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# Comparing Central Europe and the Baltic macro-economies: A Bayesian approach\*

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**Abstract.** Applying the Bayesian approach, a small open economy DSGE model was estimated using a sample of quarterly data for a macro-region formed by six Central Europe and Baltic economies: Czech Republic, Estonia, Hungary, Lithuania, Poland, and Slovakia. Estimates have been employed to investigate the effects of a financial crisis, exploring the role played by country differences in the relative performances. We also use our Bayesian estimations to compute two measures of resilience in the considered region.

**JEL:** E02, E32, E58.

**Keywords:** Financial crisis, resilience, macroeconomic performance, emerging markets, Bayesian estimations.

## 1. Introduction

The post-Communist countries present common historical foundations and, after the Berlin Wall fall in 1990, they all adopted a neoliberal agenda to cut public spending and promote trade and capital liberalization and privatization. The transformation of the Central and Eastern European region (CEE) region to relaunch European integration process and guarantee full accession to EU imposed severe policy measures, which had devastating impacts on the living conditions of people. In 2004 and 2007, ten Eastern European countries joined the EU. The

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extension of the European project to East opened up the region to deeper exposure to global booms and busts.

After several years of sustained economic growth, which led the Baltics to be termed as “Baltic Tigers,” the global financial crisis spread into the CEE region identifying preexisting vulnerabilities and regional disparities as well as heterogeneity in policy responses. The global financial crisis severely impacted all the different European economies, but the consequences were not uniform across Europe. Despite common explanatory factors, strong cross-country differences played a role. Initially the CEE region, which had previously observed strong economic dynamism, was relatively resilient. The region has been affected at the end of 2008 when the crisis was already well advanced. Common transmission mechanisms of the global financial crisis within the CEE region were the trade balance and the financial integration.

Many studies focus upon CEE economies and illustrate the effects of the global crisis within the region.<sup>1</sup> The strength of the crisis varied across CEE economies depending on the dependence on exports, the size of public sector deficits, the exposure to foreign currencies and can be also attributed to differences in exchange rate regimes. The real depreciation helped countries, such as Hungary, Poland and Romania with flexible exchange rate and inflation targeting regimes to steal an advantage over competitors whose currency was not floating. In the 2008 fall, all CEE countries experienced a contraction in GDP volumes compared to pre-crisis period, except Poland. In Baltic Republics and Bulgaria percentage decrease was double-digit. Inflation soared and unemployment increased everywhere with differences in depth.

Our aim is to adopt a DSGE modelling framework to investigate the economic performance of the Central Europe and Baltic (CEB) macro-region. Our choice follows some IMF recent insights. Roaf *et al.* (2014: 56), e.g., stress that, although Europe remains divided along “traditional” and historical west-east line, with advanced countries on one side and transition countries on the other, CEB region has more in common with the EU15 countries (and within them, the Southern Europe subgroup) than it does with former Comecon partners to the east.

In a comparative perspective, we built a small-open economy model for distinct economies of CEB macro-region and estimated them by Bayesian techniques. The model features standard nominal wage and price rigidities, monopolistic competition in the good market, real wage

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<sup>1</sup> Among others, Berglöf *et al.* (2009), Kolasa (2009, 2013), Sprenger and Vincent (2010), ECB (2010a, 2010b), Gorzelak and Goh (2010), Aslund (2011), and Bartlett and Prica (2012). Differences have been explored also within others macro-regions, e.g., in't Veld *et al.* (2011), Kollmann (2013), Kollmann *et al.* (2015, 2016).

rigidities, and financial frictions. Financial frictions assume the forms of liquidity–constrained households and limited access to the deposits for the bank system. The financial accelerator of external shocks operates on the relationships between savers and banks featured by asymmetric information. An agency problem introduces endogenous constraints on the leverage ratios. Then, credit flows are tied to the equity capital of intermediaries. A financial crisis deteriorates intermediary capital and raises credit costs, lowering lending and borrowing (Gertler and Karadi, 2011).<sup>2</sup>

In the fashion of Martin (2012), we also develop a new methodology to investigate resilience in two important dimensions, namely recovery and resistance. The latter can be defined as the relative vulnerability or sensitivity of economies within CEB region to disturbances and disruptions, whereas the former is the speed and extent of recovery from such a disruption or recession. Our methodology has been applied to our Bayesian estimations. We group our parameter estimates in two sets: structural parameters and stochastic structure. The former individuates the deep parameters affecting the economic recovery capacities after stochastic disturbances (innovations) occur; the latter governs the innovation distributions and their intrinsic persistence. Accordingly, we study the relative differences across CEB economies using Principal Component Analysis (PCA), obtaining synthetic orthogonal indexes of these differences in a parsimonious way.

Our main findings can be summarized as follows. Although some of the structural parameters within the CEB macro-region seem to be similar (i.e., those describing habit decision and risk aversion), relatively greater heterogeneity exists across countries with respect to nominal wage and price rigidities and financial frictions. Hungary and Poland behave as outlier in the region. As regards the monetary policy feedback rules, the response of central banks is quite aggressive to contrast inflation in all countries, while the response to the output gap, apart in Slovakia, is negligible. Interest rate smoothing seems to be important in the area. We find strong evidence for heterogeneity in terms of inertia of the stochastic disturbances; their persistence is relatively higher in Hungary, Lithuania, and Poland.

Looking at our measures of resilience, Central European economies exhibit quite similar paths in terms of recovery, meaning that they have similar economic structures. By contrast, Baltic

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<sup>2</sup> This approach to model credit frictions has become quite popular (e.g., Lendvai *et al.*, 2013; Andreasen *et al.*, 2013; Beqiraj *et al.*, 2016; Rannenberg, 2016), especially to study the effectiveness of unconventional monetary policy in financial crisis (e.g., Dedola *et al.*, 2013; Gertler and Karadi, 2013, 2015).

countries behave differently, being outliers placed at opposite extreme positions. The contrary occurs for resistance: Baltic countries share a similar ranking, whereas Central European economies exhibit strong differences. Centered PCA stresses the peculiarity of Hungary, reflecting its relative price flexibility. It individuates two groups of countries. On the one hand, Czech Republic, Estonia and Lithuania are characterized by a relative high preference for price stability on output and more persistence in the domestic price dynamics. On the other hand, Poland and the Slovak Republic reveal a relatively small number of households who cannot access to the financial markets. Within the last group, however, PCA individuates further differences: Slovakia (Poland) observes a relative high (low) preference for output stabilization relatively to consumption smoothing.

The rest of the paper is organized as follows. Section 2 briefly introduces our theoretical small-open economy model. Section 3 presents our estimation results. Section 4 discusses the resilience of CEB economies in a comparative perspective. Section 5 concludes.

## **2. A small open–economy model with financial imperfections**

We consider a simple small-open medium–scale New Keynesian economy characterized by nominal price and wage rigidities, consumption habits and investment adjustment costs. The economy is augmented with an imperfect banking sector by assuming that firms borrow indirectly from households through the banking sector that operates in an imperfect financial market. Financial frictions are twofold: i) Only a fraction of the households can access the credit market by financial intermediaries (limited–asset market participation assumption, LAMP henceforth).<sup>3</sup> ii) An agency problem between banks and their depositors implies that financial intermediaries are subject to endogenously determined balance sheet constraints that could limit the ability of non–financial firms to obtain investment funds (Gertler and Karadi, 2011).

The supply side of the economy is characterized by a retail competitive sector that combines intermediate goods produced by labor and capital to obtain the final consumption good. The final sector operates under imperfect competition and is subject to price stickiness. By contrast,

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<sup>3</sup> Among others, the relevance of liquidity constraints as an additional market imperfection has been highlighted by Galí *et al.* (2007), Di Bartolomeo and Rossi (2007), Coenen and Straub (2005), Forni *et al.* (2009), Di Bartolomeo *et al.* (2011), Albonico *et al.* (2017), and Ferrara and Tirelli (2017).

intermediate goods and capital producing firms operate in competitive markets. Intermediate firms borrow from the banks to acquire physical capital.

The intermediate goods sector is composed by a continuum of competitive producers. The typical firm uses labor inputs and capital to produce intermediate goods  $Y_t$  sold to retail firms, according to the following Cobb–Douglas technology:  $Y_t = A_t L_t^\alpha (u_t^k K_t)^{1-\alpha}$ , where  $\alpha \in (0,1)$  is the labor share,  $A_t$  represents the total factor productivity,  $L_t$  denotes labor inputs hired,  $K_t$  is the capital stock and  $u_t^k$  is the utilization rate of the capital. Capital acquisition is financed by borrowing from a financial intermediary.

Denoting the real wage by  $W_t$ , the real marginal cost by  $MC_t$ , the capital depreciation function by  $\delta(u_t^k)$ , and the market value of a unit of capital by  $Q_t$ , the firm's first–order conditions are:

$$W_t = \alpha MC_t Y_t / L_t$$

$$u_t^k = MC_t (1 - \alpha) \frac{Y_t}{\delta'(u_t^k) K_t}$$

$$R_{t+1}^R = \frac{MC_{t+1} (1 - \alpha) Y_{t+1} / K_{t+1} + Q_{t+1} - \delta(u_{t+1}^k)}{Q_t}$$

which implicitly define a labor and capital demand (utilization rate of the physical capital).

Capital producing firms act in perfect competition. At the end of period  $t$ , they buy capital from the intermediate sector repairing the depreciated capital and building new capital stock. Both the repaired and the new capital are then sold. A typical capital producing firm maximizes discounted profits, i.e.,  $\max E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \Lambda_{t,\tau} \left\{ (Q_\tau - 1) I_{N\tau} - \mathcal{F} \left( \frac{I_{N\tau} + I_{SS}}{I_{N\tau-1} + I_{SS}} \right) (I_{N\tau} + I_{SS}) \right\}$ , where  $\mathcal{F}(1) = \mathcal{F}'(1) = 0$  and  $\mathcal{F}''(1) > 0$ ,  $\beta \in (0,1)$  is the discount factor,  $\Lambda_{t,\tau}$  denotes the stochastic discount factor between  $t$  and  $\tau$ ,  $I_{Nt} \equiv I_t - \delta(u_t^k) K_t$  is the net capital created ( $I_t$  and  $I_{SS}$  are gross capital and its steady state) and  $Q_t$  should be interpreted as the Tobin's  $Q$ .

The first–order condition for investment then describes the following  $Q$  relation:

$$Q_t = 1 + \mathcal{F} \left( \frac{I_{Nt} + I_{SS}^O}{I_{Nt-1} + I_{SS}^O} \right) + \left( \frac{I_{Nt} + I_{SS}}{I_{Nt-1} + I_{SS}} \right) \mathcal{F}' \left( \frac{I_{Nt} + I_{SS}}{I_{Nt-1} + I_{SS}} \right)$$

$$- \beta E_t \Lambda_{t,t+1} \left( \frac{I_{Nt+1} + I_{SS}}{I_{Nt} + I_{SS}} \right)^2 \mathcal{F}' \left( \frac{I_{Nt+1} + I_{SS}}{I_{Nt} + I_{SS}} \right)$$

The domestic retail firms operate in an imperfect competition environment. Aggregation is obtained as follows:  $Y_t = \left[ \int_0^1 Y_t(j)^{(\varepsilon_p^d - 1)/\varepsilon_p^d} dj \right]^{\varepsilon_p^d / (\varepsilon_p^d - 1)}$ , where  $Y_t(j)$  is the domestic output by the domestic retailer  $j$  and  $\varepsilon_p^d$  is the elasticity of substitution between differentiated domestic goods.

In our setup, prices are sticky according to a Calvo mechanism (we denote by  $1 - \gamma_p^d$  the probability of being able to reset prices). The corresponding optimal domestic price adjustment and aggregate domestic inflation ( $\pi_t^{d,*}$ ) are then described by the following expressions:

$$\pi_t^{d,*} = \frac{\varepsilon_p^d}{\varepsilon_p^d - 1} \frac{\Upsilon_t^{d,p}}{\Xi_t^{d,p}} \pi_t^d$$

where  $\pi_t^d = P_t/P_{t-1} = \left[ \gamma_p^d (\pi_{t-1}^d)^{\gamma_{ind}^d (1 - \varepsilon_p^d)} + (1 - \gamma_p^d) (\pi_t^{d,*})^{1 - \varepsilon_p^d} \right]^{1/(1 - \varepsilon_p^d)}$  with the term  $\gamma_{ind}^d$  indicating the domestic degree of indexation to past inflation. Auxiliary variables  $\Upsilon_t^{d,p}$  and  $\Xi_t^{d,p}$  evolve as  $\Upsilon_t^{d,p} = Y_t MC_t + \beta \gamma_p^d E_t \Lambda_{t,t+1} (\pi_{t+1}^d)^{\varepsilon_p^d} (\pi_t^d)^{-\gamma_{ind}^d \varepsilon_p^d} \Upsilon_{t+1}^{d,p}$  and  $\Xi_t^{d,p} = Y_t + \beta \gamma_p^d E_t \Lambda_{t,t+1} (\pi_{t+1}^d)^{\varepsilon_p^d - 1} (\pi_t^d)^{\gamma_{ind}^d (1 - \varepsilon_p^d)} \Xi_{t+1}^{d,p}$ .

The export and import retail firms also face sticky prices; we denote by  $1 - \gamma_p^x$  and  $1 - \gamma_p^m$  the probability of being able to reset prices of the export and import retail firms, respectively.

Each of them faces the foreign demand for the domestic goods,  $X_t$ , i.e.,  $X_t(j) = \left[ \frac{P_t^x(j)}{P_t^x} \right]^{-\varepsilon_p^x} X_t$ , or the domestic demand for the foreign consumption,  $C_t^m$ , and investment,  $I_t^m$ , goods, i.e.,  $\Gamma_t(j) = \left[ \frac{P_t^m(j)}{P_t^m} \right]^{-\varepsilon_p^m} \Gamma_t$ ,  $\forall \Gamma_t = \{C_t^m, I_t^m\}$ . In analogy with the domestic retail firms, optimal price adjustments and aggregate inflation rates for the export ( $\pi_t^{x,*}$ ) and import ( $\pi_t^{m,*}$ ) optimal inflation for retail firms is described by the following expressions:

$$\pi_t^{l,*} = \frac{\varepsilon_p^l}{\varepsilon_p^l - 1} \frac{\Upsilon_t^{l,p}}{\Xi_t^{l,p}} \pi_t^l \quad \text{for } l = \{x, m\}$$

where  $\pi_t^l = \left[ \gamma_p^l (\pi_{t-1}^l)^{\gamma_{ind}^l (1 - \varepsilon_p^l)} + (1 - \gamma_p^l) (\pi_t^{l,*})^{1 - \varepsilon_p^l} \right]^{\frac{1}{1 - \varepsilon_p^l}}$ ; the parameter  $\varepsilon_p^l$  is the elasticity of substitution between differentiated  $l$ -type goods;  $\gamma_{ind}^l$  indicates the  $l$ -type goods' degree of indexation to past inflation. Auxiliary variables  $\Upsilon_t^{l,p}$  and  $\Xi_t^{l,p}$  respectively evolve as  $\Upsilon_t^{l,p} = Y_t MC_t^l + \beta \gamma_p^l E_t \Lambda_{t,t+1} (\pi_{t+1}^l)^{\varepsilon_p^l} (\pi_t^l)^{-\gamma_{ind}^l \varepsilon_p^l} \Upsilon_{t+1}^{l,p}$  and  $\Xi_t^{l,p} = Y_t +$

$\beta \gamma_p^l E_t \Lambda_{t,t+1} (\pi_{t+1})^{\varepsilon_p^l - 1} (\pi_t^l)^{\gamma_{ind}^l (1 - \varepsilon_p^l)} \Xi_{t+1}^{l,p}$ , where  $e_t$  defines the nominal exchange rate;  $MC_t^x = P_t^d / e_t P_t^x$  and  $MC_t^m = P_t^* e_t / P_t^m$  are the export and import marginal costs.

Households can be either liquidity constrained or not. However, apart from their ability to access to the financial market they share the same kind of preferences. Consumption can differ between liquidity constrained households ( $C_t^L$ ) and not constrained ones ( $C_t^O$ ). As in Galì *et al.* (2007), the aggregate consumption is  $C_t = (1 - \lambda)C_t^O + \lambda C_t^L$ , where  $\lambda$  is the fraction of LAMP households. By contrast, labor of both is supplied by a common central authority (trade union) in the labor market.

Formally, there is a continuum of households in the space  $[0,1]$ . The household  $i$ 's period preferences are  $\mathcal{U}(i)_t = (C(i)_t - h\bar{C}_{t-1})^{1-\sigma} / (1 - \sigma) - \chi L(i)_t^{1+\varphi} / (1 + \varphi)$ , where  $C_t$  and  $\bar{C}_t$  are household's and aggregate consumption,  $h \in [0,1)$  denotes the habits in consumption; parameter  $\chi$  measures the relative weight of the labor disutility;  $\varphi$  is the inverse Frisch elasticity of labor supply;  $\sigma$  is the relative risk-aversion coefficient.

Non-liquidity constrained households choose  $C_t^O$ ,  $B_t$ , and  $B_t^*$  to maximize  $\mathcal{W}_t^O = E_t \sum_{i=0}^{\infty} \beta^i \mathcal{U}_{t+i}$  being constrained by their budget constraint:  $C_t^O + B_{t+1} + e_t B_{t+1}^* = W_t L_t + \Pi_t + T_t + R_t B_t + e_t \Phi_t R_t^* B_t^*$ , where  $C_t^O$  is the consumption of the dynamic optimizer households,  $R_t$  and  $R_t^*$  are the gross real domestic and foreign return of one period real domestic and foreign bonds, respectively,  $B_t$  and  $B_t^*$  are the total quantity of short term domestic and foreign debt that the household acquires, respectively,  $\Pi_t$  are the net payouts to the household from ownership of both non-financial and financial firms and  $T_t$  is a lump sum net transfer. Finally,  $\Phi_t$  denotes the risk premium on foreign bond holdings given by  $\Phi_t = \exp [(R_t - R_t^*) - \phi_a A_t + u_t^\phi]$ , where  $A_t = e_t B_{t+1}^*$  denotes the net foreign assets (NFA) position,  $\phi_a$  denotes the risk premium elasticity to the NFA position and  $u_t^\phi$  is the risk premium shock on foreign bond holdings, which is assumed to follow a first order autoregressive stochastic process  $u_t^\phi = \rho_{uip} u_{uip,t-1}^\phi + \epsilon_{uip,t}$ .

Solving the non-liquidity constrained household's optimization problem, the first-order conditions for consumption,  $C_t^O$ , domestic and foreign bond holdings,  $B_t$  and  $B_t^*$  respectively, are:

$$q_t^O = (C_t^O - hC_{t-1}^O)^{-\sigma} - \beta h E_t (C_{t+1}^O - hC_t^O)^{-\sigma}$$



$$E_t \beta \Lambda_{t,t+1} R_{t+1} = 1$$

$$e_t E_t R_{t+1} = E_t e_{t+1} \Phi_{t+1} R_{t+1}^*$$

where  $\Lambda_{t,t+1} = \varrho_{t+1}^0 / \varrho_t^0$  denotes the stochastic discount rate.

Instead, LAMP households choose  $C_t^L$  to maximize  $\mathcal{W}_t^L = E_t \sum_{i=0}^{\infty} \beta^i \mathcal{U}_{t+i}$ , constrained by  $C_t^L = W_t L_t + T_t$ . According to the budget constraint, their optimal consumption is simply equal to

$$C_t^L = W_t L_t + T_t$$

and their marginal utility of consumption is

$$\varrho_t^L = (C_t^L - h C_{t-1}^L)^{-\sigma} - \beta h E_t (C_{t+1}^L - h C_t^L)^{-\sigma}.$$

The aggregate demand for consumption goods is obtained using a CES aggregator of domestically produced and imported consumption,  $C_t$ , and investment,  $I_t$ , i.e.,  $C_t =$

$$\left[ (1 - \nu)^{\frac{1}{\eta}} (C_t^d)^{\frac{\eta-1}{\eta}} + \nu^{\frac{1}{\eta}} (C_t^m)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \quad \text{and} \quad I_t = \left[ (1 - \nu)^{\frac{1}{\eta}} (I_t^d)^{\frac{\eta-1}{\eta}} + \nu^{\frac{1}{\eta}} (I_t^m)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \quad \text{where,}$$

from households' cost minimization problem, the demand for domestic and foreign produced consumption and investment goods are given by  $C_t^d = (1 - \nu) [P_t^d / P_t]^{-\eta} C_t$ ,  $I_t^d = (1 - \nu) [P_t^d / P_t]^{-\eta} I_t$ ,  $C_t^m = \nu [P_t^m / P_t]^{-\eta} C_t$  and  $I_t^m = \nu [P_t^m / P_t]^{-\eta} I_t$  respectively, where  $\nu$  denotes the home bias parameter and  $\eta$  is the elasticity of substitution between domestic and imported goods.  $P_t^d$  and  $P_t^m$  denote the price indexes of domestic and imported goods, respectively, such

$$\text{that: } P_t = \left[ (1 - \nu) (P_t^d)^{1-\eta} + \nu (P_t^m)^{1-\eta} \right]^{\frac{1}{1-\eta}}.$$

The banking sector is borrowed from Gertler and Karadi (2011). Each dynamic optimizer household is composed by workers and bankers. The workers supply labor and redistribute their labor income within their household. Each banker manages a financial intermediary and returns its earnings back to its family. Banks are owned by the fraction of households that are dynamic optimizers as well. Each period a fraction  $\theta$  of bankers survives while a fraction  $1 - \theta$  exits and is replaced.

Each banker can divert a fraction  $\zeta$  of funds to its household. Diverting assets can be profitable for a banker who can then default on his debt and shut down, and correspondingly represent a loss for creditors who could reclaim the fraction  $1 - \zeta$  of assets, at most.

Financial intermediaries obtain  $B_{jt+1}$  funds from the dynamic optimizer households (short-term liabilities) and lend them to non-financial firms (holding long-term assets). Each bank faces a quantity of financial claims  $S_{jt}$  by the non-financial firms and owns an amount of net worth denoted by  $N_{jt}$ . Thus, the balance sheet of an intermediary is  $Q_t S_{jt} = N_{jt} + B_{jt+1}$ , where  $Q_t$  is the relative price of a financial claim.

The bank pays back a real gross return  $R_{t+1}$  on the funds obtained from the household and earns the stochastic return  $R_{kt+1}$  on the loans to non-financial firms.  $N_{jt}$  can be thought as the intermediaries' equity capital and it is obtained as the difference between the earnings on assets ( $R_{kt+1} Q_t S_{jt}$ ) and interest payments on liabilities ( $R_{t+1} B_{jt+1}$ ). Hence:

$$N_{jt+1} = (R_{kt+1} - R_{t+1}) Q_t S_{jt} + R_{t+1} N_{jt}.$$

The term  $(R_{kt+1} - R_{t+1})$  represents the premium that the banker earns on his assets.

Each banker's objective is to maximize the expected discounted present value of its future flows of net worth  $N_t$ , that is:  $V_t = E_t \sum_{i=0}^{\infty} (1 - \theta) \theta^i \beta^{i+1} \Lambda_{t,t+1+i} N_{jt+i}$ .

A moral hazard problem is assumed to avoid that in presence of positive premium the bankers will expand their loans indefinitely. Therefore, depositors would restrict their credit to banks as they realize that  $V_{jt} \geq \zeta Q_t S_{jt}$  must hold for the banks to prevent them from diverting funds (incentive constraint), i.e., the potential loss of diverting assets (l.h.s.) should be greater than the gain from doing so (r.h.s.). Furthermore,  $V_{jt}$  can be expressed as  $V_{jt} = v_t Q_t S_{jt} + \eta_t N_{jt}$ , where  $\eta_t$  represents the expected discounted value of having an additional unit of net worth and  $v_t$  must be interpreted as the expected discounted marginal gain to the banker of expanding assets  $Q_t S_{jt}$  by a unit.

As a result, the financial intermediary can acquire assets accordingly to his equity capital:

$$Q_t S_{jt} = \frac{\eta_t}{\zeta - v_t} N_{jt} = \phi_t N_{jt}$$

where  $\phi_t$  is the private leverage ratio, i.e., the privately intermediated assets to equity ratio.

The implied expected discounted marginal gain ( $v_t$ ) to the banker of expanding assets,  $Q_t S_t$ , by a unit and the expected discounted value ( $\eta_t$ ) of having another unit of  $N_t$  keeping fixed  $S_t$  can be expressed as:<sup>4</sup>

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<sup>4</sup> For a wider discussion about the agency problem and the implied evolution of  $v_t$  and  $\eta_t$ , see Gertler and Karadi

$$v_t = E_t\{(1 - \theta)\beta\Lambda_{t,t+1}(R_{kt+1} - R_{t+1}) + \beta\Lambda_{t,t+1}\theta x_{t,t+1}v_{t+1}\}$$

$$\eta_t = E_t\{(1 - \theta) + \beta\Lambda_{t,t+1}\theta z_{t,t+1}\eta_{t+1}\}$$

where  $x_{t,t+1} = z_{t,t+1}\phi_{t+1}/\phi_t$  and  $x_{t,t+1} = (R_{kt+1}/R_{t+1} - 1)\phi_t$ .

Labor markets are imperfect. Sticky wages are set by monopolistic unions, who represent differentiated labor inputs provided by both dynamic optimizers and LAMP agents. Labor unions set the nominal wages facing nominal rigidities *à la* Calvo. Labor is aggregated according to a Dixit–Stiglitz function, where we indicate the elasticity of substitution between labor inputs by  $\varepsilon_w$ .

Formally, a typical union chooses the optimal nominal wage  $W_t^*$  to maximize a weighted utility  $\sum_{j=0}^{\infty}(\gamma_w\beta)^j \left\{ W_t^* \left( \frac{W_t^*}{W_{t+j}} \right)^{-\varepsilon_w} L_{t+j} q_{t+j} - \frac{\chi}{1+\varphi} \left[ \left( \frac{W_t^*}{W_{t+j}} \right)^{-\varepsilon_w} L_{t+j} \right]^{1+\varphi} \right\}$ , where  $q_t = \lambda q_t^L + (1 - \lambda)q_t^O$ .

Solving the above problem, we obtain the adjustment dynamics for wage inflation

$$\pi_t^{w*} = \frac{\varepsilon_w}{\varepsilon_w - 1} \frac{\Upsilon_t^w}{\Xi_t^w} \pi_t^w$$

where  $\pi_t^{w*} = W_t^*/W_{t-1}$  and  $\pi_t^w = W_t/W_{t-1} = \left[ \gamma_w(\pi_{t-1}^w)^{1-\varepsilon_w} + (1 - \gamma_w)(\pi_t^{w*})^{1-\varepsilon_w} \right]^{\frac{1}{1-\varepsilon_w}}$  with  $\gamma_w$  being the probability to keep the wage unchanged in the future. Auxiliary variables  $\Upsilon_t^w$  and  $\Xi_t^w$  evolve according to  $\Upsilon_t^w = U_{L,t}L_t + \gamma_w\beta E_t(\pi_{t+1}^w)^{\varepsilon_w}\Upsilon_{t+1}^w$  and  $\Xi_t^w = W_tL_t[\lambda q_t^L + (1 - \lambda)q_t^O] + \gamma_w\beta E_t(\pi_{t+1}^w)^{\varepsilon_w-1}\Xi_{t+1}^w$ .

The economy–wide resource constraint is given by

$$Y_t = C_t^d + C_t^x + I_t^d + I_t^x + G_t$$

$$+ \frac{\psi}{2} \left( \frac{I_t^N + I_{SS}}{I_{t-1}^N + I_{SS}} - 1 \right)^2 (I_t^N + I_{SS})$$

where  $\psi$  indicates the elasticity of investment adjustment cost and government expenditures  $G_t$  are financed by lump sum taxes  $G_t = T_t$ .

The market clearing condition in the foreign bond market requires that, at the equilibrium, the equation for NFA evolution is satisfied:

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(2011).

$$e_t B_{t+1}^* = P_t^x (C_t^x + I_t^x) - e_t P_t^* (C_t^m + I_t^m) + e_t \Phi_t R_t^* B_t^*$$

The total value of intermediated assets is:

$$Q_t S_t = \phi_t N_t.$$

Finally, the nominal interest rate  $i_t$  follows a simple Taylor rule with interest rate smoothing:

$$i_t = \rho i_{t-1} + (1 - \rho)(\kappa_\pi \pi_t + \kappa_y y_t) + \kappa_{\Delta\pi} \Delta\pi_t + \kappa_{\Delta y} \Delta y_t$$

where  $\kappa_\pi$  and  $\kappa_y$  measure the response of the monetary authority to the inflation rate and to the output gap;  $\kappa_{\Delta\pi}$  and  $\kappa_{\Delta y}$  measure the response to their variations.

### 3. Empirical analysis

#### 3.1 Data and methodology

We estimate our model, using Bayesian techniques, for a group of six CEB countries, namely: Czech Republic, Estonia, Hungary, Lithuania, Poland, and Slovakia. Our choice for this methodology is motivated by the fact that Bayesian methods outperform GMM and maximum likelihood in small samples.<sup>5</sup> The sample we consider spans from 2002:Q1 to 2016:Q3 for all the countries.

After writing the model in state-space form, the likelihood function is evaluated using the Kalman filter, whereas prior distributions are used to introduce additional non-sample information into the parameters estimation. Once a prior distribution is elicited, the posterior density for the structural parameters can be obtained by reweighting the likelihood by a prior. The posterior is computed using numerical integration by employing the Metropolis-Hastings (MH) algorithm for Monte Carlo integration. All structural parameters are supposed to be independent of one another. The mean and posterior percentiles are derived from two chains of 200,000 draws each from the MH algorithm (we discarded the initial 30% of draws). The scale for the jumping distribution in MH algorithm has been calibrated in order to achieve an acceptance rate around 25%.

For each country we perform the estimation by using eleven observable macroeconomic variables: real GDP, real consumption, real investment, export, import, real wage, price

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<sup>5</sup> For an exhaustive analysis of Bayesian estimation methods, see Geweke (1999), An and Schorfheide (2007) and Fernández-Villaverde (2010).

inflation, CPI inflation, import inflation, export inflation, and nominal interest rate.<sup>6</sup> All the data are drawn from the OECD database. The dynamics are driven by eleven orthogonal shocks, including monetary policy, productivity, domestic demand, domestic price mark-up, import price mark-up, export price mark-up, wage mark-up, capital quality, foreign GDP, risk premium, CPI inflation. As the number of observable variables equals the number of exogenous shocks, the estimation does not present problems deriving from stochastic singularity.<sup>7</sup>

Real variables are obtained using the CPI deflator. Inflation measures are obtained as the log-difference of the correspondent deflators, whereas we use the compensation rate as a measure for the wage. Short-term rates are used as a proxy for the nominal interest rate. Data exhibiting a trend have been filtered using a linear trend as in Smets and Wouters (2007). Data exhibiting a non-zero mean like inflation and nominal interest rate have been demeaned.

As common practice in Bayesian estimation, several parameters are calibrated and ruled out from the estimation. The discount factor  $\beta$  is set to 0.99; the capital share  $\alpha$  is 0.33; the depreciation rate  $\delta$  is calibrated to 0.025, implying an annual capital depreciation of 10%; the ratio of public spending over GDP is 20%.

Prior distributions are elicited according to the following rules: standard errors of the shocks follow an *Inverse Gamma* distribution with mean 0.1 and 2 degrees of freedom; the autoregressive coefficients of the shocks follow a *Beta* distribution centered on 0.5 and with standard deviation equal to 2. For the parameters with support on the interval [0,1], like, e.g., the smoothing parameter of the Taylor rule, the fraction of LAMP households, and the Calvo prices, a *Beta* distribution has been assigned; feedback parameters of the Taylor rule and investment adjustment cost follow a *Normal* distribution.

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<sup>6</sup> As, among others, Justinaino *et al.* (2010) or Gambetti *et al.* (2017), the vector of observables does not include financial variables. Their inclusion may lead to no clear improvement over the New Keynesian benchmark in terms of marginal likelihood and similarity of impulse responses to those obtained from a VAR (for a detailed discussion, see Brzoza-Brzezina and Kolasa, 2010). Moreover, in the economies of the considered region, the dynamics of domestic financial variables are more related to external factors than domestic ones.

<sup>7</sup> The problems deriving from misspecification are widely discussed in Lubik and Schorfheide (2006) and Fernández-Villaverde (2010).

## 3.2 Estimation results

### 3.2.1 Structural and stochastic features of CEB economies

Estimations of the structural parameters of our CEB economies are reported in Table 1 and 2. Tables only report posteriors.<sup>8</sup> The posterior distributions are obtained using the MH algorithm. Table 1 reports the estimation of structural parameters, whereas Table 2 reports the stochastic structure (variability and persistence of shocks). Both tables report posteriors for each country and the area average and standard deviations since we are interested in the relative performance of the area countries. We stress in bold country values above the area average.<sup>9</sup>

Table 1 – Posterior estimates (structural parameters)

	Czech Rep.	Estonia	Hungary	Lithuania	Slovakia	Poland	Mean	S.d.
Deep parameters								
$\sigma$	<b>1.92</b>	<b>1.93</b>	<b>1.97</b>	1.69	1.46	<b>2.22</b>	1.86	0.26
$\varphi$	<b>2.07</b>	<b>1.96</b>	<b>3.29</b>	<b>2.49</b>	0.25	0.25	1.72	1.23
$h$	0.80	<b>0.89</b>	<b>0.87</b>	0.80	0.79	<b>0.87</b>	0.83	0.04
Nominal frictions and indexation								
$\gamma_p^d$	<b>0.86</b>	<b>0.84</b>	0.44	<b>0.88</b>	<b>0.92</b>	<b>0.93</b>	0.81	0.19
$\gamma_p^m$	0.44	0.45	<b>0.79</b>	0.31	<b>0.66</b>	0.41	0.51	0.18
$\gamma_p^x$	<b>0.79</b>	0.65	<b>0.73</b>	0.45	<b>0.82</b>	<b>0.90</b>	0.72	0.16
$\gamma_w$	<b>0.90</b>	<b>0.89</b>	0.58	<b>0.84</b>	<b>0.94</b>	0.70	0.81	0.14
$\gamma_{ind}^d$	<b>0.26</b>	0.17	0.17	<b>0.18</b>	0.16	0.16	0.18	0.04
$\gamma_{ind}^m$	0.28	0.29	<b>0.68</b>	0.26	0.31	0.23	0.34	0.17
$\gamma_{ind}^x$	<b>0.22</b>	<b>0.27</b>	0.18	<b>0.26</b>	<b>0.24</b>	0.16	0.22	0.04
$\gamma_{ind}^w$	0.35	0.29	<b>0.59</b>	<b>0.61</b>	0.36	<b>0.51</b>	0.45	0.14
Real frictions								
$\lambda$	0.17	<b>0.28</b>	<b>0.25</b>	<b>0.26</b>	0.14	0.05	0.19	0.09
$\psi$	<b>5.91</b>	5.78	<b>6.26</b>	5.58	5.78	5.47	5.80	0.28
$\eta$	1.38	<b>1.90</b>	<b>1.91</b>	1.00	<b>2.15</b>	<b>2.78</b>	1.85	0.62
$\eta^*$	<b>1.17</b>	<b>1.26</b>	0.61	<b>1.22</b>	<b>1.23</b>	<b>1.46</b>	1.16	0.29
$\phi_a$ (x10)	<b>0.09</b>	0.01	<b>0.09</b>	<b>0.09</b>	<b>0.10</b>	<b>0.10</b>	0.08	0.03
$z$	7.44	<b>8.37</b>	6.40	7.13	<b>8.03</b>	<b>10.00</b>	7.90	1.24
Monetary policy parameters								
$\kappa_\pi$	<b>2.50</b>	<b>2.36</b>	1.91	<b>2.46</b>	1.54	<b>2.41</b>	2.20	0.39
$\kappa_y$	0.00	0.00	0.00	0.03	<b>0.17</b>	0.03	0.04	0.06
$\kappa_{\Delta y}$	<b>0.08</b>	0.00	0.03	0.01	<b>0.08</b>	0.03	0.04	0.03
$\kappa_{\Delta \Pi}$	<b>0.33</b>	<b>0.29</b>	0.09	<b>0.22</b>	0.08	0.16	0.20	0.10
$\rho$	<b>0.43</b>	<b>0.23</b>	0.20	0.20	0.12	0.19	0.23	0.11

<sup>8</sup> For each country, we report priors (mean and density) and posteriors (with their [5th, 95th] probability intervals), and the log–marginal likelihood for each country.

<sup>9</sup> Details on country estimations are reported in Appendix A: Tables A1-A6.

The estimated habit parameter and the coefficient of relative risk aversion are similar among countries and in line with other studies (see, e.g., Smets and Wouters, 2003, 2007). Some differences arise for the inverse of the Frisch labor supply elasticity: in particular, in Hungary and Lithuania estimated values are strongly above the average, while in Slovakia and Poland they are strongly below the average.

Apart from Hungary, in all countries prices and wages are quite sticky as they adjust, on average, every 5-10 quarters. Our estimation suggests that prices and wages are partially indexed to lagged inflation. Therefore, when the economy is perturbed by a shock, these variables slowly revert to the steady state. The limited asset market participation is estimated around 20% (except for Poland where it is close to zero).

The large fraction of LAMP entails that positive public spending shock can positively affect public consumption, avoiding crowding out effects. Regarding monetary policy, the central bank is aggressive in contrasting inflation in all countries, whereas its response to the output gap, apart in Slovakia, is negligible. The degree of interest rate smoothing is large in all the countries of the region and in line with the DSGE literature, where it is usually estimated to values greater than 0.7 (see, e.g., Smets and Wouters, 2003, 2007).

Table 2 reports the posterior estimations of the stochastic structure. As expected, we observe a high degree of autocorrelation for the technology shock. Capital quality shocks are important for mimicking the effects of a financial crisis. As we can see from the table, there is heterogeneity in their estimates. Concentrating on the volatility, expressed by the standard deviation, capital quality shocks have exhibited small variance in Hungary and Poland, compared with the sample mean. Its standard deviation is instead around double than the sample mean in Slovakia. Difference among countries are associated also with the persistence of the capital quality shock. A high persistence is estimated for Hungary, Lithuania, and Poland, whereas in the remaining countries the degree of inertia is small.

Table 2 – Posterior estimations (stochastic structure)

	Czech Rep.	Estonia	Hungary	Lithuania	Slovakia	Poland	Mean	S.d.
$e_a$	1.85	3.68	0.61	<b>4.73</b>	<b>5.85</b>	<b>7.80</b>	4.09	2.63
$e_g$	19.90	<b>38.28</b>	16.70	<b>23.18</b>	19.29	21.26	23.10	7.74
$e$	0.30	<b>0.42</b>	0.25	<b>0.56</b>	0.32	0.16	0.33	0.14
$e_\psi$	2.95	<b>4.45</b>	0.63	<b>4.41</b>	<b>7.83</b>	0.84	3.52	2.69
$e_{\mu pd}$	8.30	8.28	3.55	<b>13.65</b>	<b>17.21</b>	7.94	9.82	4.84
$e_{\mu pm}$	2.88	3.67	<b>19.85</b>	<b>9.02</b>	7.66	5.80	8.15	6.19
$e_{\mu px}$	<b>11.32</b>	6.89	4.69	8.41	<b>12.85</b>	<b>14.84</b>	9.83	3.83
$e_{\mu w}$	14.69	18.82	10.25	16.77	<b>33.58</b>	<b>24.59</b>	19.78	8.25
$e_\Pi$	1.15	1.21	<b>1.92</b>	<b>2.67</b>	1.39	0.99	1.55	0.63
$e_{ui p}$	3.32	<b>5.76</b>	3.46	4.19	4.46	<b>5.64</b>	4.47	1.05
$e_{y^*}$	4.42	<b>5.85</b>	3.85	<b>7.38</b>	5.19	<b>6.21</b>	5.48	1.28
$\rho_a$	<b>0.97</b>	0.58	<b>0.99</b>	<b>0.89</b>	0.76	0.73	0.82	0.16
$\rho_g$	0.79	0.82	0.83	0.79	<b>0.87</b>	<b>0.95</b>	0.84	0.06
$\rho$	0.80	0.82	<b>0.90</b>	<b>0.86</b>	<b>0.86</b>	<b>0.89</b>	0.85	0.04
$\rho_\psi$	0.38	0.12	<b>0.90</b>	<b>0.67</b>	0.32	<b>0.84</b>	0.54	0.31
$\rho_{\mu pd}$	0.10	0.13	<b>0.89</b>	0.13	0.12	0.12	0.25	0.31
$\rho_{\mu pm}$	<b>0.73</b>	0.59	0.47	<b>0.83</b>	0.23	<b>0.85</b>	0.62	0.24
$\rho_{\mu px}$	0.14	0.17	<b>0.83</b>	<b>0.86</b>	0.23	0.13	0.40	0.35
$\rho_{\mu w}$	0.38	0.37	<b>0.95</b>	0.42	0.31	0.51	0.49	0.24
$\rho_{ui}$	0.07	0.14	<b>0.24</b>	0.09	<b>0.34</b>	<b>0.35</b>	0.20	0.12
$\rho_{ui p}$	0.81	0.75	<b>0.88</b>	0.73	<b>0.88</b>	<b>0.92</b>	0.83	0.08
$\rho_{y^*}$	0.80	<b>0.90</b>	<b>0.91</b>	0.84	<b>0.90</b>	<b>0.93</b>	0.88	0.05

### 3.2.2 The recession drivers

By using our Bayesian estimation is also possible to analyze the contribution of the various shocks to the booms and busts in all the regions considered during the sample period, i.e., we can compare which shocks have mainly driven the output growth both in expansions and recessions along our sample. In our analysis, we mainly focus on determinants of the recent crisis and 90s recessions that hit the economies of the CEB region.

Figure 1 provides a historical decomposition of the GDP growth to check the shocks that have driven the fluctuations of the economy along years for our sample of estimated countries. Historical decompositions of the output growth for each country are plotted in panels (a)-(f) considering a semiannual basis. The black solid line depicts the actual series of the GDP growth, while the colored rectangles represent the (positive or negative) contribution of each single shock to the output growth. *Demand* labels shocks to the domestic demand (including public spending) and foreign GDP; the label *mark-up* groups all the shocks to price and wage



mark-up; other disturbances considered are discretionary monetary policies, capital quality and TFP.

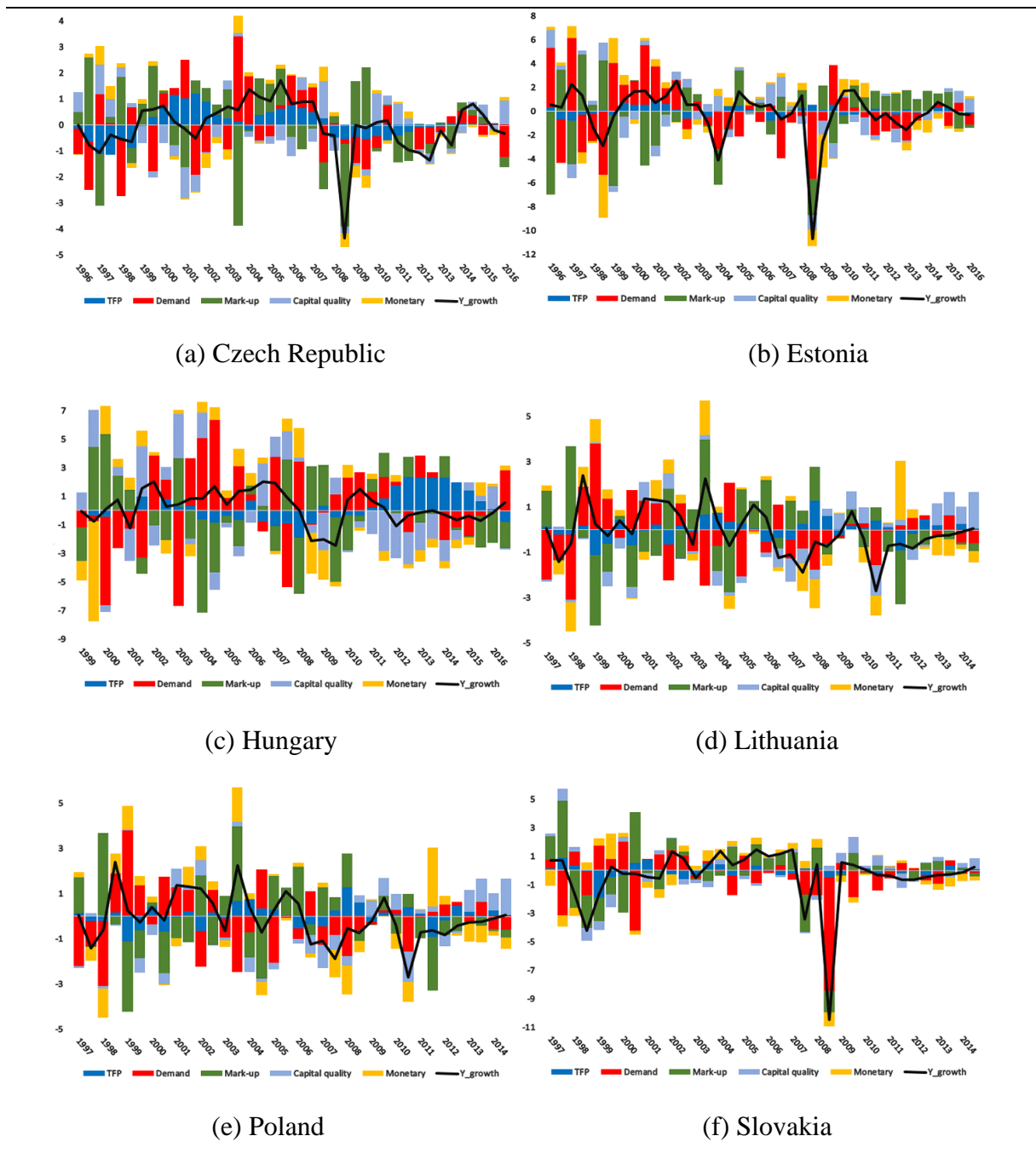


Figure 1 - GDP growth historical decomposition

We begin our investigation from the Czech Republic. In the region, together with Poland, Czech Republic is one of the economies that suffered the crisis less.<sup>10</sup> Figure 1(a) shows that the growth in the half-mid of the 2000s was driven by demand factors and positive TFP shocks. The big fall of 2009 was mainly due to negative mark-up shocks, but capital quality and restrictive monetary policy have also played some role. In late 2013, the Czech National Bank intervened to weaken the exchange rate of the official currency, namely the Czech koruna, through a monetary stimulus in order to stop the currency from excessive strengthening and to contrast deflation. Overall, the Czech economy imported the global crisis from Western Europe and its propagation was mainly driven by supply factors. Largest companies of the Czech Republic by revenue are in fact automobile manufacturers, which suffered from the lower external demand for intermediate and capital goods in 2008. Instead the financial system resulted to be less vulnerable than its counterparts in the area.

After 2000, Hungary turned into one of the worst performing countries of the region, before it was a regional champion of post-socialist economies (see Figure 1(b)). The spread of financial crisis revealed the extent its vulnerabilities. Negative mark-up and demand shock have driven the big recession of the 2008-09. Here, the 2006 demand fall was strongly driven by the fiscal adjustment package and the EU-approved convergence plan launched after the election to cut the budget deficit.

In Estonia, negative mark-up and demand shock have driven the big recession of the 2007-08 (cf. see Figure 1(c)). Here the abrupt decrease of the GDP can be related to an unsustainable economic growth model based on foreign loans and domestic consumption, weakened by a dominance of the Nordic banking groups (Raagma, 2010: 88). In Estonia demand factor were among the determinant of the recession of 1998 triggered by the Russian financial crisis; monetary policy shocks also played an important role.<sup>11</sup>

Before the financial crisis Lithuanian GDP experienced strong real growth rates, as a result, the country was often dubbed as a Baltic Tiger. However, the country's real GDP contracted by 14.9% in 2009. The slump was driven by a mix of internal and external factors. Excessive

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<sup>10</sup> The Czech economy entered the transition period in a relatively favorable position because of its attractive geographical position and the low external debt. It is characterized by a rather independent central bank since 1993 and expected a recent reform of the banking system based on the integration of supervision in 2005 and functional re-organization (consolidated supervision of all segments of financial system since 2006).

<sup>11</sup> A similar path is observed for Lithuania. The relevance of trade flows for Baltic countries during the 1995–2004 period is also stressed by Bems and Hartelius (2006). They also underline the potential explanatory power of a real interest rate risk premium.

housing boom (the price of real estate has tripled since 2002) and pessimistic expectations probably sustained capital quality shocks, which are estimated to be important, even partially offset by positive TFP changes (see Figure 1(d)). The European concentration of export also played a relevant role in the weaker performance trade of Lithuania during the crisis, which is structurally very vulnerable from outside because a large proportion of its economy depends on export-import relations (Burneika, 2010: 130).<sup>12</sup>

The Polish case is a sort of outlier, as it is only CEE country which has not noted an absolute decline of its GDP. Its relative stability is largely related to the large domestic market and EU funds for financing of infrastructure investments and other regional projects.<sup>13</sup> Negative capital quality shock (associated with falling demand and restrictive monetary policies) is the driving force for weaker performance of late 2009-early 2010 (Figure 1(e)). The following recover has been due to an improvement of the financial conditions. Looking at broader perspective, at the beginning of our sample, late 1990s, the Polish business cycle was mainly affected by monetary and demand shocks. However, Poland's economy has been the most resilient among the post-Communist countries. The Polish crisis has been termed as a velvet crisis due to preexisting favorable economic conditions compared to other neighboring countries. Among others, these are a weaker exposure to foreign currencies, a lower dependence on exports, less growing property bubbles and the flexible exchange rate regime.

Finally, we look at the case of Slovakia, which joined the European Union in 2004 and the Eurozone on 2009. Figure 1(f) shows the dramatic fall in GDP since the late 2008. The fall is mainly due to a collapse of the external demand. Apparently, it seems that the domestic financial sector cannot be counted among the sources of the crisis. As emphasized by Bucek (2010: 193), "the crisis in Slovakia is above all a response to the external global economic crisis" and "no problems have been reported related to the financial crisis in Slovak banks caused by an excess of bad credits or mortgages" (Bucek, 2010: 195). Demand disturbances together with negative mark-up and capital quality shocks were responsible of the 1998 recession, when after election, the new government was obliged to reduce previous period excessive government investment for the purposes of debt consolidation. After the crisis, Slovakia's economy recovered and exhibits robust economic performance where international

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<sup>12</sup> Lithuanian exports are about 75% of GDP, more than half of them are sold to six countries: Russia, Latvia, Poland, Germany, Estonia, and Belarus.

<sup>13</sup> It is worth mentioning the UEFA European Football Championship organized in Poland in 2012 and the related infrastructure investments.

competitiveness, fiscal and financial stability and ample foreign direct investment are all contributors. GDP growth almost reached 4 per cent on average in 2015.

Overall, the slump induced by the financial crisis has similar qualitative dynamics in Poland, Slovakia, Estonia, and Lithuania, where it is strongly driven by domestic or external demand factors, further supported (in all the country) by monetary factors. The specific capital quality shock seems to be more relevant for relatively larger countries characterized by greater domestic financial markets (Poland and Hungary). However, in the case of Hungary, the effects of financial turmoil were crowded out by improvement in productivity, which characterized the period 2010-2015. Czech Republic is an outlier suffering more from supply side factors. Czech financial sector practices and policies have been a source of stability during the financial crisis. Its resilience to financial disturbances probably reflected a sound regulatory system in the domestic financial sector, which benefitted from a consolidation program started in the mid-1990s.

#### **4. Resilience in CEB region**

This section derives some measures of resilience across countries populating the CEB area and investigates the relative performances of these countries. “A resilient society is able to cope with and react to shocks or persistent structural changes by either resisting to it (absorptive capacity) or by adopting a degree of flexibility and making small changes to the system (adaptive capacity).” (Manca *et al.*, 2017). A useful taxonomy of resilience is provided by Martin (2012), who summarizes it in four dimensions. i) Resistance as the degree of sensitivity or depth of reaction of regional economy to a recessionary shock; ii) Recovery as the speed and degree of recovery of regional economy from a recessionary shock; iii) Renewal as the extent to which regional economy renews its growth path: resumption of pre-recession path or hysteretic shift to new growth trend.; iv) Re-orientation as the extent of re-orientation and adaptation of regional economy in response to recessionary shock.<sup>14</sup>

Our paper matches the first two above dimensions, whereas it is only indirectly related to the others. We evaluate the absorptive and adaptive capacities of the CEE region and, somehow, its ex-post transformative capacity, i.e., the capacity of CEE economies to have implemented

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<sup>14</sup> Notwithstanding the growing interest, the concept of resilience is associated to some ambiguities. Ambiguities are related to the different uses and interpretations of the term. However, ambiguities should not be the rush to dismiss the concept, they vanish once that a clear definition is assumed (Martin, 2012).

in the past crises changes that permit them to cope with the recent global turmoil. Specifically, we use our estimation to quantify the relative vulnerability or sensitivity of economies within CEB region to disturbances and disruptions (resistance) and the speed and extent of recovery from such a disruption or recession (recovery). First, we built two different kinds of measures of resilience by aggregating the estimated parameters through non-centered and centered principal component analysis. Then, we use our model to investigate the relation between financial shock and CEB resilience.

We begin by investigating the differences of estimated parameters (Table 1 and 2) across countries in the CEB region by using PCA. The main idea of PCA is to reduce the dimensionality of data that may contain correlated variables, while retaining as much as possible of its variability. We adopt two kinds of PCAs in our analysis: non-centered and centered PCA. The difference between the two is in the reference used to compute the data variability. The former implies an all-zero point (vector) of reference: A country without distortion (if the selected parameters measure distortions, cf. Table 1)<sup>15</sup> and/or a country unaffected by shocks (if the selected parameters measure shock persistence and variability, cf. Table 2). By contrast, centering, or normalizing, by variables shifts the reference point (origin) to a hypothetical average stand.

Summarizing, when centering is adopted, the analysis focuses on the eventual deviation from an “average” kind of CE country.

1. Non-centered PCA elaborates Table 1 and 2 by investigating more deeply the multidimensional aspect of resilience. By applying non-centered PCA, we eliminate some non-informative correlation between countries’ parameters. Such a cleaning procedure generates a neater index for resilience in terms of recovery and resistance. The index of recovery is obtained applying PCA to a subset of estimated parameters from Table 1, precisely those that measure real or nominal adjustment costs. Hence, the reference of PCA in such a case is a near flexible economy. The index of resistance is obtained by applying non-centered PCA to the parameters estimate in Table 2. Thus, here the reference is a near steady state economy as there are no shocks and no persistence of them.

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<sup>15</sup> Note that not all estimated parameters of Table 1 measure distortions.

2. Centered PCA instead focuses on all the structural parameters reported in Table 1. As said, it aims to explain the variability of CEB countries' parameters with respect to the case of an "average" kind of CEB country.<sup>16</sup> Here, the variability across the 22 parameters for each country is reduced to few uncorrelated indexes (three), which however retain a large part of their variability. Differently, from the case of the non-centered PCA, the principal components need to be interpreted in their economic meaning which is not trivial.

Our results are described in Table 3 and Figure 2 and 3 (which report the outcomes of non-centered and centered PCA). In the main text we focus on the economic interpretation of PCA.<sup>17</sup>

We begin with the non-centered PCA analysis. The first two main components obtained from two PCAs are the recovery and the resistance index of resilience. The former is obtained from Table 1, considering subset of parameters which can be associated to nominal and real rigidities according to which the economic structure diverges from the efficient competitive equilibrium with flexible prices and wages (the subset is listed in Table 3). The latter uses all the estimated parameters from Table 2 (shock persistence and variances). As usual in non-centered analysis, the first components explain a large part of the variability (99.1% and 99.2%, respectively). The country differences are instead illustrated in Figure 2.

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<sup>16</sup> Information regarding the absolute values is not lost, but it is synthesized in the means that in such a case must be taken into account in the data analysis (see Noy-Meir 1973).

<sup>17</sup> Details are reported in Appendix B.

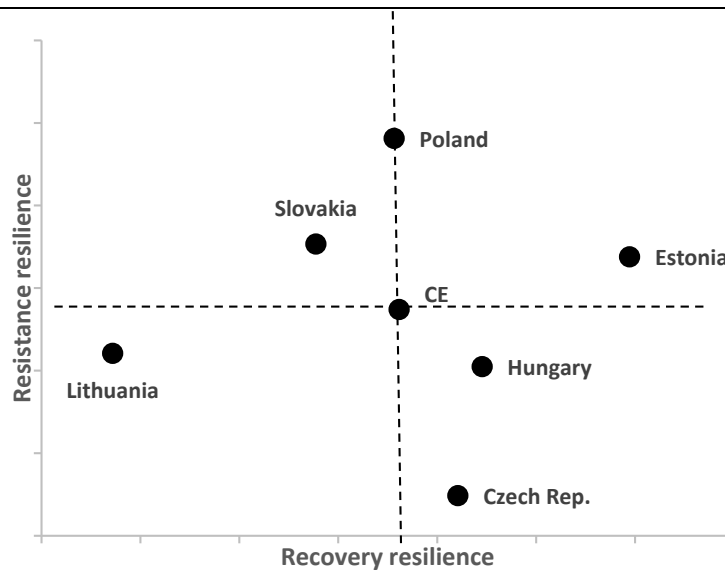


Figure 2 – Recovery and resistance indexes

The recovery index and the resistance index are depicted in Figure 2. Low values correspond to high resilience. CE indicates the position of the average country. Comparing the countries' resistance and recovery indexes to the benchmark (CE), Figure 2 shows that CEB countries exhibit quite similar values for their recovery index, meaning that they have similar economic structures. By contrast, Baltic countries are outliers placed at two extreme positions (Lithuania is relatively more flexible than Estonia). The opposite occurs for the resistance index. Baltic countries have a similar ranking, whereas Central European countries exhibit large differences. Czech Republic and Hungary are less exposed to disturbances than Slovakia and Poland.

Now we look at the structural differences entailed in Table 1. The centered PCA individuates three principal components that explain about the 77% of the estimated deep parameter variability. Specifically, the first component explains the 31%; the second component explains about the 26% of data variability; the third component explains the 19% of data variability. The components are explained below, and the exact weights (or loadings) associated with them are reported in Appendix B.

The first component can be roughly interpreted as a relative measure of real vs. the nominal rigidities affecting the economy adjustment after stochastic disturbances. It is higher when hours have low responses to changes in the real wages (inverse Frisch elasticity) and the costs of investment adjustment (relative to those stemming from capital utilization) are high; by contrast it falls in the degree of stickiness of wage domestic prices (relative to import prices).

The second component measures the relative stance for price stability. Specifically, it compares the preferences for price stability (relative to output) to a measure of competitiveness (import vs. domestic ones) and the development of financial markets (the complement of the limited asset market participation). It is also negatively affected by the inverse Frisch elasticity as long as consumption variability of households who cannot access to credit is only determined by changes in labor supply. Finally, the third component roughly compares relative preferences for output stabilization to preferences for consumption smoothing (affected by the intertemporal elasticity of substitution and the habit parameter). Summarizing, the first component is a rough measure of real rigidities relative to nominal stickiness; the second component measures the preferences for price stability relatively to the financial markets development; the last component monitors the preference for output stabilization relatively to consumption smoothing,

The country outcomes from the centered PCA are illustrated in Figure 3, where the three main components are plotted. The first and second are on the axes and the third one is measured by the area of the bubble indicating the country. The first two components clearly show the peculiarity of Hungary, reflecting its relative price flexibility. In all the other countries prices and wages are quite sticky as they adjust, on average, every 5-10 quarters. However, the different degree of LAMP groups the remaining countries in a different way. On the one hand, Czech Republic, Estonia and Lithuania are characterized by a relative high preference for price stability on output and more persistence in the domestic price dynamics, whereas Poland and Slovak Republic for a relatively small number of households who cannot enter the financial markets and their inverse of the labor supply elasticity strongly below the average. High values of this component entail a preference for price stability on output, relatively more persistence in the domestic price dynamics and a small number of households who cannot enter the financial markets. The last component individuates further differences in the last group. Poland and Slovakia are very different from the other countries and each other's. The latter (former) observes a relative high (low) preference for output stabilization relatively to consumption smoothing.

Overall, Figure 3 identifies a homogenous group of countries (Baltics and Czech Republic). Remaining countries are quite different. They diverge in the third component, but the second one groups Poland and Slovakia.



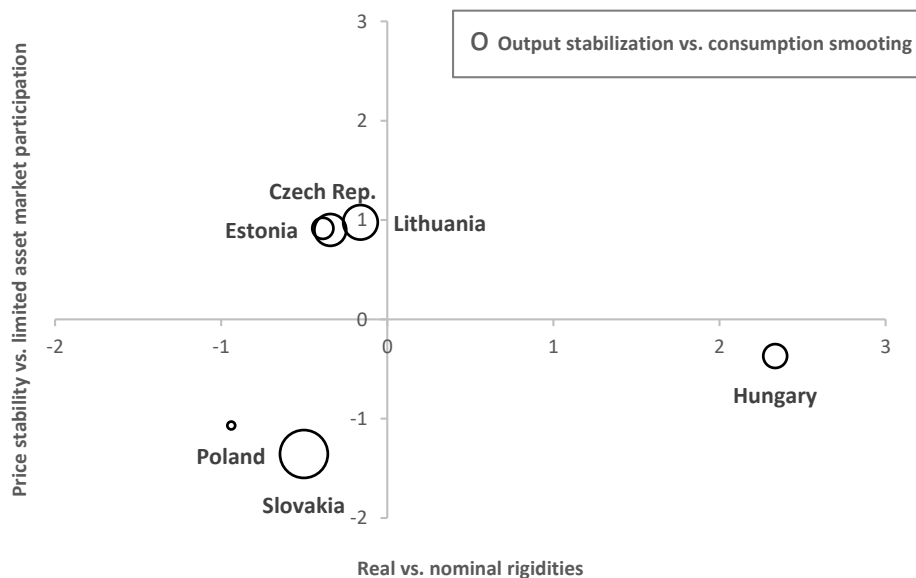


Figure 3 – Centered PCA

The effects of the financial crisis in the six estimated countries, in solid line, compared to the CEB benchmark, in dashed line are depicted in the following Figure 4 and 5 where a different interpretation in terms of source of the crisis is considered.

In Figure 4, we plot the impact of a capital quality shock on the path of output. As it can be easily noted, Czech Republic and Estonia share similar output dynamics and mimic the output path of the benchmark economy but they both observe a less pronounced fall after the shock than Poland where a more pronounced fall occurred. Instead, Hungary, Lithuania and Slovakia output path behave quite similarly in response to a capital quality shock. In fact, output in these countries experiences a contraction in GDP. Moreover, the fall in GDP is in the very short run more pronounced than the CEB average country and in the early medium run the considered countries recover faster to pre-shock output level compared to the benchmark economy.

Figure 5 depicts the impact of a net worth shock on output for each of the CEB country. Czech Republic and Estonia share similar output dynamics and mimic the output path of the benchmark but they both observe a more pronounced fall after the shock occurred. They also recover to steady state values with some period lags compared to the benchmark country. Instead, Hungary and Slovakia output path behave similarly in response to a net worth shock. Output in these countries experiences a negative double-peak with the second peak being more

marked in amplitude and smoothed than the first collapse. Moreover, the fall in GDP is less strong than the CEB average country and both countries recover faster to pre-shock output level. GDP decline in Poland, because of a net worth shock, is the most evident compared to the other countries within the region. Poland takes also much more time to recover compared to the benchmark and the other observed countries. Finally, Lithuania, after the initial GDP fall, demonstrates a relatively quick recover ability overcoming the path of the CEB average country which is initially less negatively affected by a net worth shock.

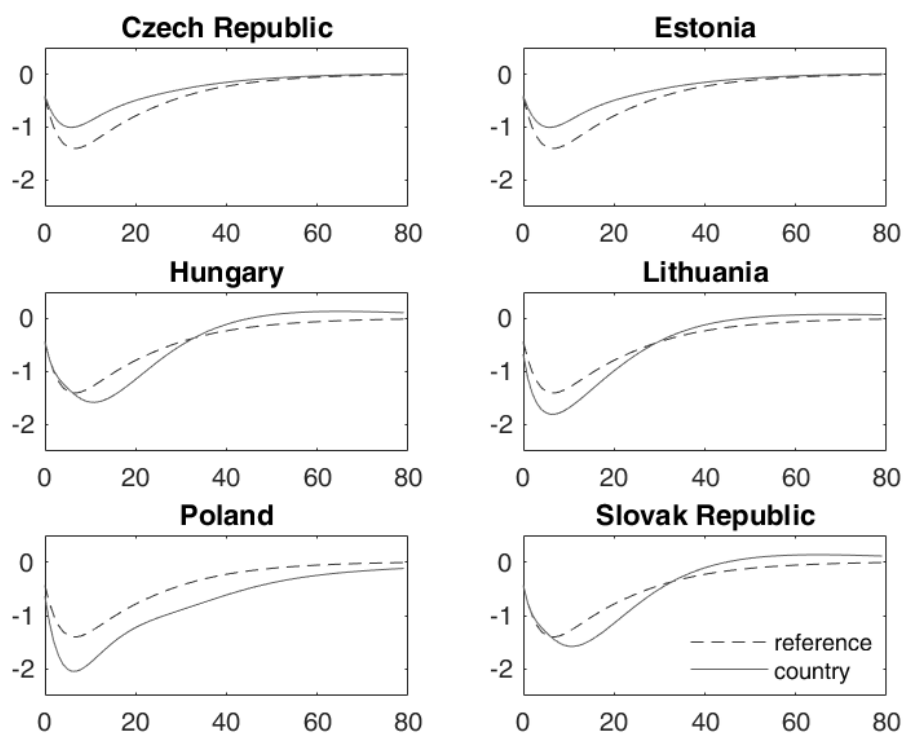


Figure 4 – Output IRF to a capital quality shock

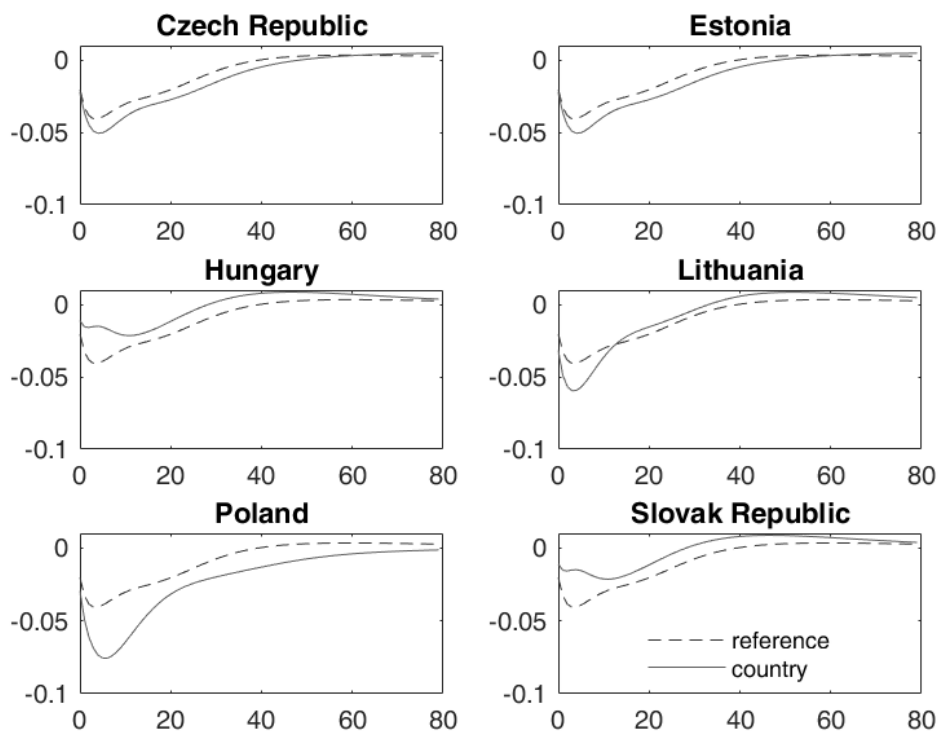


Figure 5 – Output IRF to a net wealth shock

#### 4. Conclusions

The recent financial crisis had severe but heterogeneous worldwide impacts. Strong cross-country disparities in the resistance and recovery capacities have been observed. Focusing on the Central European and Baltic macro-region (CEB), we investigated relative performance of a quite homogenous area. According to this aim, we developed and estimated by Bayesian techniques a small-open economy DSGE model, which features nominal wage and price rigidities, as well as financial frictions in the form of liquidity-constrained households and limited access to deposits for the bank system. We also investigated the resilience performance to the 2008 financial crisis within countries of this region according to their shock isolation and absorptive capacities. We focused on two dimensions of the resilience: resistance and recovery. Specifically, by using PCA on estimated parameters, we quantified the relative vulnerability or sensitivity of economies within CEB macro-region to disturbances and disruptions (resistance) and the speed and extent of recovery from such a disruption or recession (recovery).

We find that some structural parameters describing habit decision, risk aversion, monetary policy smoothing are similar within the CEB area, but others exhibit a relatively high heterogeneity (e.g., nominal wage and price rigidities and financial frictions). Hungary and Poland behave as outlier in the region. We also find strong evidence for heterogeneity in terms of inertia of the stochastic disturbances; their persistence is relatively higher in Hungary, Lithuania, and Poland. Looking at the monetary feedback rules, central banks aggressively behave in contrasting inflation in all countries of the region. By contrast, their responses to the output gap are negligible, apart in Slovakia. Regarding fiscal policies, the large fraction of LAMP estimated entails that positive public spending shock can positively affect public consumption, avoiding crowding out effects.

Applying non-centered PCA to Bayesian estimates we derived two indexes of resilience: resistance and recovery. Central European countries share similar values for their recovery index, reflecting similar economic structures. By contrast, the two Baltic economies are placed on the opposite sides of recovery: Lithuania performs relatively better than Estonia. The opposite verifies for resistance. Central European economies are characterized by large differences: Czech Republic and Hungary are less exposed to disturbances than Slovakia and Poland. Baltic countries instead share a similar estimated stochastic structure.

Centered PCA on the variability of estimated deep parameters within the country regions summarize countries heterogeneity across three main lines (components). It highlights the relative importance of real compared to nominal rigidities; monetary authorities' preferences for price stability relatively to the financial markets development; preferences for output stabilization relatively to consumption smoothing and other sources of output persistence.

Along these lines, Czech Republic, Estonia and Lithuania are characterized by a relative high preference for price stability on output and more persistence in the domestic price dynamics. By contrast, Poland and the Slovak Republic reveal a relatively small number of households who cannot access to the financial markets. Within the last group, however, PCA individuates further disparities: Slovakia (Poland) observes a relative high (low) preference for output stabilization relatively to consumption smoothing. Hungary is characterized by a relative price flexibility.

Our comparative exercises show a sort of trade-off between recovery and resistance in the resilience analysis. For instance, Hungary is the most immune country to disturbance, i.e., it is characterized by low disturbance frequencies, but it is the most vulnerable country to external

shocks, as it has the less effective economic structure to absorb them. Czech Republic, Lithuania and Slovakia show slight (strong) recovery capacity compared to Hungary (Estonia). Instead, ranked by the resistance index, Czech Republic, Lithuania and Slovakia demonstrate lower (greater) immunity than Hungary (Estonia). Estonia exhibits the lowest vulnerability to external shocks.

Despite cross-country differences with respect to pre-crisis vulnerability and resilience capacity and post-crisis policy responses, several common factors prevented disruptive macroeconomic adjustments in the region. Among others, lending arrangements from IMF and other EU financial support programs were targeted to mitigate the detrimental effects on the crisis on the economic activity.

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## Appendix A – Countries estimates

Table A1 – Czech Republic prior and posterior estimates

Parameter	Prior (mean, s.d.)	Posterior mean	90% HPD interval
$\rho_{\mu pd}$	beta (0.5, 0.2)	0.102	[0.016, 0.182]
$\rho_{\mu pm}$	beta (0.5, 0.2)	0.732	[0.590, 0.876]
$\rho_{\mu px}$	beta (0.5, 0.2)	0.144	[0.028, 0.258]
$\rho_{\mu w}$	beta (0.5, 0.2)	0.377	[0.200, 0.551]
$\rho_{\psi}$	beta (0.5, 0.2)	0.379	[0.083, 0.730]
$\rho_a$	beta (0.5, 0.2)	0.971	[0.954, 0.987]
$\rho_g$	beta (0.5, 0.2)	0.787	[0.717, 0.859]
$\rho_{y^*}$	beta (0.5, 0.2)	0.802	[0.757, 0.848]
$\rho_{ui}$	beta (0.5, 0.2)	0.065	[0.011, 0.118]
$\rho_{uip}$	beta (0.5, 0.2)	0.814	[0.769, 0.858]
$\rho_{\Pi}$	beta (0.5, 0.2)	0.434	[0.295, 0.566]
$\sigma$	norm (1.5, 0.375)	1.916	[1.379, 2.463]
$\varphi$	norm (2, 0.75)	2.065	[1.065, 3.055]
$h$	beta (0.7, 0.1)	0.796	[0.719, 0.878]
$\psi$	norm (5.5, 0.5)	5.909	[5.125, 6.657]
$\gamma_p^d$	beta (0.66, 0.1)	0.861	[0.819, 0.897]
$\gamma_p^m$	beta (0.66, 0.1)	0.435	[0.329, 0.536]
$\gamma_p^x$	beta (0.66, 0.1)	0.788	[0.724, 0.849]
$\gamma_w$	beta (0.66, 0.1)	0.899	[0.850, 0.950]
$\gamma_{ind}^d$	beta (0.5, 0.15)	0.258	[0.099, 0.407]
$\gamma_{ind}^m$	beta (0.5, 0.15)	0.282	[0.111, 0.450]
$\gamma_{ind}^x$	beta (0.5, 0.15)	0.224	[0.087, 0.358]
$\gamma_{ind}^w$	beta (0.5, 0.15)	0.347	[0.154, 0.535]
$\lambda$	beta (0.3, 0.15)	0.173	[0.126, 0.222]
$\eta$	norm (1.5, 0.25)	1.384	[1.099, 1.648]
$\eta^*$	norm (1.5, 0.25)	1.171	[0.953, 1.400]
$\phi_a$	norm (0.01, 0.001)	0.009	[0.008, 0.010]
$z$	norm (7.2, 2.5)	7.444	[5.332, 9.986]
$\kappa_{\pi}$	norm (1.5, 0.25)	2.497	[2.283, 2.726]
$\rho$	beta (0.75, 0.1)	0.800	[0.761, 0.836]
$\kappa_y$	norm (0.125, 0.05)	0.001	[0.001, 0.001]
$\kappa_{\Delta y}$	norm (0.125, 0.05)	0.078	[0.041, 0.115]
$\kappa_{\Delta \Pi}$	norm (0.3, 0.15)	0.327	[0.256, 0.402]

Table A2 – Estonia prior and posterior estimates

Parameter	Prior (mean, s.d.)	Posterior mean	90% HPD interval
$\rho_{\mu pd}$	beta (0.5, 0.2)	0.135	[0.021, 0.242]
$\rho_{\mu pm}$	beta (0.5, 0.2)	0.592	[0.354, 0.814]
$\rho_{\mu px}$	beta (0.5, 0.2)	0.174	[0.028, 0.301]
$\rho_{\mu w}$	beta (0.5, 0.2)	0.373	[0.211, 0.540]
$\rho_{\psi}$	beta (0.5, 0.2)	0.119	[0.013, 0.220]
$\rho_a$	beta (0.5, 0.2)	0.582	[0.389, 0.777]
$\rho_g$	beta (0.5, 0.2)	0.824	[0.766, 0.882]
$\rho_{y^*}$	beta (0.5, 0.2)	0.899	[0.867, 0.932]
$\rho_{ui}$	beta (0.5, 0.2)	0.139	[0.042, 0.228]
$\rho_{uip}$	beta (0.5, 0.2)	0.751	[0.690, 0.824]
$\rho_{\Pi}$	beta (0.5, 0.2)	0.233	[0.074, 0.383]
$\sigma$	norm (1.5, 0.375)	1.930	[1.399, 2.475]
$\varphi$	norm (2, 0.75)	1.963	[1.031, 2.860]
$h$	beta (0.7, 0.1)	0.886	[0.838, 0.937]
$\psi$	norm (5.5, 0.5)	5.784	[5.021, 6.534]
$\gamma_p^d$	beta (0.66, 0.1)	0.836	[0.797, 0.881]
$\gamma_p^m$	beta (0.66, 0.1)	0.447	[0.314, 0.603]
$\gamma_p^x$	beta (0.66, 0.1)	0.652	[0.546, 0.757]
$\gamma_w$	beta (0.66, 0.1)	0.889	[0.857, 0.922]
$\gamma_{ind}^d$	beta (0.5, 0.15)	0.171	[0.057, 0.282]
$\gamma_{ind}^m$	beta (0.5, 0.15)	0.287	[0.104, 0.464]
$\gamma_{ind}^x$	beta (0.5, 0.15)	0.267	[0.112, 0.428]
$\gamma_{ind}^w$	beta (0.5, 0.15)	0.288	[0.118, 0.449]
$\lambda$	beta (0.3, 0.15)	0.284	[0.224, 0.340]
$\eta$	norm (1.5, 0.25)	1.898	[1.546, 2.246]
$\eta^*$	norm (1.5, 0.25)	1.259	[0.985, 1.526]
$\phi_a$	norm (0.01, 0.005)	0.001	[0.001, 0.001]
$z$	norm (7.2, 2.5)	8.368	[6.668, 9.999]
$\kappa_{\pi}$	norm (1.5, 0.25)	2.356	[2.175, 2.558]
$\rho$	beta (0.75, 0.1)	0.820	[0.782, 0.855]
$\kappa_y$	norm (0.125, 0.05)	0.001	[0.001, 0.001]
$\kappa_{\Delta y}$	norm (0.125, 0.05)	0.001	[0.001, 0.001]
$\kappa_{\Delta \Pi}$	norm (0.3, 0.15)	0.294	[0.207, 0.385]

Table A3 – Hungary prior and posterior estimates

Parameter	Prior (mean, s.d.)	Posterior mean	90% HPD interval
$\rho_{\mu pd}$	beta (0.5, 0.2)	0.885	[0.827, 0.948]
$\rho_{\mu pm}$	beta (0.5, 0.2)	0.466	[0.163, 0.729]
$\rho_{\mu px}$	beta (0.5, 0.2)	0.834	[0.715, 0.939]
$\rho_{\mu w}$	beta (0.5, 0.2)	0.952	[0.927, 0.976]
$\rho_{\psi}$	beta (0.5, 0.2)	0.903	[0.831, 0.979]
$\rho_a$	beta (0.5, 0.2)	0.998	[0.998, 0.998]
$\rho_g$	beta (0.5, 0.2)	0.833	[0.779, 0.893]
$\rho_{y^*}$	beta (0.5, 0.2)	0.907	[0.885, 0.931]
$\rho_{ui}$	beta (0.5, 0.2)	0.237	[0.104, 0.361]
$\rho_{uip}$	beta (0.5, 0.2)	0.880	[0.851, 0.910]
$\rho_{\Pi}$	beta (0.5, 0.2)	0.198	[0.071, 0.315]
$\sigma$	norm (1.5, 0.375)	1.968	[1.397, 2.505]
$\varphi$	norm (2, 0.75)	3.294	[2.451, 4.172]
$h$	beta (0.7, 0.1)	0.870	[0.809, 0.934]
$\psi$	norm (5.5, 0.5)	6.261	[5.500, 7.006]
$\gamma_p^d$	beta (0.66, 0.1)	0.439	[0.347, 0.534]
$\gamma_p^m$	beta (0.66, 0.1)	0.793	[0.716, 0.888]
$\gamma_p^x$	beta (0.66, 0.1)	0.734	[0.664, 0.807]
$\gamma_w$	beta (0.66, 0.1)	0.585	[0.502, 0.665]
$\gamma_{ind}^d$	beta (0.5, 0.15)	0.174	[0.052, 0.287]
$\gamma_{ind}^m$	beta (0.5, 0.15)	0.677	[0.414, 0.947]
$\gamma_{ind}^x$	beta (0.5, 0.15)	0.177	[0.074, 0.272]
$\gamma_{ind}^w$	beta (0.5, 0.15)	0.586	[0.371, 0.801]
$\lambda$	beta (0.3, 0.15)	0.251	[0.187, 0.311]
$\eta$	norm (1.5, 0.25)	1.907	[1.678, 2.110]
$\eta^*$	norm (1.5, 0.25)	0.609	[0.454, 0.768]
$\phi_a$	norm (0.01, 0.001)	0.009	[0.009, 0.010]
$z$	norm (7.2, 2.5)	6.404	[3.626, 9.290]
$\kappa_{\pi}$	norm (1.5, 0.25)	1.912	[1.582, 2.259]
$\rho$	beta (0.75, 0.1)	0.899	[0.880, 0.922]
$\kappa_y$	norm (0.125, 0.05)	0.001	[0.001, 0.001]
$\kappa_{\Delta y}$	norm (0.125, 0.05)	0.032	[0.003, 0.055]
$\kappa_{\Delta \Pi}$	norm (0.3, 0.15)	0.091	[0.057, 0.123]

Table A4 – Lithuania prior and posterior estimates

Parameter	Prior (mean, s.d.)	Posterior mean	90% HPD interval
$\rho_{\mu pd}$	beta (0.5, 0.2)	0.134	[0.018, 0.252]
$\rho_{\mu pm}$	beta (0.5, 0.2)	0.833	[0.766, 0.893]
$\rho_{\mu px}$	beta (0.5, 0.2)	0.860	[0.770, 0.959]
$\rho_{\mu w}$	beta (0.5, 0.2)	0.419	[0.222, 0.632]
$\rho_{\psi}$	beta (0.5, 0.2)	0.667	[0.349, 0.934]
$\rho_a$	beta (0.5, 0.2)	0.892	[0.706, 0.989]
$\rho_g$	beta (0.5, 0.2)	0.791	[0.719, 0.855]
$\rho_{y^*}$	beta (0.5, 0.2)	0.844	[0.793, 0.897]
$\rho_{ui}$	beta (0.5, 0.2)	0.094	[0.017, 0.161]
$\rho_{uip}$	beta (0.5, 0.2)	0.732	[0.649, 0.813]
$\rho_{\Pi}$	beta (0.5, 0.2)	0.205	[0.080, 0.330]
$\sigma$	norm (1.5, 0.375)	1.690	[1.149, 2.210]
$\varphi$	norm (2, 0.75)	2.495	[1.625, 3.371]
$h$	beta (0.7, 0.1)	0.798	[0.731, 0.860]
$\psi$	norm (5.5, 0.5)	5.581	[4.712, 6.387]
$\gamma_p^d$	beta (0.66, 0.1)	0.879	[0.837, 0.925]
$\gamma_p^m$	beta (0.66, 0.1)	0.313	[0.214, 0.423]
$\gamma_p^x$	beta (0.66, 0.1)	0.454	[0.334, 0.582]
$\gamma_w$	beta (0.66, 0.1)	0.835	[0.784, 0.890]
$\gamma_{ind}^d$	beta (0.5, 0.15)	0.177	[0.062, 0.286]
$\gamma_{ind}^m$	beta (0.5, 0.15)	0.262	[0.080, 0.445]
$\gamma_{ind}^x$	beta (0.5, 0.15)	0.257	[0.092, 0.420]
$\gamma_{ind}^w$	beta (0.5, 0.15)	0.613	[0.397, 0.832]
$\lambda$	beta (0.3, 0.15)	0.255	[0.180, 0.331]
$\eta$	norm (1.5, 0.25)	1.002	[0.701, 1.262]
$\eta^*$	norm (1.5, 0.25)	1.218	[1.218, 1.218]
$\phi_a$	norm (0.01, 0.001)	0.009	[0.008, 0.010]
$z$	norm (7.2, 2.5)	7.126	[4.920, 9.973]
$\kappa_{\pi}$	norm (1.5, 0.25)	2.461	[2.176, 2.737]
$\rho$	beta (0.75, 0.1)	0.861	[0.830, 0.892]
$\kappa_y$	norm (0.125, 0.05)	0.028	[0.001, 0.052]
$\kappa_{\Delta y}$	norm (0.125, 0.05)	0.015	[0.001, 0.031]
$\kappa_{\Delta \Pi}$	norm (0.3, 0.15)	0.224	[0.153, 0.292]

Table A5 – Poland prior and posterior estimates

Parameter	Prior (mean, s.d.)	Posterior mean	90% HPD interval
$\rho_{\mu pd}$	beta (0.5, 0.2)	0.124	[0.018, 0.222]
$\rho_{\mu pm}$	beta (0.5, 0.2)	0.850	[0.779, 0.921]
$\rho_{\mu px}$	beta (0.5, 0.2)	0.134	[0.014, 0.250]
$\rho_{\mu w}$	beta (0.5, 0.2)	0.510	[0.370, 0.657]
$\rho_{\psi}$	beta (0.5, 0.2)	0.841	[0.693, 0.993]
$\rho_a$	beta (0.5, 0.2)	0.733	[0.633, 0.820]
$\rho_g$	beta (0.5, 0.2)	0.945	[0.924, 0.965]
$\rho_{y^*}$	beta (0.5, 0.2)	0.930	[0.907, 0.955]
$\rho_{ui}$	beta (0.5, 0.2)	0.350	[0.194, 0.493]
$\rho_{uip}$	beta (0.5, 0.2)	0.920	[0.898, 0.943]
$\rho_{\Pi}$	beta (0.5, 0.2)	0.192	[0.056, 0.315]
$\sigma$	norm (1.5, 0.375)	2.223	[1.737, 2.720]
$\varphi$	norm (2, 0.75)	0.250	[0.250, 0.250]
$h$	beta (0.7, 0.1)	0.867	[0.811, 0.923]
$\psi$	norm (5.5, 0.5)	5.465	[4.705, 6.251]
$\gamma_p^d$	beta (0.66, 0.1)	0.932	[0.915, 0.948]
$\gamma_p^m$	beta (0.66, 0.1)	0.410	[0.273, 0.546]
$\gamma_p^x$	beta (0.66, 0.1)	0.896	[0.840, 0.954]
$\gamma_w$	beta (0.66, 0.1)	0.700	[0.611, 0.790]
$\gamma_{ind}^d$	beta (0.5, 0.15)	0.162	[0.059, 0.261]
$\gamma_{ind}^m$	beta (0.5, 0.15)	0.234	[0.064, 0.385]
$\gamma_{ind}^x$	beta (0.5, 0.15)	0.161	[0.053, 0.255]
$\gamma_{ind}^w$	beta (0.5, 0.15)	0.508	[0.265, 0.756]
$\lambda$	beta (0.3, 0.15)	0.054	[0.040, 0.069]
$\eta$	norm (1.5, 0.25)	2.782	[2.550, 3.088]
$\eta^*$	norm (1.5, 0.25)	1.457	[1.091, 1.799]
$\phi_a$	norm (0.01, 0.001)	0.009	[0.009, 0.010]
$z$	norm (7.2, 2.5)	9.999	[9.999, 10.00]
$\kappa_{\pi}$	norm (1.5, 0.25)	2.409	[2.110, 2.689]
$\rho$	beta (0.75, 0.1)	0.890	[0.860, 0.918]
$\kappa_y$	norm (0.125, 0.05)	0.030	[0.001, 0.058]
$\kappa_{\Delta y}$	norm (0.125, 0.05)	0.029	[0.001, 0.053]
$\kappa_{\Delta \Pi}$	norm (0.3, 0.15)	0.165	[0.114, 0.210]

Table A6 – Slovakia prior and posterior estimates

Parameter	Prior (mean, s.d.)	Posterior mean	90% HPD interval
$\rho_{\mu p d}$	beta (0.5, 0.2)	0.115	[0.016, 0.202]
$\rho_{\mu p m}$	beta (0.5, 0.2)	0.228	[0.038, 0.426]
$\rho_{\mu p x}$	beta (0.5, 0.2)	0.227	[0.043, 0.412]
$\rho_{\mu w}$	beta (0.5, 0.2)	0.311	[0.121, 0.509]
$\rho_{\psi}$	beta (0.5, 0.2)	0.315	[0.164, 0.450]
$\rho_a$	beta (0.5, 0.2)	0.764	[0.655, 0.875]
$\rho_g$	beta (0.5, 0.2)	0.871	[0.817, 0.927]
$\rho_{y^*}$	beta (0.5, 0.2)	0.900	[0.866, 0.934]
$\rho_{ui}$	beta (0.5, 0.2)	0.340	[0.153, 0.518]
$\rho_{uip}$	beta (0.5, 0.2)	0.883	[0.841, 0.928]
$\rho_{\Pi}$	beta (0.5, 0.2)	0.116	[0.019, 0.203]
$\sigma$	norm (1.5, 0.375)	1.457	[0.894, 1.998]
$\varphi$	norm (2, 0.75)	0.250	[0.250, 0.250]
$h$	beta (0.7, 0.1)	0.786	[0.690, 0.887]
$\psi$	norm (5.5, 0.5)	5.783	[4.951, 6.557]
$\gamma_p^d$	beta (0.66, 0.1)	0.924	[0.901, 0.949]
$\gamma_p^m$	beta (0.66, 0.1)	0.657	[0.535, 0.783]
$\gamma_p^x$	beta (0.66, 0.1)	0.818	[0.738, 0.897]
$\gamma_w$	beta (0.66, 0.1)	0.939	[0.912, 0.966]
$\gamma_{ind}^d$	beta (0.5, 0.15)	0.156	[0.050, 0.258]
$\gamma_{ind}^m$	beta (0.5, 0.15)	0.314	[0.112, 0.505]
$\gamma_{ind}^x$	beta (0.5, 0.15)	0.236	[0.082, 0.388]
$\gamma_{ind}^w$	beta (0.5, 0.15)	0.359	[0.166, 0.565]
$\lambda$	beta (0.3, 0.15)	0.143	[0.096, 0.186]
$\eta$	norm (1.5, 0.25)	2.149	[1.869, 2.448]
$\eta^*$	norm (1.5, 0.25)	1.226	[0.914, 1.550]
$\phi_a$	norm (0.01, 0.0005)	0.010	[0.009, 0.011]
$z$	norm (7.2, 2.5)	8.035	[6.065, 9.999]
$\kappa_{\pi}$	norm (1.5, 0.25)	1.538	[1.222, 1.877]
$\rho$	beta (0.75, 0.1)	0.855	[0.809, 0.903]
$\kappa_y$	norm (0.125, 0.05)	0.168	[0.106, 0.222]
$\kappa_{\Delta y}$	norm (0.125, 0.05)	0.082	[0.052, 0.110]
$\kappa_{\Delta \Pi}$	norm (0.3, 0.15)	0.080	[0.026, 0.133]

## Appendix B – PCA analysis

Table B1 – Resilience indexes: PCA variable loadings

Recovery		Resistance	
variable	load	variable	load
$\sigma$	-0,103	$e_a$	0,044
$\varphi$	-0,018	$e$	0,068
$h$	0,578	$e_g$	0,084
$\psi$	0,652	$e_{\mu pd}$	0,057
$\gamma_p^d$	0,136	$e_{\mu pm}$	0,037
$\gamma_p^m$	0,089	$e_{\mu px}$	0,072
$\gamma_p^x$	0,146	$e_{\mu w}$	0,068
$\gamma_w$	0,184	$e_\psi$	0,037
$\gamma_{ind}^d$	0,152	$e_{y^*}$	0,121
$\gamma_{ind}^m$	0,065	$e_{ui p}$	0,121
$\gamma_{ind}^x$	0,160	$e_\Pi$	0,069
$\gamma_{ind}^w$	0,103	$\rho_a$	0,145
$\lambda$	0,290	$\rho_g$	0,401
		$\rho_{y^*}$	0,520
		$\rho_{ui}$	0,047
		$\rho_{ui p}$	0,305
		$\rho$	0,624

Table B2 – Non-centered PCA (parameter structure)

Eigenvalues						
	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6
Eigenvalues	1436,585	4,847	3,301	1,86	1,332	1,039
Percentage	99,146	0,334	0,228	0,128	0,092	0,072
Cum. Percentage	99,146	99,48	99,708	99,836	99,928	100
PCA variable loadings						
	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6
$\sigma$	-0,103	0,099	-0,327	0,414	-0,307	-0,274
$\varphi$	-0,018	0,316	0,325	0,215	-0,236	0,034
$h$	0,578	-0,083	0,129	-0,398	-0,273	0,388
$\psi$	0,652	-0,206	-0,231	0,239	0,078	-0,125
$\gamma_p^d$	0,136	0,478	0,044	-0,087	-0,084	-0,143
$\gamma_p^m$	0,089	-0,287	0,041	0,499	-0,175	0,075
$\gamma_p^x$	0,146	0,065	0,417	0,359	0,16	0,166
$\gamma_w$	0,184	0,416	-0,285	0,164	-0,017	0,029
$\gamma_{ind}^d$	0,152	0,084	-0,157	0,014	0,796	-0,118
$\gamma_{ind}^m$	0,065	-0,421	-0,037	0,194	-0,04	-0,015
$\gamma_{ind}^x$	0,16	0,244	-0,486	-0,068	-0,19	0,086
$\gamma_{ind}^w$	0,103	-0,22	0,072	-0,312	-0,182	-0,738
$\lambda$	0,29	0,246	0,437	0,118	0,028	-0,369
PCA case scores						
	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6
Czech Rep.	14,442	0,455	-0,247	0,234	0,992	-0,033
Hungary	14,789	-1,972	0,057	0,191	-0,01	-0,023
Estonia	14,491	0,274	-0,54	-0,347	-0,223	0,805
Lithuania	13,744	0,24	-0,788	-0,677	-0,239	-0,608
Slovakia	14,155	0,685	-0,03	1,005	-0,488	-0,134
Poland	14,313	0,382	1,524	-0,422	-0,051	-0,036
CE	14,323	0,011	-0,001	-0,003	-0,003	-0,005



Table B3 – Non-centered PCA (stochastic structure)

Eigenvalues						
	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6
Eigenvalues	1766,292	5,428	4,089	2,398	1,182	1,114
Percentage	99,202	0,305	0,23	0,135	0,066	0,063
Cum. Percentage	99,202	99,507	99,736	99,871	99,937	100
PCA variable loadings						
	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6
$e_a$	0,044	-0,354	0,046	0,111	-0,012	-0,423
$e$	0,068	0,011	-0,52	0,076	-0,002	0,057
$e_g$	0,084	-0,176	-0,292	-0,455	0,04	0,257
$e_{\mu p d}$	0,057	-0,244	-0,205	0,45	-0,085	0,13
$e_{\mu p m}$	0,037	0,323	0,067	0,058	-0,531	-0,171
$e_{\mu p x}$	0,072	-0,28	0,191	0,257	0,408	-0,097
$e_{\mu w}$	0,068	-0,347	0,076	0,264	-0,188	0,134
$e_{\psi}$	0,037	-0,221	-0,23	0,313	-0,209	0,482
$e_{y^*}$	0,121	-0,204	-0,341	0,019	0,149	-0,479
$e_{uip}$	0,121	-0,313	-0,055	-0,341	-0,077	-0,138
$e_{\Pi}$	0,069	0,22	-0,353	0,218	-0,191	-0,312
$\rho_a$	0,145	0,387	-0,009	0,305	0,358	0,064
$\rho_g$	0,401	-0,14	0,172	-0,055	0,121	-0,036
$\rho_{y^*}$	0,52	-0,025	-0,007	-0,222	-0,195	0,18
$\rho_{ui}$	0,047	-0,152	0,326	0,099	-0,458	-0,166
$\rho_{uip}$	0,305	0,043	0,336	0,118	0,089	0,161
$\rho$	0,624	0,221	-0,085	0,045	0,021	-0,098
PCA case scores						
	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6
Czech Rep.	14,743	0,493	0,166	0,211	0,851	0,436
Hungary	16,189	1,761	0,537	-0,21	-0,444	-0,006
Estonia	15,524	-0,678	-0,719	-1,095	-0,145	0,352
Lithuania	15,605	0,248	-1,429	0,467	0,056	-0,51
Slovakia	16,267	-0,916	0,281	0,903	-0,449	0,398
Poland	16,907	-0,85	1,065	-0,277	0,187	-0,617
CE	15,87	0,009	-0,016	0	0,01	0,008

Table B4 – Centered PCA

Eigenvalues					
	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5
Eigenvalues	6.882	5.719	4.274	2.98	2.144
Percentage	31.282	25.998	19.427	13.547	9.746
Cum. Percentage	31.282	57.28	76.707	90.254	100
PCA variable loadings					
	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5
$\sigma$	0.024	-0.02	-0.467	0.143	-0.027
$\varphi$	0.288	-0.271	-0.005	0	0.063
$h$	0.115	0.012	-0.388	-0.188	-0.271
$\psi$	-0.376	0.004	0.063	-0.023	0.062
$\gamma_p^d$	0.277	0.225	0.112	0.046	-0.238
$\gamma_p^m$	-0.059	0.295	-0.121	0.309	-0.249
$\gamma_p^x$	-0.262	-0.116	0.295	-0.012	-0.193
$\gamma_w$	-0.02	-0.238	0.046	0.471	-0.034
$\gamma_{ind}^d$	0.373	0.072	0	0.027	-0.068
$\gamma_{ind}^m$	-0.116	-0.254	0.273	-0.241	-0.145
$\gamma_{ind}^x$	0.179	0.04	-0.1	-0.086	0.573
$\gamma_{ind}^w$	0.193	-0.287	0.112	-0.247	-0.129
$\psi$	0.327	-0.023	0.101	0.161	-0.254
$\eta$	-0.062	0.334	-0.237	-0.02	-0.208
$\eta^*$	-0.374	0.013	-0.072	-0.062	0.039
$\phi_a$	0.049	0.197	0.109	0.284	0.468
$z$	-0.283	0.166	-0.252	-0.049	-0.083
$\kappa_\pi$	-0.126	-0.293	-0.271	0.093	0.167
$\kappa_y$	-0.115	0.277	0.321	-0.096	-0.011
$\kappa_{\Delta y}$	-0.052	0.157	0.284	0.405	-0.051
$\kappa_{\Delta \Pi}$	-0.156	-0.353	-0.085	0.134	-0.13
$\rho$	-0.035	-0.271	-0.052	0.428	-0.084
PCA case scores					
	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5
Czech Rep.	-0.388	-0.915	0.261	1.38	-0.15
Estonia	-0.343	-0.9	-0.413	-0.802	-0.948
Hungary	2.335	0.37	-0.252	0.084	-0.013
Lithuania	-0.162	-0.978	0.421	-0.619	1.027
Slovakia	-0.502	1.355	1.369	-0.17	-0.244
Poland	-0.94	1.069	-1.386	0.128	0.328