $\delta = 0.013$, was taken from Vasilev (2015b). It was estimated as the average quarterly depreciation rate over the period 1999-2020. The parameters describing the behavior of entrepreneurs, are set as in Cakici (2012). Finally, the process followed by the TFP process is estimated from the detrended series by running an AR(1) regression and saving the residuals. Table 1 below summarizes the values of all model parameters used in the paper.

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
ψ	0.100	Share of foreign deposits in FIs	Set
μ	0.100	Share of capital left behind	Set
π	0.600	Stochastic probability of death	Set
R^*	1.010	International gross interest rate	Data average
p^H	0.800	Success probability of a "good" project	Set
p^L	0.100	Success probability of a "bad" project	Set
PB	0.100	Private benefit, when a "bad" project is successful	Set
ρ_a	0.701	AR(1) persistence coefficient, TFP process	Estimated
σ_a	0.044	st. error, TFP process	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 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 government purchases ratios by construction; Consumption-, investment-, and net export 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. The after-tax return, where $\bar{r} = (1 - \tau^y)r - \delta$ 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	0.692	0.731
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
nx/y	Net exports-to-output ratio	-0.044	-0.053
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

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. In the next section, we study the dynamic behavior of model variables to an isolated shock to the total factor productivity process.

5.1 Impulse Response Analysis

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

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 - investment, labor supply, loans, and government consumption also increase contemporaneously. However, private consumption and next exports fall. Those two results are at serious odds with data - where consumption and net exports in Bulgaria are strongly procyclical, e.g. Vasilev (2009). This raises serious issues with the model, when it comes to using the setup for policy analysis.[13]

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 domestic deposits, and supplies more hours worked. 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, 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.

Sensitivity analysis was also performed with the values of the parameters describing entrepreneur behavior, as well as the financial openness parameter, ψ. The results are qualitatively unchanged and are thus not presented here; as expected, higher ψ increases the amplification of the technology shock, as more foreign deposits provide cheaper funds from abroad, which helps to increase productivity via the expansion of domestic credit.

6 Conclusions

Financial openness 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

[13]As pointed in Cakici (2012), this is declared a success for the model, as more financial openness will lead to more foreign financial inflows. In addition, as a result of the shock, the households rather save than consume, which was shown to be the case in Mendoza (1991) for small open economies under imperfect capital mobility.

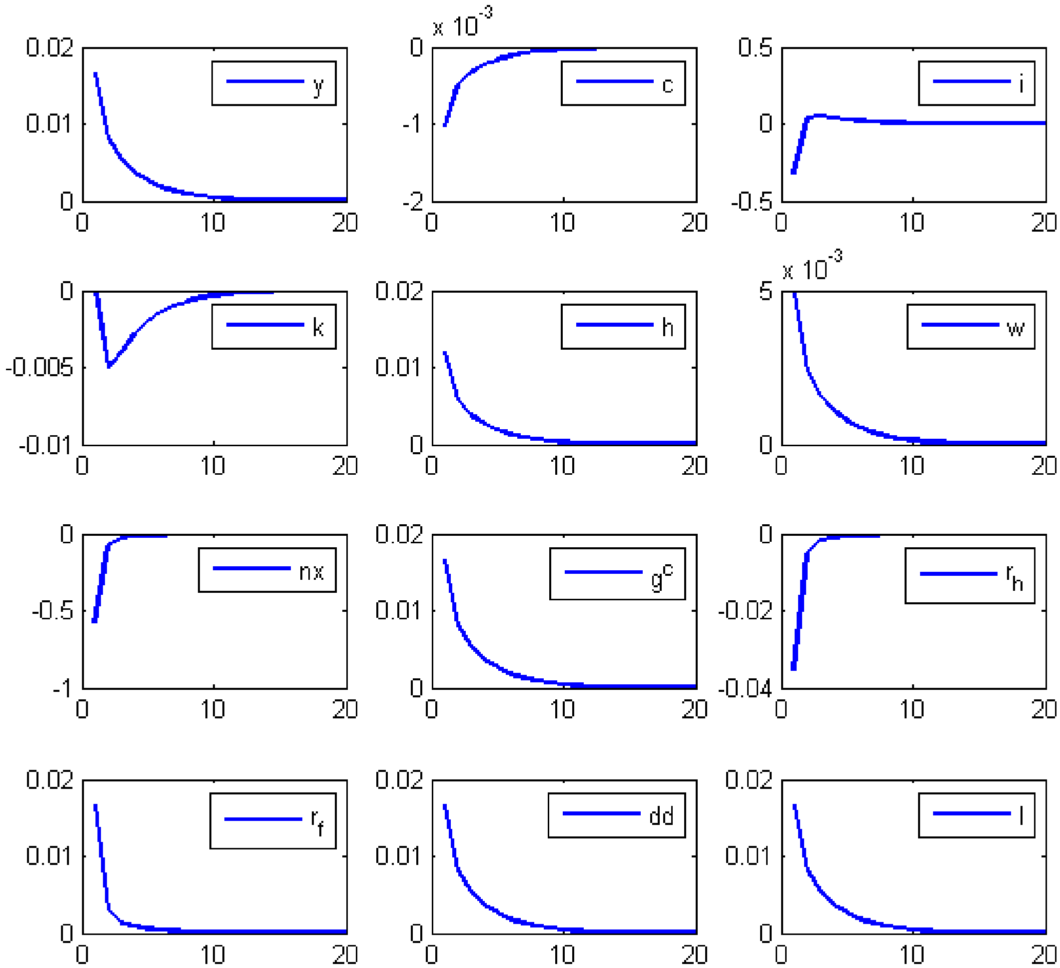

Figure 1: Impulse Responses to a 1% surprise innovation in technology

introduction of the currency board arrangement (1999-2020). The quantitative importance of financial openness is investigated for the stabilization of cyclical fluctuations in Bulgaria. The computational experiment performed in this paper reveals that greater financial openness increases the impact of technology shocks on output, investment, consumption, labor hours, and net exports. This amplification effect is due to the following channel - that openness provides a cheap access to foreign funds. Unfortunately, the new results come at odds with a major empirical observation, i.e. that consumption and net exports strongly pro-cyclical; the model, however, produces a countercyclical consumption, as well as net exports. Thus, such a setup is not yet ready to be used for policy analysis.

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