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**Master Thesis**

## Business Cycles in Bulgaria and the Baltic Countries: An RBC Approach

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**BUSINESS CYCLES IN BULGARIA AND THE BALTIC  
COUNTRIES: AN RBC APPROACH**

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Submitted to  
Central European University  
Department of Economics

In partial fulfillment of the requirements for the degree of Master of Arts

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## **ABSTRACT**

This paper explores the business cycle in Bulgaria and the Baltic countries: Estonia, Latvia and Lithuania during the 1993-2005 period. The paper aims at deepening the understanding of the nature of output fluctuations. The neoclassical approach will be employed, much in the spirit of the Real Business Cycle (RBC) literature, which gives a general equilibrium picture of the transition process. The model used in this paper follows the methodology of King, Plosser and Rebelo (1988). Calibration parameters, taken from data on Bulgarian and Baltic economies, are used in the estimation procedure. Both the model and data series show that the major drop in output was due to productivity. In addition, the timing of the banking reforms coincides with the improvement of economic performance. This is a strong indication that banking regulations in place were crucial for the output performance throughout the period in Bulgaria and the Baltic countries, a finding that has important implications for economic policy.

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## INTRODUCTION

This paper is inspired by the business cycle literature; the nature of fluctuation of macroeconomic variables is still not fully understood. Indeed, several explanations have been proposed and tested empirically, but none of them seem to provide a full account for output movements. Monetarists, led by Friedman and Schwartz (1963) argue it was mainly due to monetary shocks, while another school of economic thought sticks to real factors. Representatives of the latter include Fisher and Horiuchi (2001), who point to productivity shocks; Prescott (2002) adds government policies, and Bergoeing et al. (2002) focus particularly on banking regulations. The effects of banks on the real side of the economy is emphasized in Bernanke (1981, 1987), Bernanke and Gertler (1988), Williamson (1987) and Cole and Ohanian (2001). In addition, Bernanke and James (1990) add that the gold standard, for example, contributed to the crisis during the Great Depression in the US of 1929-1933 by acting as a straightjacket to the economy.

The reason why some economists turned to the US Great Depression episode was that it still constitutes a puzzle for the business cycle theory. There was a prolonged recession coupled with unemployment rate up to 25% over the period 1929-39. Negative effects of a similar magnitude were experienced in many other countries all over the world at that time as well. Much later, during the 90s, all countries in Central and Eastern Europe featured a significant cyclical evolution as well. Their economies underwent a thorough transformation with a major restructuring of their previously planned economies.

This paper will explore the business cycle in Bulgaria and the Baltic countries: Estonia, Latvia and Lithuania in the 1993-2005 period. This particular time frame was used



as it is supposed to provide the most reliable data. The emphasis is on these particular countries because they all kept their fixed exchange rate regimes throughout the period (with a slight exception for Bulgaria, which adopted a currency board in 1997), much like the countries during the Great Depression that were on the gold standard. Baltic countries did not exist before 1992 as independent states, while Bulgarian data is of dubious quality in the first years of the regime change. In addition, Bulgaria avoided serious reform in the early years of transition (Mihov 2001) - the initially pursued shock therapy did not find wide public and political support, so a course towards gradualism was taken. Thus it is put at a more or less equal footing with the Baltic countries in terms of economic reforms.

The dataset compiled by Benczur and Ratfai (2005) will be used as it contains up-to-date information on business cycle regularities in the countries from Central and Eastern Europe. Moreover, this paper builds on their study by providing a theoretical framework for much of their applied work. This study finds that productivity is the main reason for the initial drop in output in the period of interest. Thus the paper aims at deepening the understanding of the business cycle in those countries and emphasizing the importance of the financial system for the real side of the economy, where the effect is through the productivity channel.

Although transition economies in Central and Eastern Europe were thoroughly investigated throughout the previous decade, we contribute to the literature by looking at their experience through another lens. In this paper the neoclassical approach will be employed, much in the spirit of the Real Business Cycle (RBC) literature, which gives a general equilibrium picture of the transition process. This approach of using growth accounting in a

business cycle framework was pioneered by Cole and Ohanian (1999). The aim here is to use the basic neoclassical RBC model and apply it to a group of transition countries.

The model used in this paper follows the methodology of King et al. (1988, 2002) as presented also by Cerny and Lazarova (1994). Calibration parameters, taken from data on Bulgarian and Baltic economies, are used in the estimation procedure; a growth accounting exercise following Solow's (1957) approach is performed, which calculates Total Factor Productivity (TFP) as residuals from the production function. Then simulations are performed in order to see how the theoretical model tracks the data series of different aggregates.

A common critique is that TFP does not tell you much about the factors lying behind the *Solow residuals*. The way to reconcile this is to provide some episodes from the economic history of Bulgaria and the Baltic countries that could serve as possible explanations and try to judge which ones are plausible. The most difficult case is with institutional factors and structural issues since they are almost impossible to quantify. Nevertheless, we will try to determine from the data and economic history which reforms were relatively more important for the drop in the TFP.

Both the model and data series show that the major drop in output was due to productivity. In addition, the timing of the banking reforms coincides with the improvement of economic performance. This is a strong indication that banking regulations in place were crucial for the output performance throughout the period in Bulgaria and the Baltic countries.

The paper is structured as follows: the next chapter provides a review of the literature in order to place the paper in the relevant field of economic research. The stories that serve as

possible explanations for the transition are discussed in the second chapter in order to illustrate the dynamics of the economies of interest. The third part describes the theoretical model and provides justification for the calibrated parameters. Model predictions are discussed and then compared against the countries' economic history as well as the existing findings in the business cycle literature. In the concluding section, the results are summarized, their importance with respect to policy is emphasized and directions for further research are provided.

## LITERATURE OVERVIEW

The literature on the subject can be roughly divided into two clusters: papers that perform a general equilibrium analysis using a business cycle approach, and those who go for the descriptive approach. The first cluster can be sub-divided according to the results obtained: some find TFP to be the cause for output movement, first in the US and then extended to other countries around the globe as well. They do not answer, however, what is behind this residual from estimation. Others claim it was not productivity and that the model was mis-specified. Thus they put in their models additional twists such as factor underutilization, rigidities and trade restrictions. Their effect, however, is not sufficient to explain output fluctuations when those additional complications are put in a general equilibrium. Not all explanations, however, are quantifiable: some examples are structural issues such as institutional arrangements and legal framework.

Therefore, the influence of those factors is explained by another group of economists in a descriptive way only, without any rigorous formal modeling. Rostowski (1996) compares the Great Depression in the US to the transition process in Central and Eastern Europe. He notes, however, that in the initial years of transition investment fell less than GDP did compared to the depression in the US. Using a simple financial accelerator model, Rostowski (1996) concludes that in the cases of Poland and Hungary there was a major restructuring. According to the author, this was triggered by a shift in demand that followed from the trade liberalization and that of prices. This was a “real shock” to enterprises, which in the RBC literature is denoted by a shock to technology and productivity. In short, enterprises did not suffer from excess capacity but only lacked “the right kind of productive capacity” (p.225). However, according to the author, enterprises were not able to invest because of the

imposition of hard budget constraints and tight monetary policy in place. In addition, Rostowski (1996) also finds that the “credit crunch” (Calvo and Coricelli, 1992) hypothesis is not in line with the data, thus rejecting the hypothesis that a reduction in aggregate demand caused the output fall.

Ohanian (2001), however, is of another opinion. He argues that the large productivity decrease that occurred during the Great Depression in the US is unlikely to be due to “technological regress”. Other factors, such as a decrease in organizational capital – the knowledge and know-how firms use to organize production, lie behind the productivity fall. In an earlier paper discussing Italy, Perri and Quadrini (2000) also argue that the depth and the duration of the Italian Great Depression (1929-38) cannot be explained by the productivity shocks only, but rather by trade restrictions and real wage rigidities.

Still, Amaral and MacGee (2001) show that TFP shocks account for a significant part of the Canadian depression. However, they do not have any theory to explain TFP behavior. Banking shocks account only for a small part of the downturn, and are insignificant in explaining the slow recovery. The number of commercial failures was not as high in Canada as it was in the US. What is more, Canada did not experience any bank failures, despite the fall of a number of branches.

Fisher and Horbstein (2001) find also changes in productivity to be important factors of the Great Depression in Germany – around less than two-thirds of the fall in output. An interesting difference is that the crisis in the financial sector came when the Depression was already in place. This factor, however, contributed to the length and severity of the Depression.

In Cole and Ohanian (2000) the banking shock story explains only a small portion of the output fall during the US Great Depression as well. According to the authors, the banking shock was small, and its result to the aggregate economy was even smaller. Cole and Ohanian (2000), however, admit that worse banking crises in theory should bring about deeper recession. They propose that economists should focus their attention on real factors more because they may be to blame for the initial fall in output, which will show in the TFP. The idea is that a real shock caused productivity to decrease in the US Great Depression and this is likely to be the case in the sample of countries of interest in this paper.

Beaudry and Portier (2001), while investigating the French Depression, found that technological change was not sufficient to account for the French depression episode, but institutional change and market regulations were likely to explain the episode. The depression in France, however, was not accompanied by a banking crisis.

Chari, Kehoe and McGrattan (2003) build a business cycle model, calibrated for the US, with wedges, respectively referred to *as labor wedges, investment wedges and efficiency wedges*. They conclude that the drop in output (1929-33) was due to both efficiency and labor wedges, while solely the latter was the reason for the subsequent slow recovery (1933-39). Chari et al.'s contribution is the frequently overlooked explanation of the efficiency factor. Their claim is that it was not so much skills or knowledge loss, but more the result of poor government policies, policies that led to the prolonged depression. These policies persisted for a long time and it is their effect on the economy that shows up in the shock component.

Kehoe and Ruhl (2003) suggest that movements in TFP explain the low growth period in Switzerland and New Zealand. However, since there is no accepted theory of TFP, this factor may incorporate the effect of country's institutions – taxes, openness to foreign competition, legal system, etc. In Switzerland, for example, it is a sector-specific technological change that explains the economy's poor growth record. Moreover, the way the rules of the game are set may encourage or discourage productivity and efficiency. Thus the authors went on a quest "...searching for changes in the institutional structure in those countries that took place around the beginning of their depressions and have persisted throughout the period."(16)

Hopenhayn and Neumeyer (2003) claim the fall in output per worker in Argentina in 1975-90 was also partly due to productivity growth, together with labor reallocation and capital deepening. Their critique is that growth accounting exercises explain everything with TFP, which is exogenous in the model and there are many reasons that lie behind that variable. In the Argentinean case, according to Hopenhayn and Neumeyer (2003), those could be commercial policies, exchange rate controls, tax structure, tariffs and non-tariff barriers, expectation of bank runs, and confiscation of deposits. These factors increased the cost of capital and relative price of investment goods. This caused a bad investment environment which led to stagnation in capital accumulation and induced labor reallocation.

Bergoeing et al. (2002) focus their attention on Mexico and Chile in the last two decades of the 20<sup>th</sup> century. In their study, they test four stories about the different paths of economic recovery: *standard monetarist story*, *real wage story*, *debt overhang story* and *structural reforms (trade policy, fiscal policy, privatization, the banking system and bankruptcy procedures)*. Bergoeing et al. (2002) do not find these explanations to hold in the

data, except for the privatization, the banking system and bankruptcy procedures. To demonstrate this, they do a growth accounting exercise and show that the two different paths of recovery in Chile and Mexico were due to the different evolution of TFP. Then the authors look into the government policies that could account for the TFP difference. The authors conclude it was the banking system and the bankruptcy procedures that made the difference, because both countries had already undertaken privatization before the observation period.

External shock, according to Bergoening et al (2002), was what triggered the TFP decrease in Mexico and Chile. In the cases of Bulgaria and the Baltic countries, this could be attributed to the movement to a market economy. This is also a technology shock, since it deals with operational efficiency and better resource management. In addition, the drop in productivity was exacerbated by the government policies (mainly banking regulations and bankruptcy procedures) in place and led to fragility in the financial sectors of the economies of interest. In a survey paper, Prescott (2002) also claims government policies can lead to prosperity or depressions.

The problem Hayashi and Prescott (2002) identify with Japan in the 1990s was the low productivity growth rate. Their growth accounting exercise, which takes TFP as exogenous, fits the data well. Japan experienced a fall in TFP productivity and increase in the capital-output ratio during the 1990s. According to them, growth theory leaves no role to financial intermediation and any frictions in it. Despite the collapse of bank loans and the “credit crunch”, firms found other ways to finance their investment – which were roughly close substitutes to bank credit.



The story that was very popular in the 1980s and that has passed a series of empirical tests was the banking system channel developed by Williamson (1987) and Bernanke (1983, 1987). Williamson (1987) shows that a RBC with endogenous financial intermediation mimics US data better than a monetary model. In this RBC model, it is the credit supply mechanism, together with inter-temporal substitution that propagates stochastic disturbances. Financial intermediation emerges as the mechanism for carrying out borrowing and lending in an environment of asymmetric information and costly monitoring. Monitoring costs can be interpreted as costs of bankruptcy, as in Bernanke (1981, 1983), and they play an important role in the propagation of real shocks in the economy.

Bernanke (1981) argues that the bankruptcy risk, especially when an economy-wide phenomenon, plays an important role in the propagation of recessions. The author focuses on the implications of the interaction between lenders and borrowers for the business cycle. He assumes that this problem occurs after there has been a drop in output, and financial distress magnifies that effect through the income-spending multiplier. In most of the cases it is not only the interest rate of the loan but also the size of the loan that matters. Bernanke finds that bankruptcy risk was important in the Great Depression in 1929-33. In a follow-up paper, Bernanke (1983) also claims financial collapse prolonged the money-neutrality, while Bernanke and Gertler (1988) find that bank lending channels are likely to be important during periods where financial markets are heavily regulated, e.g when there is a maximum deposit interest rate (regulation  $Q$  in US). The limitation of their work, however, is that the authors do not look at the problem in a general equilibrium. They find only that banking crises and loss in output are correlated but they do not measure the negative effect of the banking factor for the economy.

Walsh (2003) devotes a whole chapter in his book *Monetary Theory and Policy* on the credit channel of monetary policy. He argues that many economists are of the opinion that credit markets play a crucial role in the transmission of nominal shocks to the real economy (so called *credit view* of the economy). Bank funds, for example, may have no close substitutes and in this sense be regarded as special from the investors' point of view. When the economy features such credit market imperfections, this has macroeconomic implications for the response of the economy to real shocks and their propagation over time. Thus, Walsh urges for a general equilibrium analysis to assess the effect of credit market frictions. Adverse selection, moral hazard (borrower's behavior is influenced by the loan contract) and other issues connected to the agency costs (asymmetric information, incomplete collateralization) also decrease investment due to the uncertainty that arises in the economy.

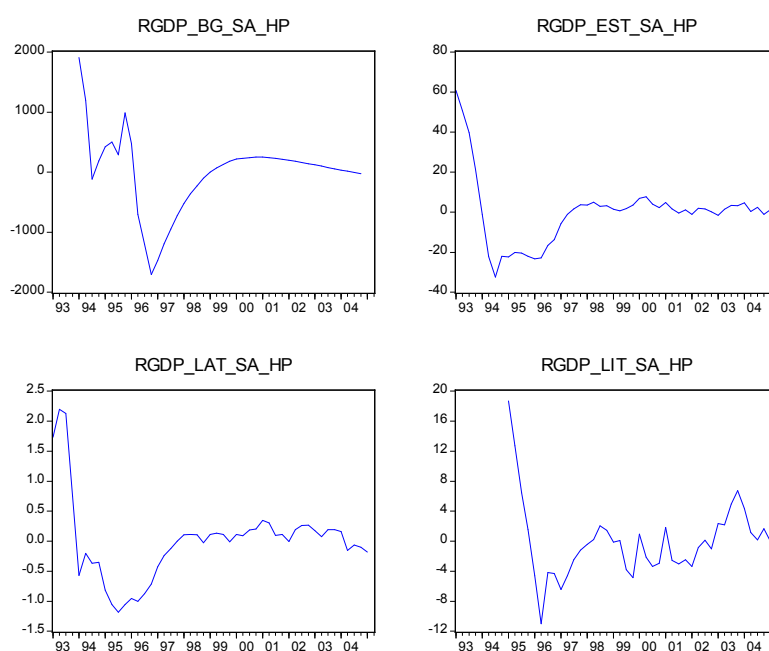
Indeed, the clusters mentioned at the beginning of the chapter overlap to a certain extent. Yet, there is a need for greater cohesion, a centripetal force to bring the two streams in the literature closer together, and to re-establish the link between banking and productivity in the transition context of Bulgaria and the Baltic countries. We take the best of the two worlds and combine them in pursuit of the answer to the output fall during the transition in Bulgaria and the Baltic countries. We start with a general theory in order to get the broad picture and then match our theoretical results with empirical facts. As noted, the literature in the field necessitates the use of a general equilibrium model, from which TFP will be estimated in order to see the effect of productivity on output. We will compare the movement in the TFP with the timing of reforms to see which factor could be not only a good explanation, but also to match the time of implementation. In this way we also show that RBC is a useful tool for studying the transition countries as well and to establish an unexploited niche in the field. In

the next section, before we presenting the model, some background information on the Bulgarian and Baltic economies is provided.

## ECONOMIC OVERVIEW OF BULGARIA AND THE BALTIC COUNTRIES

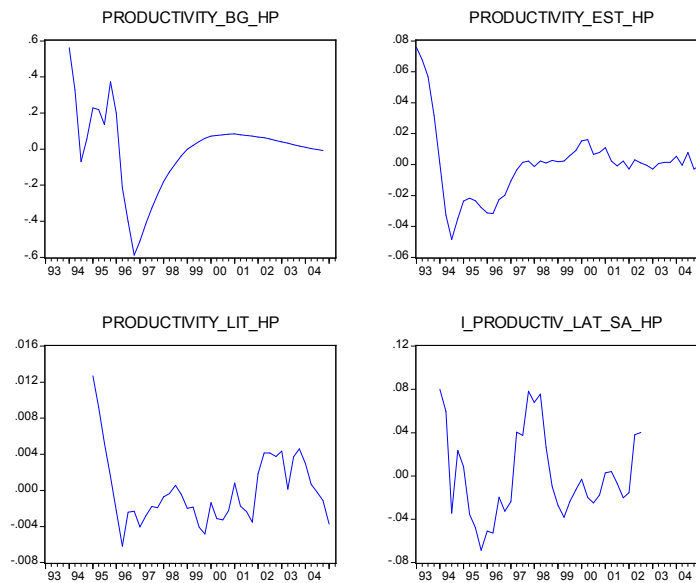
Both the Baltic countries and Bulgaria were connected to the Soviet Union: Estonia, Lithuania and Latvia being part of the Russian Federation, while Bulgaria played the role of a satellite country. Heavy industry, especially that of the Bulgarian economy, was complementary to that of the Soviet Union. After the breakup of the Soviet Union in 1989, all countries faced a common external shock, which was the movement to the market economy and the world market prices of their tradables. Fig.1 below shows the rapid collapse in the beginning and then the slow recovery.

**Fig.1 Cyclical fluctuations of Real GDP, 1993-2005**



When we compare this to the productivity cycle (see Fig.2 on the next page), we note that the cycle follows that of real output, shown in Fig.1, very closely. The only exception is Latvia because we use industrial productivity due to data limitations. (Industrial productivity cycle, however, tracks the one of industrial production.)

**Fig.2 Productivity fluctuations, 1993-2005**



Romer (2001) also notes that “productivity - output per worker-hour - almost always declines during recessions” (171) and that fluctuations are distributed very unevenly over the components of output. Our case it seems to be a productivity story as well. Thus reforms that affect TFP directly will have a better explanatory power.

To get the whole picture, however, we should also discuss the four principle GDP components: consumption, investment, government purchases and net exports (see appendix A1.1). The first factor, consumption, is highly volatile. This fact cannot be attributed solely to transformation and IMF stabilization programs. Consumption spending proportional to the size of the economy is highest in Bulgaria - about 70-80% of GDP. An important component of consumer spending in all the four countries in our study is considered to be imported durables from the West. In addition, as noted by Benczur and Ratfai (2005) consumption habits are strong, and savings “for a rainy day” are in hard currency.

The second component, investment, also fluctuates a great deal (see appendix A1.1 for all macroeconomic indicators) due to the transformation in the economy: old plants are scrapped, new plants are opened, foreign direct investment (FDI) and capital inflows are attracted. During this process, government purchases are curtailed at the expense of the rapid expansion of the private sector. At the same time fiscal balances are put in order, and budgetary items switch categories to reflect Western accounting standards. Government spending diminishes in size compared to the economy, but governments themselves do not decrease in importance as the agent setting the rules of the market game. In addition, all the economies are small, and take international prices as given. After the fix, these countries saw their currencies appreciating in real terms. Another common feature is that all the countries have significant trade and current account (CA) deficits, mostly due to the catching-up process and the capital inflows. It is important to note as well the widespread weaknesses in the banking system (especially regulations and bankruptcy procedures) in the early 90s.

The economic overview of Bulgaria and the Baltic countries demonstrates that all four countries show a sufficient degree of similarity. This justifies a more abstract level of analysis, an approach to be pursued using a general-equilibrium model. A formal description of the model follows in the next chapter.

## MODEL DESCRIPTION

In this section a simplified picture of the economy is presented, following the reasoning provided by King et al. (1988). Their basic RBC model will be used in order to try to explain what we observe in the data. Model predictions will then be compared to the fluctuations in the data and conclusions based on the reading from economic history will be drawn, principally that productivity and banking regulations explain a great deal of the fall in output in Bulgaria and the Baltic countries during the 1993-2005 period.

All agents in the theoretical economy are assumed to be identical, and thus can be thought of as a dynasty that is living infinitely. In addition, due to the symmetry principle applied, we can focus on just one agent, or household, and later generalize the results for the whole population. Each relationship in the economy is specified in a separate sub-section. After the model is solved, a first-order Taylor approximation is used to linearize around the steady-state and examine the cyclical fluctuations.

### 1.1 Preferences

Preferences of an infinitely-living household are represented by the following utility function

$$U = \sum_{t=0}^{\infty} \beta^t u(C_t, L_t), \quad 0 < \beta < 1 \quad (1)$$

where  $u$  has a constant elasticity of substitution with respect to consumption and leisure

$$u(C_t, L_t) = \frac{1}{1-\sigma} C_t^{1-\sigma} v(L_t) \quad (2)$$

and  $C_t$  and  $L_t$  denote consumption and leisure, respectively, in period  $t$ . The function  $u(C_t, L_t)$  is assumed to be strictly increasing, concave, twice continuously differentiable and

to satisfy Inada conditions<sup>1</sup>, which ensure interior solution (if feasible). For the calibration, a logarithmic specification will be used (the case when  $\sigma = 1$ )

## 1.2 Technology

There is one homogenous good in the economy, which is produced according to the following technology

$$Y_t = A_t K_t^{1-\alpha} (N_t X_t)^\alpha \quad (3)$$

The production function features constant returns to scale. In addition, it is concave, twice continuously differentiable and satisfies the Inada conditions. The labor-augmenting technology is needed for the model to achieve a steady-state: in equilibrium, the steady-state growth of the labor force is zero.

## 1.3 Capital Accumulation

The goods produced in each period can be either invested or consumed. Physical capital depreciates at a constant rate  $\delta$ , and the following equation of motion always holds true:

$$K_{t+1} = I_t + (1 - \delta)K_t \quad (4)$$

In this paper, the definition for investment by Benczur and Ratfai (2005) will be used. Those authors only gross capital formation because the change in inventories is too small to be of importance.

---

<sup>1</sup>  $\lim_{C_t \rightarrow 0} \frac{\partial U(C_t, L_t)}{\partial C_t} = \infty$ ,  $\lim_{C_t \rightarrow \infty} \frac{\partial U(C_t, L_t)}{\partial C_t} = 0$ ,  $\lim_{L_t \rightarrow 0} \frac{\partial U(C_t, L_t)}{\partial L_t} = \infty$ ,  $\lim_{L_t \rightarrow \infty} \frac{\partial U(C_t, L_t)}{\partial L_t} = 0$



## 1.4 Resource constraints

There are two constraints that hold in each period:

- The time devoted to work and that used for leisure activities equal to the time endowment, here normalized to unity.

$$L_t + N_t = 1 \quad (5)$$

- Consumption and investment must not exceed output

$$C_t + I_t \leq Y_t \quad (6)$$

## 1.5 Steady State

Having the necessary concavity conditions, we can use the second welfare theorem and solve the central planner problem as one of a decentralized economy and find the competitive solution. In order to obtain an economy that achieves a steady state, all variables

must be written in efficiency units, e.g.  $c = \frac{C}{X}$ ,  $k = \frac{K}{X}$ ,  $i = \frac{I}{X}$ , etc. The utility function,

technology and the two resource constraints are reformulated in efficiency variables. The labor-augmenting technical progress is assumed to have a constant growth rate, expressed as

$$X_t = e^{(\gamma-1)t}, \text{ where } \gamma \geq 1 \quad (7)$$

Thus we obtain the expressions below for the utility function, the production function, the state equation for capital and the income-expenditure constraint, respectively,

$$U = \sum_{t=0}^{\infty} (\beta^*)^t \frac{1}{1-\sigma} c_t^{1-\sigma} v(L_t) \quad (8)$$

$$y_t = A_t k_t^{1-\alpha} N_t^\alpha \quad (9)$$

$$\gamma k_{t+1} = i_t + (1-\delta)k_t \quad (10)$$

$$y_t \geq i_t + c_t \quad (11)$$

where  $\beta^* = \beta\gamma^{1-\sigma}$ . The Lagrangean associated with the optimization problem of interest is

$$\mathcal{L} = \sum_{t=0}^{\infty} (\beta^*)^t \left\{ \frac{1}{1-\sigma} c_t^{1-\sigma} v(1-N_t) + \lambda_t \left[ A_t k_t^{1-\alpha} N_t^\alpha - c_t + (1-\delta)k_t - \gamma k_{t+1} \right] \right\} \quad (12)$$

The representative household chooses  $c_t, N_t, k_{t+1}$ . The First-Order Conditions (FOCs) together with the income-expenditure constraint and the transversality condition (TVC) for capital are as follows:

$$c_t^{-\sigma} v(1-N_t) - \lambda_t = 0 \quad (13)$$

$$-\frac{1}{1-\sigma} c_t^{1-\sigma} v'(1-N_t) + \alpha \lambda_t A_t \left( \frac{k_t}{N_t} \right)^{1-\alpha} = 0 \quad (14)$$

$$-\lambda_t \gamma + \beta^* \lambda_{t+1} \left[ A_{t+1} \left( \frac{N_{t+1}}{k_{t+1}} \right)^\alpha + (1-\delta) \right] = 0 \quad (15)$$

$$A_t k_t^{1-\alpha} N_t^\alpha - c_t + (1-\delta)k_t - \gamma k_{t+1} = 0 \quad (16)$$

$$\lim_{t \rightarrow \infty} (\beta^*)^t \lambda_t k_{t+1} = 0 \quad (17)$$

## 1.6 Steady-state Dynamics

In order to obtain the quantitative impact of changes in  $A_t$ , we linearize the FOC equations (13)-(16) around the steady state with respect to  $A, k, N, c, y$ . All those variables are expressed as percentage deviations from the steady state, e.g.

$$\hat{c}_t = \ln \frac{c_t}{c} = \frac{c_t - c}{c} \quad (18)$$

Using the log-linearization technique as described by King et al. (2002), Campbell (1994) and Uhlig (1999) we obtain the following equations

$$\zeta_{cc} \hat{c}_t - \zeta_{cl} \frac{N^{ss}}{1-N^{ss}} - \hat{\lambda}_t = 0 \quad (19)$$

$$\zeta_{lc} \hat{c}_t - \zeta_{ll} \frac{N^{ss}}{1-N^{ss}} \hat{N}_t - \hat{\lambda}_t - \hat{A}_t - (1-\alpha)\hat{k}_t + (1-\alpha)\hat{N}_t = 0 \quad (20)$$

$$\lambda_{t+1} + \eta_A \hat{A}_{t+1} + \eta_k \hat{k}_{t+1} + \eta_N \hat{N}_{t+1} = \hat{\lambda}_t \quad (21)$$

$$\hat{y}_t = \hat{A}_t + \alpha \hat{N}_t + (1 - \alpha) \hat{k}_t = s_c \hat{c}_t + s_i \Phi \hat{k}_{t+1} - s_i (\Phi - 1) \hat{k}_t \quad (22)$$

where  $\zeta_{ab} = \frac{d \ln u_a}{d \ln b}$  is the elasticity of marginal utility of  $a$  with respect to  $b$ . For the Cobb-

Douglas technology  $\eta_A = \frac{\gamma - \beta(1 - \delta)}{\gamma}$ ,  $\eta_k = -\alpha \eta_A$ ,  $s_i = (1 - \alpha) \frac{\gamma + \delta - 1}{r + \delta}$  and  $s_c$  are shares of

investment and consumption in output ( $s_c + s_i = 1$ ),  $\Phi = \frac{\gamma}{\gamma - (1 - \delta)}$

In order to find the dynamics of the capital formation, a system of two first-order difference equations in  $\hat{\lambda}_t$  and  $\hat{k}_t$ , which are obtained from eq. (19), (20) and (22):

$$\begin{pmatrix} \hat{k}_{t+1} \\ \hat{\lambda}_{t+1} \end{pmatrix} = W \begin{pmatrix} \hat{k}_t \\ \hat{\lambda}_t \end{pmatrix} + R \hat{A}_{t+1} + Q \hat{A}_t \quad (23)$$

The system has a general solution in the form

$$x_{t+1} = W x_t + v_t \quad (24)$$

With the initial state  $x_0$  given and  $v_t$  specified, the expression above may be rewritten as

$$x_t = W^t x_0 - \sum_{j=0}^{t-1} W^{t-j-1} v_{t+j} \quad (25)$$

To satisfy the TVC condition we choose  $\lambda_0$  in such a way so that  $W x_0 = \mu_1 x_0$ , where  $\mu_1$  is the smaller of the two eigenvalues of  $W$ . Equation (25) can then be rewritten as

$$x_t = \mu_1 x_0 - \sum_{j=0}^{t-1} W^{t-j-1} v_{t+j} \quad (26)$$

Plugging that back into the expression for  $x_{t+1}$  we obtain

$$x_{t+1} = \mu_1 x_0 - \sum_{j=0}^t W^{t-j} v_{t+j} + \mu_1 \sum_{j=0}^t W^{t-j-1} v_{t+j} = \mu_1 x_t + \mu_1 W^{-1} v_t + \sum_{j=0}^t (\mu_1 W^{-1} - I) v_{t+1+j} =$$

$$\begin{aligned}
&= \mu_1 x_t + \mu_1 W^{-1} v_t + P \begin{pmatrix} 0 & 0 \\ 0 & 1 \end{pmatrix} P^{-1} \left( \frac{\mu_1}{\mu_2} - 1 \right) \sum_{j=0}^{\infty} \mu_2^{-j-1} v_{t+1=j} = \\
&= \mu_1 x_t + B_1 v_t + B_2 \sum_{j=0}^{\infty} \mu_2^{-j-1} v_{t+1=j} \tag{27}
\end{aligned}$$

The columns of matrix P are formed by the eigenvectors of matrix W

$$W = P \begin{pmatrix} \mu_1 & 0 \\ 0 & \mu_2 \end{pmatrix} P^{-1} \tag{28}$$

The solution equation (27) allows us to decide on the capital stock in the next period based on the capital stock in the current period and the current and future values of the TFP  $\hat{A}_t$ .

$$\hat{k}_{t+1} = \mu_1 \hat{k}_t + \psi_1 \hat{A}_t + \psi_2 \sum_{j=0}^{\infty} \mu_2^{-j} \hat{A}_{t+1+j} \tag{29}$$

where the expressions for  $\psi_1, \psi_2$  can be derived from eq.(28).

## 2 Real Business Cycles

Now we remove the assumption of perfect foresight and introduce a stochastic shock guiding the TFP behavior.

### 2.1 Linear RBC Model

The starting equation is (29), which describes the path of capital formation. Then a particular stochastic process for  $\hat{A}_t$  is specified, in this case AR(1) with a coefficient of persistence  $\rho$ , and replace  $\hat{A}_{t+j}$  with their expected values given information at time t. The dynamics of the state variables  $\hat{k}_t, \hat{A}_t$  is then given by the linear system

$$s_{t+1} = \begin{pmatrix} \hat{k}_{t+1} \\ \hat{A}_{t+1} \end{pmatrix} = \begin{pmatrix} \mu_1 & \pi_{kA} \\ 0 & \rho \end{pmatrix} \begin{pmatrix} \hat{k}_t \\ \hat{A}_t \end{pmatrix} + \begin{pmatrix} 0 \\ \varepsilon_{A,t+1} \end{pmatrix} = Ms_t + \varepsilon_{t+1} \tag{30}$$

The other linear equations specify how consumption, efficient labor, investment and output depend on the state-variable vector  $s_t$ . Those equations are derived from (19)-(22) and also using (30). In vector form, they stand as follows

$$z_t = \begin{pmatrix} \hat{c}_t \\ \hat{N}_t \\ \hat{y}_t \\ \hat{i}_t \end{pmatrix} = \begin{pmatrix} \pi_{ck} & \pi_{cA} \\ \pi_{Nk} & \pi_{NA} \\ \pi_{yk} & \pi_{yA} \\ \pi_{ik} & \pi_{iA} \end{pmatrix} \begin{pmatrix} \hat{k}_t \\ \hat{A}_t \end{pmatrix} = \Pi s_t \quad (31)$$

## 2.2 Population Moments

The formulation above facilitates the calculation of population moments once we know the variance-covariance matrix  $\sum_{tt}$  or the state vector  $s_t$ .

$$\text{var}(x_{t+j} x_t^T) = M^j \sum_{tt} \quad (32)$$

$$\text{var}(z_{t+j} x_t^T) = \Pi M^j \sum_{tt} \quad (33)$$

It is easy to verify that

$$\sum_{11} = \text{var}(\hat{A}_t) = \frac{\sigma^2}{1 - \rho^2} \quad (36)$$

$$\sum_{22} = \text{var}(\hat{k}_t) = \frac{\pi_{kA}^2 \sigma^2}{(\rho - \mu_1)^2} \left( \frac{\rho^2}{1 - \rho^2} + \frac{\mu_1^2}{1 - \mu_1^2} - \frac{2\mu_1\rho}{1 - \mu_1\rho} \right) \quad (37)$$

$$\sum_{12} = \sum_{21} = \text{cov}(\hat{A}_t, \hat{k}_t) = \frac{\pi_{kA}^2 \sigma^2}{\rho - \mu_1} \left( \frac{\rho^2}{1 - \rho^2} - \frac{\mu_1}{1 - \mu_1\rho} \right) \quad (38)$$

## 2.3 Parameterization of the Model

Calibration approach, pioneered by Kydland and Prescott (1982) will be used when solving the model. Parameters of the model were estimated using quarterly data for Bulgarian and the Baltic countries. Data series are taken from Benczur and Ratfai's (2005) dataset.

### 2.3.1 Labor Share in Output

Kydland and Zarazaga (2002) recommend that a higher value be chosen for the calibration because labor share is likely to be measured low because it does not take into account self-employed and those engaged in family enterprises or in the shadow economy. In this paper, however, an estimate from the series generated by Ganev (2005) will be used, with standard errors in brackets:

$$\hat{\alpha}_{BG} = 0.43 (0.07) \quad (37)$$

### 3.3.2 Depreciation

A linear depreciation scheme will be used, where

$$\delta = \frac{I_t - (K_{t+1} - K_t)}{K_t} \quad (38)$$

Ganev (2005) finds it to be 0.05 for Bulgaria. We will use the same depreciation rate for all the four countries because we assume the same production technology being available everywhere.

### 3.3.3 Hours

The variable number of hours worked was not reported in the data set used. As there are no observations to determine both hours and stationary hours  $N^{ss}$ , we set them to 0.4, as done in Cerny and Lazarova (1994) for Czechoslovakia. This corresponds to a 9-hour working day, which is a reasonable assumption, given the fact that working hours are fixed during the period. Here we implicitly make use of Hansen's (1985) *indivisible labor* idea that workers are working either fixed number of hours or zero, and total hours depend on

employment only. In addition, Cooley and Prescott (1995) also do not differentiate between total hours and employment in their model.

### 3.3.4 Growth

On the balanced growth path all variables grow at a constant rate  $\gamma - 1$ , that is

$$\ln Y_t = \ln y_t + (\gamma - 1)t = \ln \bar{y}_t + \hat{y}_t + (\gamma - 1)t \quad (39)$$

$$\ln C_t = \ln c_t + (\gamma - 1)t = \ln \bar{c}_t + \hat{c}_t + (\gamma - 1)t$$

$$\ln I_t = \ln i_t + (\gamma - 1)t = \ln \bar{i}_t + \hat{i}_t + (\gamma - 1)t$$

$$\ln K_t = \ln k_t + (\gamma - 1)t = \ln \bar{k}_t + \hat{k}_t + (\gamma - 1)t$$

Output, consumption, investment and capital are regressed on a common time trend and independent constant terms in order to obtain an estimate for  $\gamma - 1$ :

$$\begin{array}{cccc} \hat{\gamma}_{BG} - 1 = 0.005, & \hat{\gamma}_{EST} - 1 = 0.013, & \hat{\gamma}_{LAT} - 1 = 0.0133, & \hat{\gamma}_{LIT} - 1 = 0.0129 \\ (0.001) & (0.0005) & (0.0009) & (0.0009) \end{array}$$

It is not surprising that estimates show a common trend growth rate for the Baltic countries, a fact which we utilize in the calibration process later on.

### 3.3.4 TFP

TFP was calculated using the definition in Benczur and Ratfai (2005). Since there is not much variation in capital due to the deterministic nature of the estimated series, Solow residuals will follow closely the movement in labor productivity, obtained as a ratio of GDP and employment. Seasonally adjusted and de-trended productivity series were then tested for stationarity using the standard Dickey-Fuller test. At 1% level of significance we rejected the presence of a unit root. Then we regresses  $\hat{A}_t$ , HP- detrended on its lagged value, assuming

productivity follows an AR (1) process<sup>2</sup>. The coefficient in front of the lagged term measures persistence (standard errors reported in brackets). In addition, the variance of the shock was calculated from the residuals of the regression, and is assumed to be normally distributed.

$$\hat{A}_t = \alpha + \rho \hat{A}_{t-1} + u_t$$

$$\hat{\rho}_{BG} = 0.76 (0.08), \text{ s.d}(\hat{u}_t)_{BG} = 0.11011$$

$$\hat{\rho}_{EST} = 0.56 (0.05), \text{ s.d}(\hat{u}_t)_{EST} = 0.00831$$

$$\hat{\rho}_{LAT} = 0.49 (0.12), \text{ s.d}(\hat{u}_t)_{LAT} = 0.001991$$

$$\hat{\rho}_{LIT} = 0.59 (0.08), \text{ s.d}(\hat{u}_t)_{LIT} = 0.027727$$

Persistence measures for the productivity shock is quite similar among the Baltic countries, in the range 0.49-0.59, while Bulgaria has a much higher estimate – 0.76, together with the highest volatility in the shock process.

### 3.4 Calibration

Below are provided the calibration parameters and steady-state values, which are divided in two groups, those for Bulgaria and another set for the Baltic countries. That particular division was necessitated by the great similarity in terms of economic performance in Estonia, Latvia and Lithuania. To solve the model, we use the Morten Ravn's GAUSS code for the model by King et al. (1988).

Parameters	Bulgaria	Baltic countries
Labor share $\alpha$	0.43	0.43
Share of time allocated to work $N$	0.4	0.4
Growth rate of TFP $\gamma$	1.005	1.013
Real interest rate $r$	0.065/4=0.015	0.065/4=0.015
Depreciation rate $\delta$	0.05	0.05
Persistence of TFP shock $\rho$	0.76	0.56
Standard deviation of TFP shock	0.11011	0.00831
Discount factor $\beta^* = \beta\gamma^{1-\sigma}$	0.989	0.989
Elasticity of MU of consumption $\sigma$	1	1

<sup>2</sup> The regression for Latvia was run for industrial productivity only due to data limitations.



Steady-state values	Bulgaria	Baltics
$A^{ss}$	10	10
$Y^{ss}$	1467.735	1467.7352
$C^{ss}$	733.192	672.1673
$K^{ss}$	12628.061	12628.0611
$I^{ss}$	694.543	795.5678
$K^{ss} / Y^{ss}$	8.6038	8.6038
$W = AP^{ss} = Y^{ss} / N$	3669.338	3669.3379

A peculiarity of the model is that it predicts too high capital-output ratio of around 8.6. That art effect, however, can be explained with the excessive capital accumulation during the central planning era and low utilization of machines at the same time. In Bulgaria, the ratio is above 3.5, while for a typical market economy it is around 3.

### 3.5 Stochastic Simulation

Two simulation of the model was done with 500 experiments and a horizon of 50 observations in order to correspond to the time span in the data. One of the specifications was calibrated using data for Bulgaria, and the other corresponds to the Baltic countries. The latter is named after Estonia in the paper because Estonian data for the technology shock was used in this simulation. Then the predicted results are compared to the estimates in Benczur and Ratfai (2005) in the tables 1-6 below.

**Table 1: GDP**

	GDP volatility	Autocorrelation
<b>Bulgaria</b>	4.2	0.66
<b>Estonia</b>	2.46	0.67
<b>Latvia</b>	1.89	0.65
<b>Lithuania</b>	2.53	0.56
<b>Model EST</b>	1.1027 (0.1434)	0.375(0.1343)
<b>Model BG</b>	0.2827 (0.0454)	0.5478 (0.1257)

GDP volatility is measured as the standard deviation of GDP.  
Autocorrelation is measured as the AR (1) coefficient in the series.

**Table 2: Consumption (C)**

	BG	EST	LAT	LIT	Model EST	Model BG
<b>Abs. Volatility</b> <sup>1</sup>	5.48	3.41	2.38	2.45	0.1406(0.0194)	0.0669 (0.0177)
<b>Rel. Volatility</b> <sup>2</sup>	1.30	1.38	1.39	0.97	0.1275(0.0045)	0.2346 (0.0385)
<b>Cyclicalit</b> <sup>3</sup>	0.78	0.60	0.22	0.26	0.9155(0.0314)	0.6438 (0.0490)
<b>Persistence</b> <sup>4</sup>	0.56	<b>0.65</b>	0.18	0.28	<b>0.4379</b> (0.1337)	0.8355 (0.0725)

**Table 3: Investment (I)**

	BG	EST	LAT	LIT	Model EST	Model BG
<b>Abs. Volatility</b>	14.36	12.37	10.45	9.39	1.9272(0.2516)	0.553 (0.0872)
<b>Rel. Volatility</b>	3.42	5.02	6.12	3.71	1.7475(0.0064)	1.9568 (0.0217)
<b>Cyclicalit</b>	0.39	0.69	0.20	0.72	0.9997(0.0064)	0.9945 (0.0022)
<b>Persistence</b>	0.45	<b>0.37</b>	0.09	0.62	<b>0.3763</b> (0.1343)	<b>0.5328</b> (0.1268)

**Table 4: Employment (N)**

	BG	EST	LAT	LIT	Model EST	Model BG
<b>Abs. Volatility</b>	4.56	1.32	3.29	2.15	0.5855(0.0764)	0.1473 (0.0230)
<b>Rel. Volatility</b>	1.09	<b>0.54</b>	1.74	0.85	<b>0.5309</b> (0.0021)	0.5216 (0.0094)
<b>Cyclicalit</b>	-0.17	0.47	0.63	0.13	0.9983(0.0007)	0.9773 (0.0094)
<b>Persistence</b>	0.87	0.75	0.84	0.68	0.3793(0.1341)	0.5254 (0.1275)

**Table 5: Technological productivity<sup>5</sup> (A)**

	BG	EST	LAT	LIT	Model EST	Model BG
<b>Abs. Volatility</b>	6.71	2.18	3.08	3.10	0.8423(0.1098)	0.2203 (0.0346)
<b>Rel. Volatility</b>	1.60	0.89	1.74	1.22	0.7638(0.002)	0.7797 (0.011)
<b>Cyclicalit</b>	0.74	0.84	0.42	0.73	0.9992(0.0003)	0.9903 (0.0039)
<b>Persistence</b>	0.76	<b>0.56</b>	<b>0.49</b>	<b>0.59</b>	0.3776(0.1342)	<b>0.5295</b> (0.127)

**Table 6: Real Wages**

	BG	EST	LAT	LIT	Model EST	Model BG
<b>Abs. Volatility</b>	7.64	2.41	3.45	6.16	0.5193(0.0674)	0.1422 (0.0248)
<b>Rel. Volatility</b>	1.82	0.98	1.83	2.43	0.4709(0.0021)	0.5021 (0.0166)
<b>Cyclicalit</b>	0.57	0	0.23	0.45	0.9978(0.0009)	0.9762 (0.0072)
<b>Persistence</b>	<b>0.64</b>	-0.01	0.73	0.77	0.3743(0.1343)	<b>0.6269</b> (0.1222)

Data Source: Benczur and Rattfai (2005), author's estimates

Notes: All data is at quarterly frequency, seasonally adjusted and de-trended using HP filter.

1. Absolute Volatility is measured as the standard deviation of the series
2. Relative Volatility is measured as the ratio of the standard deviation of the series of the variable of interest and real GDP
3. Cyclicalit is measured as the contemporaneous correlation between the variable and real GDP.
4. Persistence is measured as the AR(1) coefficient in the series
5. Productivity measure in the data corresponds more to the real wage in the model, as it is defined as output/labor hours. By no means it is claimed that the definition for productivity used in this paper, as well as in Romer (2001) and Benczur and Rattfai (2005) captures the whole effect of the TFP. No matter which of the two measures we use, however, the results obtained are qualitatively identical.

Both model specifications generally under-predict the absolute and relative volatilities of the variables in the data but that is a typical feature of such simple models, e.g. Cooley and Prescott (1995). The only exclusion is the relative volatility of employment for the Estonian model. In addition, the model calibrated for Estonia tends to over-predict cyclical measures and under-predict persistence estimates, with the exception of investment persistence, which is an exact match. Despite this particular deficiency of the model, actual persistence values fall within two standard deviations from the simulated ones and thus are considered to be statistically close to that of the model.

The model for Bulgaria gets closer estimates, although it overestimates the cyclical parts as well. The model performs much better with persistence measures: it over-predicts the measure for consumption, but gets a close match for investment and real wages, and a value in the 99% confidence interval for output autocorrelation and persistence measures for employment and technology shock.

At first sight, the model in its two specifications does not seem to be an effective one. Some important limitations of the analysis should be noted, however. The model is extremely simplistic: Our model does not have a government sector and there is no external sector or money, which is a somewhat restrictive framework. In addition, we use quarterly data for ten years and the model has a horizon of 50 observations. This may be too short a period for long-term tendencies to show up in the model. Cerny and Lazarova (1994) obtain similar results for Czechoslovakia when they use annual data for 1948-1983 period. Their explanation lies in the fact that central planning is not well described by a RBC model. In our case, the countries undertook serious transformation throughout the period and were not considered as market economies until towards the end of the period. The transition countries

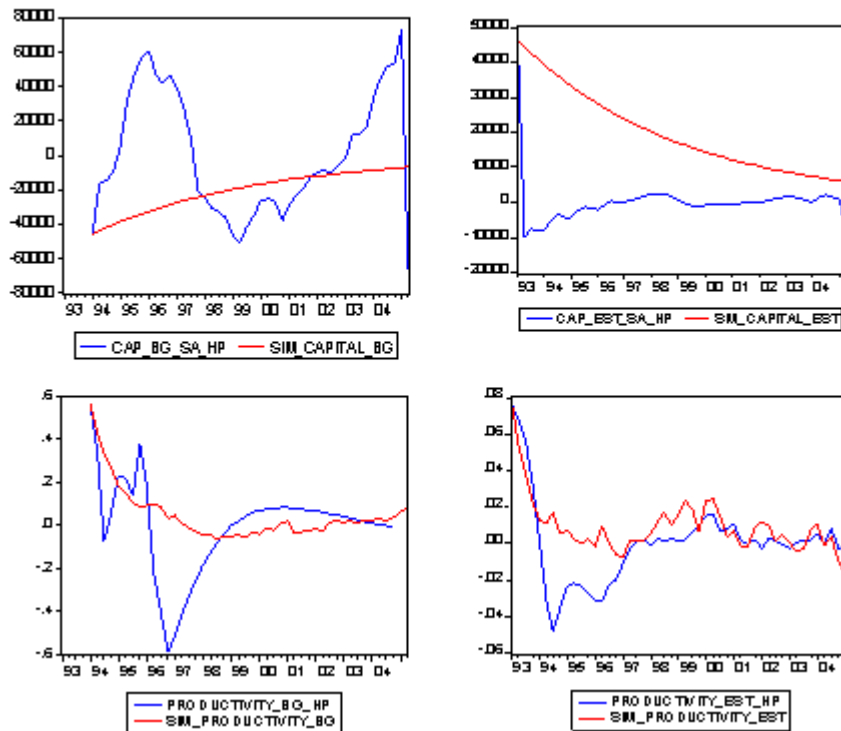
are likely to be off the balanced-growth path. The assumption of the same technology and preferences may not hold: the utility function may not be logarithmic and capital and labor markets are far from perfect in the countries we investigate. Employment, for example, is still not entirely market-based during the period with a high public sector and too much administrative staff. In addition, there were privatization deals that had clauses for preserving the levels of employment. Data limitation is also an issue, since industrial employment was used for Latvia, which is a very crude estimate.

The model, however, performs quite well in tracking the cyclical path of capital and productivity<sup>3</sup>. That is the great achievement of the RBC model, where all variables are driven by productivity shocks. The financial crisis episode in Bulgaria in 1996-97 is not captured by the model, though. This, however, cannot be blamed on the model, as this crisis period was an outlier event. Figure 3 on the next page shows the match of simulated and actual series of capital and productivity cycles.

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<sup>3</sup> Both empirical and model data are H-P filtered, as in Kydland and Prescott (1982).

**Fig.3 Cyclical fluctuations of actual vs simulated capital and productivity**



The explanation why the simulated capital series do not closely follow the cycle in the data is due to the assumption that capital stock is zero before the period. This seems to be a strict assumption, as demonstrated by Fig.3 above. However, the same problem with capital is noted by Cerny and Lazarova (1994) in their RBC study on Czechoslovakia. The conflict between theory and data may be due to the linear depreciation scheme used to estimate capital series. This is in line with Doms and Dunne's (1998) study, which shows that depreciation in US plants features important non-linearities.

In conclusion, both specifications generally capture the cyclical effects and persistence measures and this is an important contribution to the literature. In addition, the overall poor fit is a general phenomenon in the RBC literature: King et al (1988) admit that in order for a neoclassical RBC model to match data well, the productivity shock should be highly persistent, with an autocorrelation coefficient of the order of 0.95-0.99. In this way the dynamics of output are almost entirely determined by the persistence of the shock. Moreover,

in their analysis the authors do not use HP-filtered series. Thus, in the appendix A2, we perform a sensitivity analysis for both specifications by taking the autocorrelation coefficient to be 0.95 as in King et al. (1988). It does not provide qualitatively different results, though.

As we have demonstrated in this chapter, the basic RBC model fits the facts in Bulgaria and the Baltic countries quite well, given its oversimplified structure. This shows that neoclassical models have a great potential in researching business cycles in transition economies. In the next section, we connect model predictions with particular events in the countries of interest during 1993-2005.

## **PREDICTIONS OF THE THEORETICAL MODEL IN LIGHT OF THE ECONOMIC HISTORY IN BULGARIA AND THE BALTIC COUNTRIES**

After the completion of the technical exercise, we go back to data once again in order to do a reading of economic history in Bulgaria and the Baltic countries in light of the evidence from the model. Below we provide some stories, following the structure proposed by Bergoing et al. (2002). Following their argument, the paper focuses particularly on monetary aggregates, real wages, trade, foreign debt and structural reforms.

### **Standard Monetarist Story**

One of the frequently prescribed medicines for a country in a recession is to expand its money supply in the short to medium-term (because in the long-run that monetary expansion is going to cause hyperinflation) in order to speed up recovery. This was a common story for the Great Depression, as noted by Bergoing et al. (2002). There is ample evidence (Friedman and Schwarz (1963), Bernanke (1995), Bernanke and James (1990)) that countries that abolished the gold standard and increased their money supply recovered much of their lost output. One could argue that almost all central bankers in Central and Eastern Europe in the beginning of the transition process were monetarists, since they applied the approach advocated by this school of economic thought.

There are plenty of reasons, however, why this story does not hold water in our case: The transition economies that pursued expansionary monetary policy featured “stagflation,” stagnation coupled with hyperinflation and not deflation in the US and Europe. This was because the countries that inflated to preserve employment, regained little or no output at the expense of unleashing the inflationary spiral. What is more, high inflation in transition

countries led to sharp drops in output growth over time. That was because former centrally-planned economies had its tax administration at a very early stage of development in the beginning of the transition. The usual way to finance budget deficits was to monetize them and collect the necessary funds through seigniorage. Inflation, as it is well-known in monetary economics, is the most distortionary tax of all, and has a detrimental effect on the subsequent growth – in Latin American countries this period of high inflation was regarded as “the lost years”. This particular experience, however, contradicts to a certain extent Cole and Ohanian’s (2001) claim that monetary shocks are not persistent.

The charts in the appendix A3 present data on the rates of growth of the M2 aggregate and inflation, measured as annual percentage change in money supply and CPI in Bulgaria and the Baltic countries. It should be noted, however, that three of the countries in our sample– Bulgaria (since April 1997), Estonia (June 1992) and Lithuania (April 1994) have currency board arrangements (CBA), while Latvia (1994) went for a fixed ER. Therefore, money supply in all those countries becomes an endogenous variable, a function of the capital flows into the country. In case of negative productivity shocks and/or capital outflows, CBA exacerbates the problem since the money supply will contract and make the recession at hand even bigger. The three Baltic countries went immediately for a fix after separating from Russia, while Bulgaria had a free float till 1997 due to lack of international reserves. Bulgaria also had a bad growth experience during the period 1991-1997, except for a feeble recovery in 1994-95 before the hyperinflation in 1996-97. The conjuncture changed dramatically for the better after the introduction of the CBA.

Another key feature of the Bulgarian economy during the 1989-1997 period was the high inflation. Mihov (2001) discusses several studies that investigated factors causing



inflation and found that monetary policy was not a statistically significant determinant of inflation: M2 monetary aggregate increased in BG by 500% while inflation rose by 1500%. Mihov's explanation of this unusual phenomenon was that the "policy actions undertaken by the Bulgarian central bank before 1997 lacked credibility and were not implemented in a timely manner"(p.404). This is in line with Sargent and Wallace's (1981) argument about the fiscal theory of price level and the *unpleasant monetarist arithmetic*. Their idea is that restrictive monetary policy in the present leads to inflation in the future if fiscal deficits balloon and they are financed by resorting to the printing press. Thus tight policy ex ante is unsustainable ex post and makes matters worse.

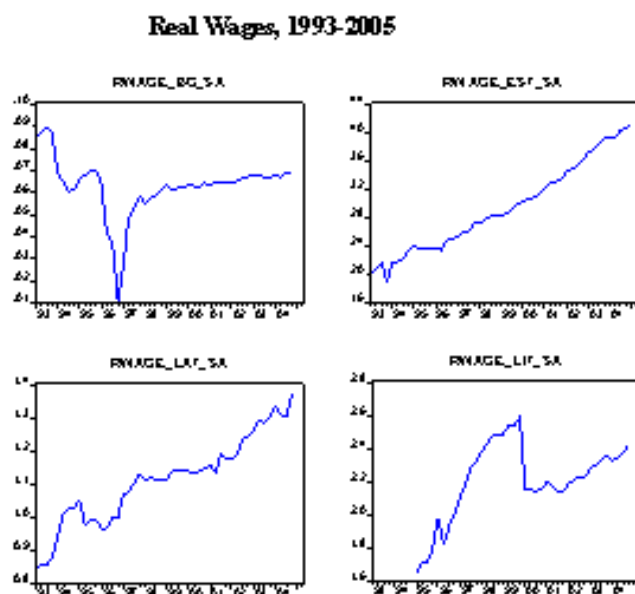
In conclusion, the monetarist story is to a great extent unable to explain the recovery of the countries in the sample. This does not mean, however, that monetary factors could contribute to the downturn of the economy. However, the fixed exchange rate regime may have interacted with the banking regulations. During the Great Depression, for example, the countries on the gold standard that were running trade deficits were forced to deflate. Actually, a fixed regime in the Baltic countries and Bulgaria established long-run low inflation credibility and led to higher growth and FDI. Banking regulations were improved, western accounting standards were implemented, a better screening process was put in place, and monetization of deficits was forbidden.

## Real Wage Story

Corbo and Fischer (qtd in Bergoeing et al. (2002)) propose that countries that discontinue backward-looking wage indexation recover very fast because as a result of that policy, real wages fall, which together with the depreciating exchange rate leads to export boom.

We do not see such an effect in the data, as shown in Fig.4 below, though. The only case when the real wage drops is in Bulgaria during the financial crisis in 1996-97, but that is the period when the trade surplus turns into deficit. Indeed, there were backward-indexation schemes of the nominal wages with the inflation in Bulgaria before 1996. As inflation decreased after the crisis, however, real wages increased.

Fig.4



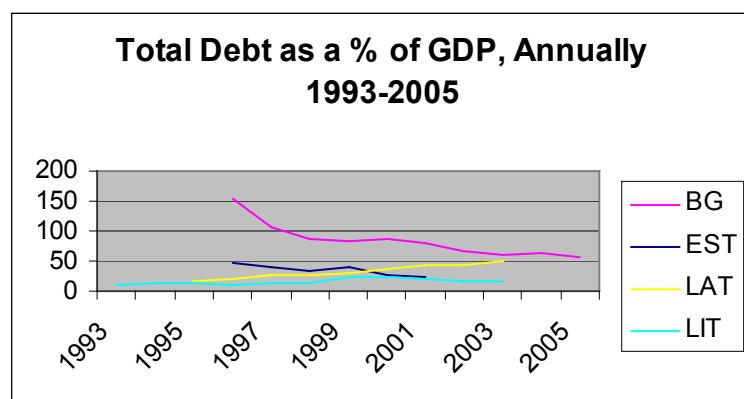
All the other countries have their real wages steadily increasing, with the broken trend in Lithuania being due to the change in the peg in 2000 from the US\$ to the Euro. Given the fact that in all the countries there are nominally fixed ER, a significant part of inflation in Estonia, due mainly to the Balassa-Samuelson effect and real convergence in the tradable

sector, led to an increase in the RER and the real wages. The result was widening of the trade deficit. Thus, we do not see the depreciating real ER story that would boost exports.

### Debt Overhang Story

In 1989, Bulgaria declared a moratorium on its foreign debt, and was effectively cut off from borrowing on the international capital markets. On the other hand, the Baltic countries had clean balance sheets when they separated from the Soviet Union. The reason behind this was that Russia took over their liabilities and committed to honor their debts. As seen in Fig.5 below, Baltic countries have levels of debt below 50% which are sustainable. Estonia and Lithuania, for example, have debt/GDP ratio below 10%.

**Fig.5**



Source: IFS

In our case Sachs' (1985) hypothesis of debt overhang is not true: there is no fear on the investor's side to be taxed heavily in the future as a way to generate revenue to pay back the debt. Just the opposite happened: FDI was attracted because of the stable currency and macroeconomic indicators, and future accession to the EU.

Only in the Bulgarian case were there some complications: after the Brady plan was put in place – Bulgarian Brady bonds were put as a mark of disgrace to warn investors that the country had been a bad borrower once in the past. Thus there was a need for debt restructuring once the economy started picking up. Brady bonds were swapped for Eurobonds in 2003 on a voluntary basis and that was done by the Ministry of Finance in order to show commitment to pay back, re-establish a good reputation, and get access to capital markets. In addition, some versions of the debt overhang story claim it is the public debt that matters and more specifically contingent liabilities such as bailing out of the banking sector in times of systematic distress.

**Fig.6**



Source: Benczur and Raffai (2005)

Fig.6 above shows a common drop in investment rates around the Russian crisis in 1998 and 2003 after the terrorist attacks in the US. Another cause for the ups and downs in investment in BG was due to the stop-go nature of structural reforms and the 2002-03 Kosovo crisis. This picture is consistent with Rostowski (1996), who claims that the fact the investment as a ratio to GDP did not fall that much is due to restructuring of the economy and change in the structure of demand.

## **Structural Reforms Story**

This story made the difference for some Latin American countries (see Bergoing et al. 2002) and served as a good explanation for the relatively better economic performance of Chile compared to Mexico in 1980-2000. Structural reforms notion unites reform packages in the spheres of trade and fiscal policy, as well as privatization, banking regulations and bankruptcy procedures. Of all the reforms, the ones that seem to have the biggest effect on the productivity, and their implementation to coincide with a recovery, are the banking regulations and bankruptcy procedures.

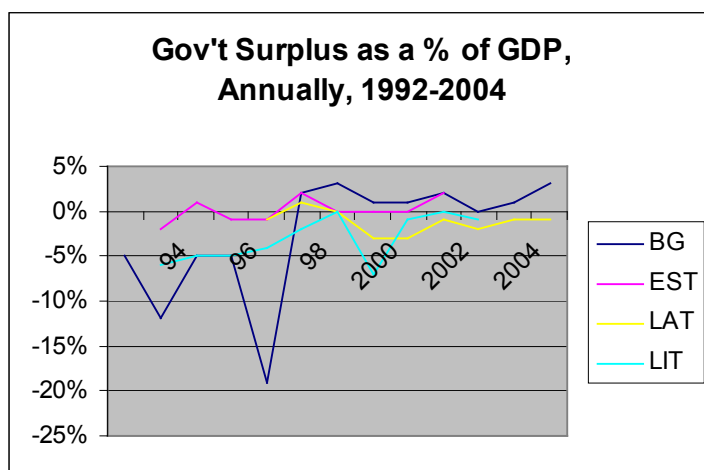
### *Trade Policy*

From the very beginning, the Baltic countries oriented themselves towards the EU, while Bulgaria was undecided whether to affiliate to Russia or to the Western Europe. Still, all countries went for large-scale trade liberalization and elimination of tariffs after recommendations by the World Trade Organization (WTO) and International Monetary Fund (IMF) missions. In addition, the Baltic countries used to trade with Russians metals, which were quoted at below market prices. Thus, there were good profit opportunities for exporting Baltic firms and banks, and the latter entered. But Russia also moved to world prices and the arbitrage opportunities decreased. Banks had to find other profitable lending opportunities to sustain their position. Through this channel a banking crisis had an effect on trade through trade credit arrangements and in this way put a strain on the budget.

## *Fiscal policy*

In theory, tax reforms have an effect on capital accumulation and real wages. Tax rates also influence the incentive to work, and high rates do not translate automatically into a higher fiscal revenue. The reason behind this was the absence of an efficient tax administration. Thus fiscal authorities in the transition countries decreased tax rates, which led to an increase in tax revenue. At the same time governments cut on unnecessary expenditures and slashed excess employment in public administration, and achieved an expansionary fiscal contraction (Kopits 1998). This is important because transition countries cannot pursue Keynesian policies since some of them have a large amount of debt already (Bulgaria). Moreover, in a fixed exchange rate regime fiscal policy is stronger but you cannot expand it in a traditional way because it will undermine the credibility of that hard peg (which happened in Argentina in 2002). There is also an important lag between implementation of changes in government policy and their effect on productivity. In our case, the relatively short time span may be unable to catch this effect.

**Fig.7**



*Source: IFS, Author's calculations*

Fig.7 above shows that most of the countries are running balanced budgets, or small surpluses, as required by law in Estonia. Indeed, all four countries were running significant

budget deficits during the banking crises: 5-6% in Lithuania in 1993-94, for example, and even reaching 19% in Bulgaria in 1996.

### *Privatization*

There are some measurement issues with this story: first, the different privatization programs in Bulgaria and the Baltic countries, which makes it hard to determine which one was the most successful. In addition, it is difficult to estimate the effect of privatization since there was a lot of “cherry-picking” on the investors’ side: that is, ex ante profitable companies were privatized first. Nevertheless, there is a consensus among economists that privatization leads to the establishment of a market relationship between firms and banks. It is also a way to deal with the bailing out problem: For the Baltics, for example, there was a common (mis)perception that banks are Russian-backed (Flemming and Talley, 1996). Thus privatization in the banking sector led to an opening of private banks and a closing down of inefficient state banks (see Table 7 below).

**Table 7 Commercial banks in Bulgaria**

	1990	1991	1992	1993	1994	1995	1996	1997
Total	70	78	59	41	45	47	31	34
Private	2	10	14	18	25	29	15	18
Foreign	0	0	0	1	3	5	7	10

*Source: Mihov 2001*

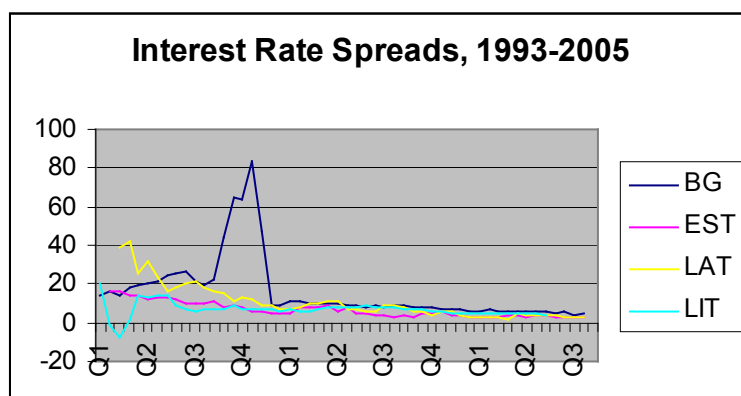
### *The Banking System*

Banking crises have an important implication for the real side of the economy. Usually the negative effect is in the slower recovery in production, and growth in general. That is due to people’s loss of faith in the banking system, which impedes the intermediation

of savings into investment. It is also the case that there was a change in the government after a banking crisis in all the Baltic countries and in Bulgaria.

Standard neoclassical growth models do not feature financial intermediation, “nor is there a standard definition of a banking shock” (Cole and Ohanian, 2000). These authors claim that bank closing in the US worsened the information content needed to screen investment projects. In our case it is more the other way round: inefficient banks were closed so bank capacity increased. Inflation was lowered with the introduction of a currency board, so the cost of intermediation fell, and his effect is clearly identified in the interest spreads (see Fig. 8 below).

**Fig.8**



Source :IFS

The story in many Latin American countries is connected to the macroeconomic stabilization. Very tight monetary policy increases nominal interest rates and, at the same time, brings down inflation. Real interest rates turn from negative to positive and many borrowers face difficulties paying back their loans and thus banks realize losses, and their portfolios deteriorate.



Fleming and Talley (1996) note the major ways in which the banking system is exposed to stress: in all four countries it is usually the enterprises that are the main borrowers. During the course of transition, they become subject to hard budget constraints and no longer receive government subsidies to cover their losses. In addition, inflation declines and real interest rates become positive, so it is harder on the firms' side to service their debts. Budget deficit in Bulgaria and Latvia ballooned, which decreased the demand for short-term Treasury bills by banks. As a result, the financing of the budget became problematic: the Latvian and Bulgarian government, for example, also allocated credit denominated in foreign currency with public guarantee to the private sector. These funds were mostly wasted and now the government has to pay them back, which made the situation at hand even worse. This liability of the government led to inflation and a deterioration of banks' balance sheets, setting the ground for bank panics. Table 8 below provides detailed information on the deterioration of the quality of bank loans in Bulgaria, which inevitably happens when banks provide loans without the necessary screening process and sufficient collateral.

**Table 8 Credit portfolio of Bulgarian Commercial banks, 1993-99 ( in per cent)**

	<b>1993</b>	<b>1994</b>	<b>1995</b>	<b>1996*</b>
Standard	7.61	17.69	25.91	43.67
Doubtful group A	82.75	66.88	54.55	33.89
Doubtful group B	2.19	3.46	4.18	10.67
Loss	7.45	11.97	15.35	11.77
Provisions available	7.18	23.58	23.74	105.42
	<b>1997*</b>	<b>1998*</b>	<b>1999*</b>	
Standard	58.2	69.0	73.3	
Watch	8.6	10.0	9.3	
Substandard	5.9	5.6	2.2	
Doubtful	4.7	1.7	3.3	
Loss	22.7	13.6	12.0	

*Source: Caporale et al (2002)*

Note: \* Banks in liquidation are excluded

The reason was that bankers were in the beginning of the process of learning the tricks of the market economy. In addition, there was no good collateral for loans: bank supervisors were also learning the trade. Furthermore, agents were making mistakes on a systematic basis because they were not internalizing the costs of their bad decisions. As the transition process went further, bankers started “catching up”(Fleming and Tally, 1996). Corruption and rent-seeking activities are also to blame: due to the loose supervisory regime, managers perceived banks as an endless source of cheap finances and that caused moral hazard problems. Another major issue was the absence of an efficient enforcement mechanism for the process of liquidation of insolvent banks.

What the government can do is to establish an adequate legal framework for banking and financial services, develop effective bank supervision and regulation, free banks from political influence and foster effective bank management. Accounting based on Western standards is needed, and not one based on historical costs, as well as audits. The institutional demands that that rules of the game be properly specified, and a bigger governance role be given to the Central Bank and bank supervision. There is also need to react very quickly before it becomes too late: Liquidation of banks, rehabilitation for those that are too big to fail –will have a serious negative effect on the banking system and the economy as a whole. The expansion of loans should not be so fast because it decreases the quality of the credits given, and there should be more careful screening in place.

After the introduction of the currency board in Bulgaria, there was a significant change in banks’ behavior (for more on the firm-bank relationships see Nenovsky et al. 2003). This was mostly due to the improvements in bank legislation and regulation: banks were required to report every large credit they gave and to better monitor the status of the

loans outstanding. A loan was categorized now as non-performing if the delay of payments was more than 30 days, which is much shorter period of time compared to 90 days previously. In addition, there is very little room for the central bank to act as a lender of last resort. The interest spread also decreased, as well as the credit/GDP ratio. Even today, as Mihov (2001) claims, bank loans are the primary source of outside financing for Bulgarian firms.

#### *Bankruptcy procedures<sup>4</sup>*

In theory, the reform in bankruptcy procedures should increase the incentives for capital accumulation, as well as its efficiency, as was the case in Chile (Bergoening et al 2002). Higher productivity growth can be an effect of the right timing in privatization, banking and bankruptcy procedures reforms. Before reforms, government policies distorted the functioning of the market mechanism. Resources were misallocated both within and between sectors. As a result of this, the economy goes below its Production Possibilities frontier (PPF), due to the fall in aggregate productivity. Moreover, it is not only those static negative effects, but also dynamic consequences dealing with the entry/exit decisions of firms.

Static effect is due to the discriminatory attitude towards government and private firms. The loss-making state enterprises are subsidized from the corporate tax revenue collected from the profit-making private enterprises. This is done in order to preserve the jobs of the employees in the public sector. In addition, government companies produce too much, while the private sector produces too little. On the aggregate level, production is lower than

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<sup>4</sup> The exposition in this sub-section relies heavily on the arguments provided by Bergoening et al. (2002)

the one in a market environment. Resources are not used to their maximum efficiency and this is translated into lower productivity growth.

The connection with the banking story is that it was very often the case that the two sectors received credits at different interest costs. This was done either through a transfer from the budget to state companies, or simply private companies paid a higher interest cost to compensate for the below market rate loan given to the public enterprises. This credit policy also distorts capital allocation, as illustrated in the simple models in Bergoing et al (2002). In the short run, capital is assumed to be fixed in quantity and its allocation among sectors is distorted by the credit policy in place. This misallocation of capital will decrease the incentive to take loans in order to invest in productive capacity and will decrease the speed of capital accumulation. In this way the lower level of capital in the economy will lead to a lower level of production.

The dynamic effects are connected to the firms' entry/exit decision: with government protection, high-cost producers that cannot cover their expenses are kept in the market. This has a discouraging effect on entry of privately-managed enterprises and also poses barriers to the entry of new firms. This is bad for the economy since usually private firms come with newer technology. Without innovation and learning, however, the losses in productivity over time rise in an exponential manner. Atkinson and Kehoe (qtd in Bergoing 2002) give an idea how big losses for the economy can be when they accumulate over time. In this sense, opening for trade exercises pressure on inefficient firms to close and leaves more room for private companies.

The countries' economic history has demonstrated that banking regulations and bankruptcy procedures have important effects on the real side of the economy, which acts through the productivity channel. More specifically, they affect the allocative efficiency of resources, both in a static and dynamic manner. The other stories either do not have a significant effect on TFP, or do not hold water in our case. This does not mean they are not worth discussing: debt and fiscal policy, for example have important background effects.

## CONCLUSION

In this paper the cyclical fluctuations and productivity growth during transition in Bulgaria and the Baltic countries: Estonia, Latvia and Lithuania was explored. The present paper aimed at deepening the understanding of business cycles in transition countries and emphasizing the importance of the financial system for the real side of the economy. This study estimated a simple RBC model, using the classical paper by King, Plosser and Rebelo (1988) in a closed-economy framework. This was done in order to get a general-equilibrium picture of the transition process and not just do a piecemeal analysis. The model was calibrated for Bulgaria and the three Baltic countries: Estonia, Latvia and Lithuania.

Both the model and data series show that the major drop in output was due to productivity, a result obtained also in Amaral and Macgee (2001), Hayashi and Prescott (2002), Kehoe and Ruhl (2003). In addition, the analysis performed showed that the fall in TFP may be due to the banking regulations. In addition, the timing of the banking reforms coincides with the improvement of the economic performance, as in Bernanke (1981, 1983), Bergoing et al (2002), Hopenhayan and Neumeier (2003). This is a strong indication that banking regulations in place were crucial for the output performance throughout the period in Bulgaria and the Baltic countries.

The major limitation of the model is that it is too simplistic. Despite the simplicity, we were unable to find data on some of the variables and had to use estimates in our calibration. In addition, there is no government sector with distortionary taxation explicitly modeled, e.g. as in Baxter and King (1993), Campbell (1994) and McGrattan (1994). In future work government shocks will be allowed for, which is expected to solve the shock persistence problem.

Another suggestion for further research is motivated by Aguiar and Gopinath's (2004) paper – "Emerging Market Business Cycles: The Cycle is the Trend." The authors advocate the view that shocks in developing countries are persistent and they affect the trend. As a result, these permanent shocks change the expected future output trajectory.

A promising area of improvement is to go deeper into the micro-foundations and get sectoral data. The latter could be put in a more rigorous model setup. The theoretical framework may incorporate, for the sake of richer analysis, additional complications such as heterogeneous agents (McCallum 1987), factor underutilization, variable labor supply and labor hoarding, wage and price adjustment, monopolistic markups (Rotemberg and Woodford 1995), capital adjustment costs, and heterogeneity of capital.

## **APPENDIX**

### **A1: DATA**

All data were seasonally adjusted using X-11 multiplicative procedure, except for the net capital flows, for which X-11 additive was used because of the negative values in some of the observations. In addition, X-11 is a standard procedure in the literature. The trend was extracted using Hodrick-Prescott filter using the default  $\lambda = 1600$  parameter.

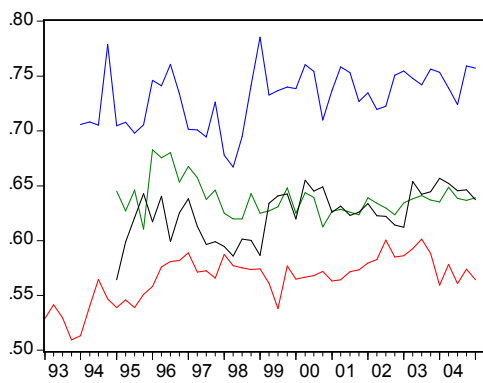
Productivity is defined as real GDP divided by total employment, as done by Romer (2001) and Benczur and Ratfai (2005). For Latvia, GDP was divided by industrial employment due to data limitations.

Annual inflation is calculated by taking a fourth difference of the CPI series

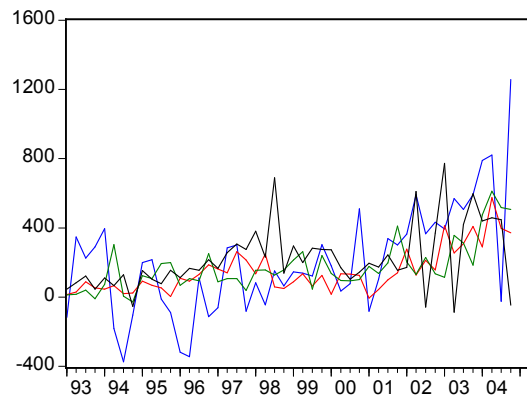
Interest spreads are calculated as a difference between lending rate and deposit rate.



### A.1.1 MACROECONOMIC INDICATORS, 1993 - 2005



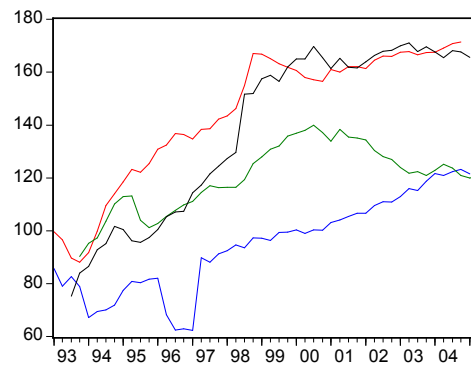
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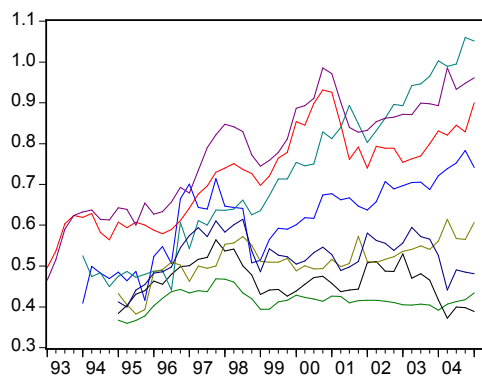
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 — NCF\_LIT\_SA



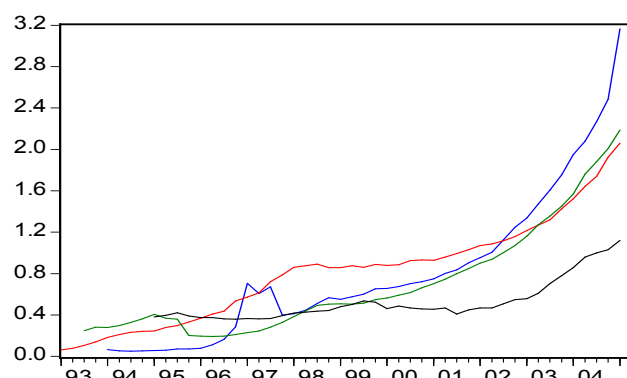
— CA\_TO\_GDP\_BG  
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 — CA\_TO\_GDP\_LAT  
 — CA\_TO\_GDP\_LIT



— REER\_BG\_SA  
 — REER\_EST\_SA  
 — REER\_LAT\_SA  
 — REER\_LIT\_SA



— EXPTPGDP\_BG\_SA  
 — EXPTPGDP\_EST\_SA  
 — EXPTPGDP\_LAT\_SA  
 — EXPTPGDP\_LIT\_SA  
 — IMPTOGDP\_BG\_SA  
 — IMPTOGDP\_EST\_SA  
 — IMPTOGDP\_LAT\_SA  
 — IMPTOGDP\_LIT\_SA



— PRCRTOGDP\_BG\_SA  
 — PRCRTOGDP\_EST\_SA  
 — PRCRTOGDP\_LAT\_SA  
 — PRCRTOGDP\_LIT\_SA

## APPENDIX A2: SENSITIVITY ANALYSIS

The tables below present the results obtained from the alternative specification of the model, namely with autocorrelation coefficient  $\rho$  equal to 0.95. Neither of the two alternative specifications, however, produces qualitatively different results than those in the original specifications. Indeed, absolute and relative volatilities increase in size. Still, they are much smaller than the ones in the data. The predicted cyclical measures are still too high, while persistence measures match well with those in the data.

### GDP(Y)

	<b>GDP volatility</b>	<b>Autocorrelation</b>
<b>Bulgaria</b>	4.2	0.66
<b>Estonia</b>	2.46	0.67
<b>Latvia</b>	1.89	0.65
<b>Lithuania</b>	2.53	0.56
<b>Model EST</b>	1.2443(0.2488)	0.6585 (0.1184)
<b>Model BG</b>	0.2968(0.0574)	0.658(0.118)

GDP volatility is measured as the standard deviation of GDP.

Autocorrelation is measured as the AR(1) coefficient in the series.

### Consumption (C)

	<b>BG</b>	<b>EST</b>	<b>LAT</b>	<b>LIT</b>	<b>Model EST</b>	<b>Model BG</b>
<b>Abs. Volatility<sup>1</sup></b>	5.48	3.41	2.38	2.45	0.4529 (0.1191)	0.1092(0.0282)
<b>Rel. Volatility<sup>2</sup></b>	1.30	1.38	1.39	0.97	0.361(0.041)	0.3646(0.0413)
<b>Cyclicalit<sup>3</sup></b>	0.78	0.60	0.22	0.26	0.8673(0.0345)	0.8673(0.0348)
<b>Persistence<sup>4</sup></b>	0.56	0.65	0.18	0.28	0.7907(0.0975)	0.7894(0.0976)

### Investment (I)

	<b>BG</b>	<b>EST</b>	<b>LAT</b>	<b>LIT</b>	<b>Model EST</b>	<b>Model BG</b>
<b>Abs. Volatility</b>	14.36	12.37	10.45	9.39	1.9781(0.3922)	0.5261(0.0992)
<b>Rel. Volatility</b>	3.42	5.02	6.12	3.71	1.5906(0.0277)	1.7744(0.0314)
<b>Cyclicalit</b>	0.39	0.69	0.20	0.72	0.9952(0.0021)	0.9932(0.003)
<b>Persistence</b>	0.45	0.37	0.09	0.62	0.6443(0.1195)	0.642(0.119)

### Employment (N)

	<b>BG</b>	<b>EST</b>	<b>LAT</b>	<b>LIT</b>	<b>Model EST</b>	<b>Model BG</b>
<b>Abs. Volatility</b>	4.56	1.32	3.29	2.15	0.5284(0.0981)	0.126(0.0233)
<b>Rel. Volatility</b>	1.09	0.54	1.74	0.85	0.4262(0.019)	0.4255(0.0148)
<b>Cyclicalit</b>	-0.17	0.47	0.63	0.13	0.9654(0.0159)	0.9647(0.0162)
<b>Persistence</b>	0.87	0.75	0.84	0.68	0.632(0.1194)	0.6319(0.1192)

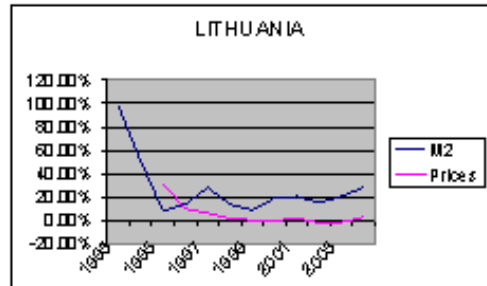
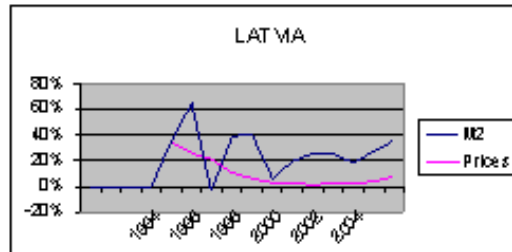
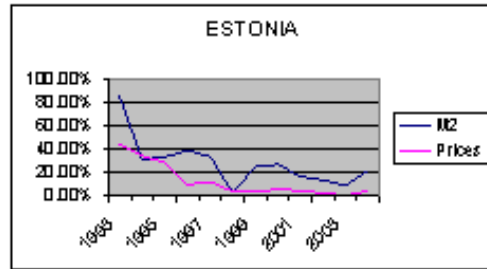
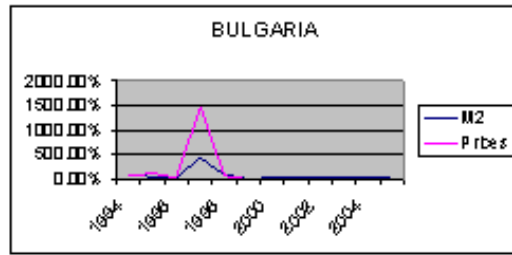
**Technological productivity (A)**

	<b>BG</b>	<b>EST</b>	<b>LAT</b>	<b>LIT</b>	<b>Model EST</b>	<b>Model BG</b>
<b>Abs. Volatility</b>	6.71	2.18	3.08	3.10	0.9976(0.1883)	0.2389(0.0445)
<b>Rel. Volatility</b>	1.60	0.89	1.74	1.22	0.8038(0.0237)	0.8061(0.0187)
<b>Cyclical</b>	0.74	0.84	0.42	0.73	0.9863(0.0062)	0.9871(0.0058)
<b>Persistence</b>	0.76	0.56	0.49	0.59	0.6377(0.1194)	0.6378(0.1191)

**Real Wages**

	<b>BG</b>	<b>EST</b>	<b>LAT</b>	<b>LIT</b>	<b>Model EST</b>	<b>Model BG</b>
<b>Abs. Volatility</b>	7.64	2.41	3.45	6.16	0.745(0.1594)	0.1784(0.0373)
<b>Rel. Volatility</b>	1.82	0.98	1.83	2.43	0.5973(0.0212)	0.5995(0.021)
<b>Cyclical</b>	0.57	0	0.23	0.45	0.9832(0.0062)	0.983(0.0063)
<b>Persistence</b>	0.64	-0.01	0.73	0.77	0.6963(0.115)	0.6956(0.1148)

### A3: M2-Prices Charts



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## GAUSS CODE USED

```

===== @
@ PROGRAMME BY MORTEN RAVN @
===== @
@
===== @
@ THE KING, PLOSSER AND REBELO
SOLUTION ALGORITHM @
===== @
@ DIMENSION OF CONTROL SPACE (NC), STATE AND COSTATE VECTORS (NS),
EXOGENEOUS STATE VECTOR (NN) @
@ ORDERING OF VARIABLES:
C: C(T) N(T)
S: K(T) LAMBDA(T)
E: A(T) @
NAMEC="C"|"N";
NAMEK="K";
NAMEL="LAMBDA";
NAMEE="A";
NC=2; NS=1; NN=1;
===== @
@ ECONOMIC PARAMETER VALUES @
===== @
@ FACTOR SHARES (SK,SN) AND THE ELASTICITY OF SUBSTITUTION (ZETAKN).
WE USE COBB-DOUGLAS SPECIFICATION @
SN=0.43; SK=1-SN;
ZETAKN=1.00;
XIKK=-SN*ZETAKN; XIKN= SN*ZETAKN;
XINN=-SK*ZETAKN; XINK= SK*ZETAKN;
@ GROWTH RATE OF TECHNICAL CHANGE AND DEPRECIATION @
GAMMAX=1.005; DELTAK=0.050;
@ DISCOUNT FACTOR AND REAL INTEREST RATE @
RR=0.065/4;
BSTAR=GAMMAX/(1+RR);
@ STEADY STATE SHARE OF TIME TO MARKET ACTIVITIES @
NBAR=0.400;
===== @
@ STEADY STATE CALCULATIONS @
===== @
@ - THE TRANSFORMED ECONOMY @
@ THE RATIO PHI AND CAP-OUTPUT RATIO ARE @
PHI=GAMMAX/(GAMMAX-(1-DELTAK));
KYRATIO=(BSTAR*SK)/(GAMMAX-BSTAR*(1-DELTAK));
@ STEADY STATE CONSUMPTION AND INVESTMENT SHARES @
SI=KYRATIO*GAMMAX/PHI; SC=1-SI;
ABAR=10;
YSS=(ABAR^(1/SN))*(KYRATIO^(SK/SN))*NBAR;
CSS=SC*YSS;
@ PARAMETERS OF PREFERENCES
SIGMA IS THE ABSOLUTE VALUE OF THE ELASTICITY OF MARGINAL UTILITY
OF CONSUMPTION @
SIGMA=1;
@ THETA WE DETERMINE SO THAT IT IS CONSISTENT WITH THE STEADY
STATE NUMBER OF HOURS WORKED @
THETA=((SC*NBAR)/(SN*(1-NBAR)))/(1+(SC*NBAR)/(SN*(1-NBAR)));
@ FROM WHICH WE CAN GET THE ELASTICITIES OF PREFERENCES @
@ WE HAVE TWO MAIN POSSIBILITIES:
SIGMA=1 - ADDITIVELY SEP.
SIGMA>>1 - MULTIPLICATIVELY SEP. @
XICC=THETA*(1-SIGMA)-1; XILC=THETA*(1-SIGMA);

```

```

@ THE OTHER TWO ELASTICITIES ARE FREE SO LONG AS XICL=0 IF SIGMA=1 @
XICL=(1-THETA)*(1-SIGMA); XILL=(1-THETA)*(1-SIGMA)-1;
@ STEADY STATE ELASTICITIES OF MARGINAL PRODUCT OF CAPITAL @
ETAA=(GAMMAX-BSTAR*(1-DELTAK))/GAMMAX;
ETAK=-SN*ETAA;
ETAN=SN*ETAA;
ETAI=BSTAR*DELTAK*SI*YSS;
@ ===== @
@ BASIC SYSTEM MATRICES @
@ ===== @
@ MATRICES IN CONTROL SYSTEM @
@ THE CONTROLS ARE: C(t) N(t) @
MCC=ZEROS(NC,NC);
MCC[1,1]=XICC; MCC[1,2]=-XICL*NBAR/(1-NBAR);
MCC[2,1]=XILC; MCC[2,2]=-XILL*NBAR/(1-NBAR)-XINN;
MCS=ZEROS(NC,NS*2);
MCS[1,1]=0; MCS[1,2]=1;
MCS[2,1]=XINK; MCS[2,2]=1;
MCE=ZEROS(NC,NN);
MCE[1,1]=0;
MCE[2,1]=1;
@ MATRICES IN STATE EQUATIONS @
MSS0=ZEROS(2*NS,2*NS);
MSS0[1,1]=ETAK; MSS0[1,2]=1;
MSS0[2,1]=SI*PHI; MSS0[2,2]=0;
MSS1=ZEROS(2*NS,2*NS);
MSS1[1,1]=0; MSS1[1,2]=-1;
MSS1[2,1]=-SK-SI*(PHI-1); MSS1[2,2]=0;
MSC0=ZEROS(2*NS,NC);
MSC0[1,1]=0; MSC0[1,2]=-ETAN;
MSC0[2,1]=0; MSC0[2,2]=0;
MSC1=ZEROS(2*NS,NC);
MSC1[1,1]=0; MSC1[1,2]=0;
MSC1[2,1]=-SC; MSC1[2,2]=SN;
MSE0=ZEROS(2*NS,NN);
MSE0[1,1]=-ETAA;
MSE0[2,1]=0;
MSE1=ZEROS(2*NS,NN);
MSE1[1,1]=0;
MSE1[2,1]=1;
@ ===== @
@ RELATIONS LINKING EXTRA FLOW VARIABLES (OUTPUT, PRODUCTIVITY
AND INVESTMENT) TO FUNDAMENTAL CONTROLS AND STATES @
@ ===== @
@ THE ORDER OF VARIABLES IS:
Y(T) AP(T) I(T) @
NAMEXC="Y"|"AP"|"I";
NXF=3;
@ 1. EXTRA FLOWS ON CONTROLS [C N]' @
FVC=ZEROS(3,NC);
FVC[1,1]=0; FVC[1,2]=SN;
FVC[2,1]=0; FVC[2,2]=SN-1;
FVC[3,1]=-SC/SI; FVC[3,2]=SN/SI;
@ 2. EXTRA FLOWS ON STATES AND SHOCKS [K A]' @
FVKE=ZEROS(3,NS+NN);
FVKE[1,1]=SK; FVKE[1,2]=1;
FVKE[2,1]=SK; FVKE[2,2]=1;
FVKE[3,1]=SK/SI; FVKE[3,2]=1/SI;
@ EXTRA FLOWS ON CO-STATES [LAMBDA] @
FVL=ZEROS(3,NS);

```

```

@ ===== @
@ FUNDAMENTAL STATE-COSTATE DIFFERENCE EQUATION @
@ ===== @
MSss0 = MSS0 - MSC0*(INV(MCC))*MCS;
MSss1 = MSS1 - MSC1*(INV(MCC))*MCS;
MSse0 = MSE0 + MSC0*(INV(MCC))*MCE;
MSse1 = MSE1 + MSC1*(INV(MCC))*MCE;
@ THE FUNDAMENTAL DIFFERENCE EQUATION IS PUT IN NORMAL FORM @
W = -(INV(MSss0))*MSss1;
R = (INV(MSss0))*MSse0;
Q = (INV(MSss0))*MSse1;
@ ===== @
@ EIGENVECTOR-EIGENVALUE DECOMPOSITION OF STATE TRANSITION MATRIX @
@ ===== @
@ FIRST WE FIND THE REAL PARTS OF THE EIGENVALUES (X1)
AND EIGENVECTORS (X3) @
{X1,X2,X3,X4}=EIGRG2(W);
@ SECONDLY WE FIND THE INDICATOR (IND1) OF THE ORDER OF THE MAXIMUM
ABSOLUTE EIGENVALUES (AMU) @
AMU=ABS(X1);
IND1=SORTIND(AMU);
@ THIRDLY WE ORDER THE COLUMNS OF THE EIGENVECTORS (X3) BY THIS
INDICATOR RESULTING IN P @
P=ZEROS(2*NS,2*NS);
I=1;
DO UNTIL I>2*NS;
P[1:2*NS,I]=X3[1:2*NS,IND1[I,1]];
I=I+1;
ENDO;
@ FINALLY WE FORM A DIAGONAL MATRIX (MU) IN WHICH THE DIAGONAL HAVE
THE EIGENVALUES IN ASCENDING ABSOLUTE VALUE, I.E. WE USE THE
INDICATOR FUNCTION IND1 AGAIN @
MU=ZEROS(2*NS,2*NS);
I=1;
DO UNTIL I>2*NS;
MU[I,I]=X1[IND1[I,1],1];
I=I+1;
ENDO;
@ WE NOW HAVE P AND MU FOR WHICH WE KNOW THAT P*MU*P^-1=W (ALSO
X3*DIAG(X1)*X3=W) @
@ ===== @
@ PARTITIONING THE MATRICES @
@ ===== @
MU1=MU[1:NS,1:NS];
MU2=MU[NS+1:2*NS,NS+1:2*NS];
P11=P[1:NS,1:NS];
P12=P[1:NS,NS+1:2*NS];
P21=P[NS+1:2*NS,1:NS];
P22=P[NS+1:2*NS,NS+1:2*NS];
PS=INV(P);
PS11=PS[1:NS,1:NS];
PS12=PS[1:NS,NS+1:2*NS];
PS21=PS[NS+1:2*NS,1:NS];
PS22=PS[NS+1:2*NS,NS+1:2*NS];
RKE=R[1:NS,1:NN];
RLE=R[NS+1:2*NS,1:NN];
QKE=Q[1:NS,1:NN];
QLE=Q[NS+1:2*NS,1:NN];

```

```

===== @
@ COMPOSITE EXPRESSIONS @
===== @
SP1=- (INV(MU2))*(PS21*RKE+PS22*RLE);
SP2=- (INV(MU2))*(PS21*QKE+PS22*QLE);
KLK=P11*MU1*(INV(P11));
KTL=(P11*MU1*PS12+P12*MU2*PS22)*(INV(PS22));
===== @
@ COMPUTATION OF STEADY STATE @
===== @
@ THE ORDERING OF VARIABLES (DESCRIBED IN MDR.X1) IS:
K A L C N Y A P C @
YSS=(ABAR^(1/SN))*(KYRATIO^(SK/SN))*NBAR;
CSS=SC*YSS;
ISS=SI*YSS;
KSS=ISS/(GAMMAX-(1-DELTAK));
APSS=YSS/NBAR;
ASS=ABAR;
NSS=NBAR;
LSS=1; @ THIS VALUE IS WRONG BUT WE ARE NOT INTERESTED IN
THE EVOLUTION OF SHADOW PRICES @
@ STEADY STATE VALUES IN SSVAl @
SSVAL=KSS|ASS|LSS|CSS|NSS|YSS|APSS|ISS;
NAME=NAMEK|NAMEE|NAMEL|NAMEC|NAMEXC;

===== @
@ COMPUTATION OF DECISION RULES @
===== @
@ IN THIS PROGRAM WE WILL COMPUTE MARKOV DECISION RULES (MDR)
FOR THE LINEAR DYNAMIC MODEL @
@ THE EXOGENEOUS VARIABLES (A(T)) WILL BE ASSUMED TO BE
GENERATED BY AR(1) PROCESSES WITH TRANSITION MATRIX RHO @
RAA=0.76;
RHO=ZEROS(NN,NN);
RHO[1,1]=RAA;
@ USING THE COMPOSITE EXPRESSION, WE HAVE @
FL = SP1*RHO + SP2;
IRHO=EYE(ROWS(RHO));
I=1;
LEE=ZEROS(NS,NN);
DO UNTIL I>NS;
Q=FL[I,1:NN];
MU2I=1/MU2[I,I];
DSUM=INV((IRHO-MU2I*RHO));
LEE[I,1:NN]=Q*DSUM;
I=I+1;
ENDO;
===== @
@ CAPITAL DECISION RULES @
===== @
KEC=RKE*RHO+QKE+KTL*LEE;
ULE=(INV(PS22))*LEE;
ULK=- (INV(PS22))*PS21;
===== @
@ SYSTEM DECISION RULES @
===== @
MKE=ZEROS(ROWS(KLK)+NN, COLS(KLK)+COLS(KEC));
MKE[1:ROWS(KLK),1:COLS(KLK)]=KLK;
MKE[ROWS(KLK)+1:ROWS(KLK)+NN,1:NS]=ZEROS(NN,NS);

```

```

MKE[1:ROWS(KEC),COLS(KLK)+1:COLS(KLK)+COLS(KEC)]=KEC;
MKE[ROWS(KEC)+1:ROWS(KEC)+ROWS(RHO),COLS(KLK)+1:COLS(KLK)+COLS(KEC)]=RHO;
@===== @
@ INCORPORATION OF SHADOW PRICE, CONTROLS AND OTHER FLOWS @
@===== @
LKE=ZEROS(NS,NS+NN);
LKE[.,1:COLS(ULK)]=ULK; LKE[.,COLS(ULK)+1:COLS(ULK)+COLS(ULE)]=ULE;
Z=(INV(MCC))*MCS;
M0CK=Z[1:NC,1:NS];
M0CL=Z[1:NC,NS+1:2*NS];
M0CE=(INV(MCC))*MCE;
M0CKE=(M0CK+M0CL*ULK)~(M0CE+M0CL*ULE);
FKE=FVC*M0CKE+FVKE+FVL*LKE;
H=LKE|M0CKE|FKE;
LOCATE 1,1;
FORMAT /LDS 4,3;
OUTPUT ON;
OUTPUT FILE=KPR.OUT RESET;
"-----";
" NEAR STEADY STATE DYNAMICS AND PARAMETERIZATION ";
"-----";
"-----";
" ----- PIS ----- ";
" ";;$NAME[1:NS+NN,1]";
I=1;
DO UNTIL I>NS;
$NAME[I,1];MKE[I,];
I=I+1;
ENDO;
I=1;
DO UNTIL I>NS;
$NAME[I+NN+NS,1];LKE[I,];
I=I+1;
ENDO;
I=1;
DO UNTIL I>NC;
$NAME[I+2*NS+NN,1];M0CKE[I,];
I=I+1;
ENDO;
I=1;
DO UNTIL I>NXF;
$NAME[I+2*NS+NN+NC,1];FKE[I,];
I=I+1;
ENDO;
"-----";
WAIT;
FORMAT 4,4;
"-----";
" ----- PARAMETERIZATION ----- ";
"-----";
"FULL SHOCK TRANSITION MATRIX [A ]";RHO;
"LABOUR SHARE ";;SN;
"ELASTICITY OF SUBSTITUTION ";;ZETAKN;
"SIGMA ";;SIGMA;
"THETA ";;THETA;
"STEADY STATE HOURS WORKED ";;NBAR;
"GROWTH RATE ";;GAMMAX;
"BSTAR ";;BSTAR;
"DEPRECIATION RATE ";;DELTAK;
"CAPITAL-OUTPUT RATIO ";;KYRATIO;

```

```
"CONSUMPTION SHARE ";;SC;
"REAL INTEREST RATE ";;RR;
"-----";
```

```
OUTPUT OFF;
```

```
@ THIRD PROGRAM - COMPUTATION OF
IMPULSE RESPONSE FUNCTIONS @
```

```
@ ORDERING OF VARIABLES
```

```
S: (MKE-TRANSITION) K A
```

```
H: L C N Y AP I @
```

```
@ CHOOSE SHOCK (ORDERING IS [K A]) @
```

```
S=0|1;
```

```
@ FORECAST HORIZON @
```

```
NIR=40;
```

```
@ GENERATING IMPULSES @
```

```
T=SEQA(1,1,NIR);
```

```
IR=ZEROS(ROWS(MKE)+ROWS(H),NIR);
```

```
I=1;
```

```
DO UNTIL I>NIR;
```

```
IR[1:ROWS(MKE),I]=S;
```

```
IR[ROWS(MKE)+1:ROWS(IR),I]=(H*S);
```

```
S=MKE*S;
```

```
I=I+1;
```

```
ENDO;
```

```
@ PLOT IMPULSE RESPONSES @
```

```
LIBRARY PGRAPH;
```

```
GRAPHSET;
```

```
/* 1. TRANSITION PATH IF K IS NOT KSS */
```

```
TITLE("TRANSITIONS TO STEADY STATE");
```

```
_PLEGCTL={2,3,1.7,4.5};
```

```
_PLEGSTR="K \000\"
```

```
"C \000\"
```

```
"N \000\"
```

```
"Y \000\"
```

```
"AP \000\"
```

```
"I \000\";
```

```
XY(T,IR[1,.]~IR[4:8,.]);
```

```
/* 2. IF YOU HAVE A SHOCK THEN USE THIS NOW */
```

```
TITLE("REACTION TO SHOCK TO A");
```

```
_PLEGCTL={2,3,1.7,4.5};
```

```
_PLEGSTR="K \000\"
```

```
"A \000\"
```

```
"C \000\"
```

```
"N \000\"
```

```
"Y \000\"
```

```
"AP \000\"
```

```
"I \000\";
```

```
XY(T,IR[1:2,.]~IR[4:8,.]);
```

```
@ FOURTH PROGRAM - SIMULATION OF THE MODEL @
```

```
clear all;
```

```
T=HSEC;
```

```
@ ORDERING OF VARIABLES
```

```
S: (MKE-TRANSITION) K A
```

```
H: L C N Y AP I @
```

```
@ CHOOSE STANDARD ERRORS OF SHOCKS @
```

```
SA=0.00852;
```

```
@ USING THIS WE SET UP THE LOADING MATRIX FOR THE SHOCKS @
```

```
E=ZEROS(NS+NN,NS+NN); @ NOTE THAT CAPITAL FORMS THE FIRST ELEMENT @
```

```
E[2,2]=SA;
```

```

@ NUMBER OF EXPERIMENTS @
NEXP=500;
@ SIMULATION HORIZON @
NIR=50;
@ CHOOSE THE STACKING OF EXPERIMENTS - HERE THERE IS A TRADE OFF:
THE MORE EXPERIMENTS THAT ARE STACKED THE FASTER BUT ONE
RISKS RUNNING OUT OF MEMORY - REMEMBER THAT NUMBER OF EXPERIMENTS
MUST BE AN INTEGER TIMES STACKING @
STACK=50;
@ MATRIX OF STEADY STATE VALUES @
SV1=ONES(NIR,ROWS(MKE)+ROWS(H)).*SSVAL';
@ INCLUDE HPFILTER @
UU=0;
#include HP1;
@ FINALLY CHOOSE THE SEED FOR THE RANDOM NUMBER GENERATOR @
RNDSEED 7654321;
@ INITIALIZE MATRICES OF MOMENTS @
STD=ZEROS(ROWS(MKE)+ROWS(H),NEXP); @ ABSOLUTE STANDARD DEVIATIONS @
STDR=ZEROS(ROWS(MKE)+ROWS(H),NEXP); @ STD.DEV. RELATIVE TO OUTPUT @
AU=ZEROS(ROWS(MKE)+ROWS(H),NEXP); @ AUTOCORRELATIONS @
@ CORRELATIONS (NEXT) ARE ORDERED SO THAT WE GET CORRELATIONS WITH
DOMESTIC OUTPUT, AND THE CORRELATIONS OF N AND APN @
COR=ZEROS((ROWS(MKE)+ROWS(H)+1),NEXP); @ CORRELATIONS @
@ VECTOR OF VARIABLE NAMES @
VAR1=NAME;
VAR2=NAME|"N-APN";
COR1=1|2|3|4|5|6|7|8|5;
COR2=6|6|6|6|6|6|6|7;
LOCATE 1,5;"SIMULATING ROUND NO:";
IT=1;
DO UNTIL IT>NEXP/STACK;
DAT1=ZEROS(NIR,ROWS(MKE)+ROWS(H));
IT1=1;
DO UNTIL IT1>STACK;
LOCATE 1,28;STACK*(IT-1)+IT1;
IR=ZEROS(NIR,ROWS(MKE)+ROWS(H));
SS=E*RNDN(NIR+1,ROWS(E));
S=SS[.,1];
I=1;
DO UNTIL I>NIR;
IR[I,1:ROWS(MKE)]=S';
IR[I,ROWS(MKE)+1:COLS(IR)]=(H*S)';
S=MKE*S+SS[.,I+1];
I=I+1;
ENDO;
Z=ONES(NIR,8);
IR1=SV1.*(Z+IR);
DAT=LN(IR1[.,1:8]);
DAT1=DAT1~DAT;
IT1=IT1+1;
ENDO;
DAT=DAT1[.,ROWS(MKE)+ROWS(H)+1:COLS(DAT1)];
UU=ZEROS(ROWS(DAT),COLS(DAT));
CALL HP1(DAT);
CLEAR DAT1;
CLEAR DAT;
IT1=1;
DO UNTIL IT1>STACK;
DAT=UU[.,(ROWS(MKE)+ROWS(H))*(IT1-1)+1:(ROWS(MKE)+ROWS(H))*IT1];

```

```

@ ABSOLUTE STANDARD DEVIATIONS @
STD[,STACK*(IT-1)+IT1]=100*STDC(DAT);
@ STANDARD DEVIATIONS RELATIVE TO Y @
J=1;
SY1=STD[6,STACK*(IT-1)+IT1];
STDR[,STACK*(IT-1)+IT1]=STD[,STACK*(IT-1)+IT1]/SY1;
@ AUTOCORRELATIONS @
X=DAT[2:NIR,]; X1=DAT[1:NIR-1,];
X2=X'*X1;
X3=SQRT(DIAG(X'*X))*(SQRT(DIAG(X1'*X1)));
X4=X2./X3;
AU[,STACK*(IT-1)+IT1]=DIAG(X4);
@ CORRELATION MATRIX @
X=DAT*DAT;
X1=SQRT(DIAG(X));
X2=X1*X1';
X3=X./X2;
J=1;
DO UNTIL J>ROWS(COR);
COR[J,STACK*(IT-1)+IT1]=X3[COR1[J,1],COR2[J,1]];
J=J+1;
ENDO;
IT1=IT1+1;
ENDO;
CLEAR DAT;
IT=IT+1;
ENDO;
STD1=(MEANC(STD));
SSTD=STDC(STD);
STDR1=MEANC(STDR);
SSTDR=STDC(STDR);
AU1=MEANC(AU);
SAU=STDC(AU);
COR1=MEANC(COR);
SCOR=STDC(COR);

LOCATE 2,5; " TOTAL TIME";;(HSEC-T)/100;
WAIT;
@ PRINTING RESULTS OUT @
OUTPUT FILE=KPR.OUT;
OUTPUT ON;
"DATE";;(DATE);
"NO. OF SIMULATIONS";;NEXP;
" STANDARD DEVIATIONS AND AUTOCORRELATIONS";
"VARIABLE ABSOLUTE (Sd) RELATIVE TO Y (Sd) AUTOCOR (Sd)";
J=1;
DO UNTIL J>ROWS(STD);
$VAR1[J,1];;STD1[J,1];;SSTD[J,1];;STDR1[J,1];;SSTDR[J,1];;AU1[J,1];;SAU[J,1];
J=J+1;
ENDO;
WAIT;
" CONTEMPORANOUS CORRELATIONS (WITH Y UNLESS OTHERWISE STATED)";
"VARIABLE COR (Sd) ";
J=1;
DO UNTIL J>ROWS(COR1);
$VAR2[J,1];;COR1[J,1];;SCOR[J,1];
J=J+1;
ENDO;
WAIT;

```



OUTPUT OFF;  
CLEAR ALL;