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Resilience, crisis contagion, and vulnerability in Central Europe and the Baltics

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Contents

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Abstract

The recent financial crisis had serious worldwide impacts. Initial resilience and good past performances led to the illusion that the Central and Eastern European (CEE) region was able to decouple from developments in advanced economies. This initial illusion was however immediately denied since the crisis spread to that region just with a lag. The CEE region was, in fact, suddenly placed at the epicenter of the emerging market crisis. Further, the consequences of the crisis were not uniform among countries of the CEE region. Strong cross-country disparities in the resistance and recovery capacities have been observed. Focusing on a CEE sub-region, the Central Europe and the Baltics (CEB), our research project aims to analyze and disentangle the resilience performance to the 2008 financial crisis within countries of this region according to their shock isolation and absorptive capacities.

We develop a new methodology to investigate two important dimensions of resilience, 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 is based on Bayesian estimation techniques for general equilibrium models. We build and estimate a DSGE model for a small-open economy, 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. Then 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. Finally, we use the two sets to compare the relative recovery (resistance) country performances of a single country to those of a hypothetical economy characterized by a CEB average structural (stochastic) set of estimated parameters. Precisely, considering estimated parameters as variables of a cross-sectional dataset organized by country, we first look at national differences considering as reference a *hypothetical country*, where there are no distortions and/or unaffected by disturbances; second we use, as reference, a *hypothetical average country*, built on the estimated parameter means.

1 Introduction

The global financial crisis had a serious impact on mature and emerging economies. The consequences were not uniform. Europe was characterized by strong cross-country differences in the resistance and recovery capacities. The economic decline was more intense in the countries at the periphery of the European Union and in those with fragile public finances. Initially, the crisis only marginally affected the Central and Eastern European region, which had previously observed high growth rates. The past good performance and the initial resilience led to claims that the region had "decoupled" from developments in advanced economies. However, the decoupling hypothesis was an illusion, the crisis spread to the CEE region just with a lag. After the Lehman Brothers crack, in fact, the CEE region was suddenly placed at the epicenter of the emerging market crisis (Roaf *et al*., 2014).[1]

Our aim is to analyze and disentangle the resilience to the financial crisis within the CEE region. Specifically, we focus on CEB region. Although CEE transition countries have reached remarkable progress in the past quarter century, strongly converging to the West Europe, their relative status has changed over time and exhibited relevant differences. Roaf *et al*. (2014) showed that Europe remained divided along "traditional" and historical west-east lines, with advanced countries on one side and transition countries on the other. However, they also observe a more rapid progress in Central Europe and the Baltics than in Southeast Europe and the CIS and note that those countries are more close to the Mediterranean ones than other CEE economies.[2] They finally stressed that CEE emerging economies should be thus clustered into two regions, one closer to the integration with the continent and another farther.

Even within Central Europe and the Baltics, the impact of the crisis on economic activity has varied widely across countries, reflecting differences in exposure and vulnerability to the financial shocks as well as heterogeneity in policy responses. We plan to measure and explain the disparities in the resistance and recovery capacities of CEB economies by estimating and simulating medium–scale DSGE models. Specifically, our objective is to measure two dimensions of the regional resilience, namely resistance and recovery. The former is the vulnerability or sensitivity of a regional economy to disturbances and disruptions. The latter is the speed and extent of recovery from such a disruption or recession (Martin, 2012).

We built a small-open economy model for distinct Central Europe and Baltic economies and estimate it by Bayesian techniques. The model features standard nominal wage and price 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).

Once estimated, we first investigate the differences of estimated parameters across countries populating CEB region by using the principal component analysis (PCA). Considering estimated parameters as variables of a cross-sectional dataset organized by country, we reduce its dimensionality focusing on correlated variables retaining as much as possible of its variability. Specifically, PCA searches for a few uncorrelated linear combinations (principal components) of the original variables that capture most of the information in the original variables (cf. Di Bartolomeo and Marchetti, 2004). We focus

[1] Comparing the performances of 183 economies, Didier *et al.* (2012) also claim against the decoupling hypothesis with reference to emerging economies and their resilience.

[2] After the global and euro zone crises, the Central Europe and Baltic 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 (Roaf *et al.*, 2014: 56).

on two cases. In the first we look at the difference using as reference a *hypothetical country* where there are no distortions and/or unaffected by disturbances (non-centered PCA). In the second, as reference we use a *hypothetical average country*, built on the estimated parameter means (centered PCA).

Finally, we use our Bayesian estimations to compute two measures of resilience to financial frictions. First, we look at the different stochastic structure estimated, the estimated standard deviations of the financial shocks and their auto–correlation give us a measure of the different vulnerability (or sensitivity) of Central Europe emerging markets. Second, we impose to all the countries within the Central Europe region a common stochastic structure and use simulations to derive a measure of their different recovery capacities. Then we investigate the effects of a financial crisis, exploring the role played by country differences in the relative performances.

Our main findings can be summarized as follows.

1. By using our Bayesian estimations and non-centered PCA analysis, we construct two measures of resilience, in terms of resistance and recovery. 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 resistance: Baltic countries share a similar ranking, whereas CEB countries exhibit large differences (Czech Republic and Hungary are less exposed to disturbances than Slovakia and Poland).
2. The multidimensional aspect of resilience is further investigated by applying centered PCA to our parameter estimates. Eliminating non-informative correlations, we individuate three principal components that explain about the 77% of the estimated deep parameter variability. 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 reveals the preference for output stabilization relatively to consumption smoothing and other sources of output persistence.
3. Centered PCA stresses the peculiarity of Hungary, reflecting its relative price flexibility. It then 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.
4. Investigating the impact of the financial crisis in the Baltic and Central European countries on output, we find that a capital quality and net worth shock have a similar impact on Czech Republic and Estonia, on the one hand, and on Hungary, Lithuania; Poland, and Slovakia, on the other. The latter group suffers more severe GDP contractions after financial turmoil. Countries also exhibit different recovery capacities.
5. Our comparative exercise shows that Hungary is the most vulnerable country to external shocks, as it has the less effective economic structure to absorb them. However, Hungary is also the most immune country compared to the rest of the economies considered, as it is also characterized by low disturbance frequencies. Estonia exhibits instead the lowest vulnerability to external shocks. Given the two polar cases described above, 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).

Our paper is related to research that studies the resilience of regional economies and the recent strand of DSGE model that introduces financial frictions into a New Keynesian framework.

Concerning the first strand of literature, notwithstanding the growing interest among macro–economists, regional analysts, spatial economists, and economic geographers, the concept of resilience is associated to some ambiguities. Ambiguities are related to the different uses and interpretations of the term.[3] However, ambiguities should not be the rush to dismiss the concept, they vanish once that a clear definition is assumed (Martin, 2012).

A useful taxonomy of resilience is provided by Martin (2012). He summarizes resilience 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. Our paper matches the first two dimensions, whereas it is only indirectly related to the others.

An alternative related definition of resilient society is provided by Manca *et al*. (2017: 5). "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). At the limit, when disturbances are not manageable anymore, the system needs to engineer bigger changes, which in extreme cases will lead to a transformation (transformative capacity)." 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 in the past crises changes that permit them to cope with the recent global turmoil.

Regarding the developments of DSGE literature in the direction of financial frictions, we borrow the specification of the banking sector from Gertler and Karadi (2011) and Gertler and Kiyotaki (2011), explicit modeling financial intermediation. An agency problem introduces endogenous constraints on the leverage ratios of intermediaries. As a result, in the financial sector, credit flows are tied to the equity capital of intermediaries. A deterioration of intermediary capital raises credit costs, lowering lending and borrowing. Their approach to model credit frictions has become quite popular (e.g., Lendvai *et al*., 2013; Andreasen *et al*., 2013; Beqiraj *el 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).[4]

The rest of the paper is organized as follows. Section 2 briefly illustrates the impact of the global financial crisis within the CEE region. Section 3 describes our theoretical regional model. Section 4 presents our estimation results. By using our empirical outcomes, Section 5 discusses the resilience of CEB economies in a comparative perspective. Section 6 concludes.

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[3] See Christopherson *et al.* (2010), Hudson, (2010), Pendall *et al.* (2010), Martin (2012).

[4] Alternative models have been suggested, other New Keynesian extensions to financial frictions are built on the external finance premium introduced by Carlstrom and Fuerst (1997), Bernanke *et al.* (1999) or collateral constraints based on Kiyotaki and Moore (1997). Different approaches are critically surveyed by Gertler and Kiyotaki (2010), Christiano *et al.* (2014) and Brzoza-Brzezina *et al.* (2015).

2 Central Europe region and the financial crisis

CEE economies and, among them, Central Europe and the Baltics have been severally affected by recent global financial turmoil. External shocks, from Lehman Brothers' collapse to the euro-zone sovereign debt crisis, had devastating effects, hitting CEE hardest among the emerging markets regions. The weak performance of CEE region resulted from the combination of initial imbalances and external financial shocks. The imbalances that built up in the Great Moderation period left in fact the transition economies highly vulnerable. However, CEE countries were differently impacted by global financial instability according to the strength, timing and speed of the impact. For instance, the crisis was managed quite well by Poland and the Czech Republic, while the Baltic States, Bulgaria and Romania experienced huge collapse in GDP. As a result, the debate on resilience capacity, i.e., the multidimensional attitude of economic systems to isolate from, absorb shocks, adapt or transform towards new sustainable development path, emerged with stronger emphasis in the aftermath of the crisis.

The eruption of the global financial crisis triggered high risks of banking instability in CEE region. The expected unwinding of real estate booms and the potential disruptive adjustment of exchange rates, and macroeconomic imbalances were expected to wreak havoc on bank balance sheets. However, banking crises were generally avoided; portfolio losses in fact were gradually absorbed by considerable preexisting buffers and macroeconomic adjustment proceeded more smoothly than expected. [5] Notable exceptions were Latvia, Ukraine, and (somehow) Slovenia.[6]

The global and euro zone crises hard hit the CEE region through their open economy channel. The crash of property prices in some countries and distressed domestic financial markets, where financial institutions were exposed by toxic debts, triggered a massive contraction of lending (global deleveraging) and reduced the willingness of financial markets to finance sovereign debt. The recession then reduced demand for exports in Western Europe, impacting on production and employment in CEE small-open economies[7] and to a less extent to larger CEE economies, as Poland and Romania. In 2009 all CEE countries faced massive reduction in their exports on GDP. The best performance was that of Romania: a reduction of 14% on previous period (in 2008 it was instead +14%); the worst country was instead Lithuania, where exports fall of 27% (in 2008 the share was 29%, but with opposite sign).

In the aftermath of the Lehman Brothers' collapse, the most evident effect of the crisis was a decrease in GDP growth rate followed by absolute decrease in its volume. A dramatic slump happened in 2009. All CEE countries experienced a fall in GDP volumes compared to 2008, except Poland. In Baltic Republics percentage decrease was two-digit.

The impact of the recessionary shock on the growth path of CEB economies is shown in Figure 1. This national picture observes quite disparate—in fact, strongly divergent—GDP growth patterns among the major countries of the region. Heterogeneous trends are the product of multiple underlying forces and processes. Central Europe and Baltic countries have differently reacted to the financial turmoil and consequent recession exhibiting disparities in the degree of resilience. The crisis strongly affected the Baltic countries, which were livelier before the Lehman Brothers' crash. A similar pattern can be observed

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[5] Several factors prevented disruptive macroeconomic adjustments; among them, lending arrangements from IMF and other EU in member countries; EBRD, EIB, and World Bank provided funds to the banking system. Banking systems also benefited from the prevalence of parent-subsidiary relationships.

[6] Latvia experienced the collapse of a large bank, Ukraine had widespread problems, and Slovenia observed relatively small and targeted recapitalization.

[7] It is worth noting that exports in the Czech and Slovak Republics, Estonia and Hungary account for about 70-80% of GDP.

in Czech Republic and Hungary. Poland and Slovak Republic GDP were only moderately affected. Indeed, Poland has not experienced recession, keeping all the time positive rate of GDP growth. Already in 2009, Poland and Slovakia experienced a real GDP above their 2007 level. Other countries take much more time to recover.

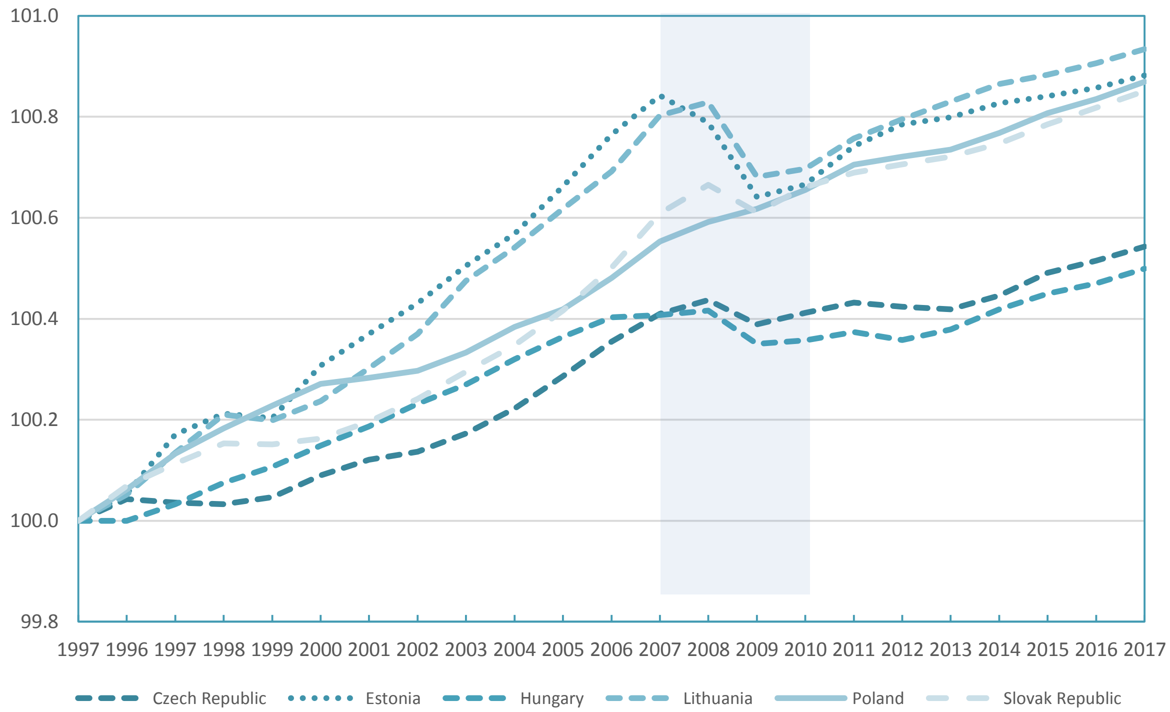

Figure 1 – Growth and recessionary shocks in selected CEB economies, GDP [1997=100] (Source IMF)

Similar patterns can be observed in the employment dynamics. As noted by Martin (2012), movements in employment are more significant since it tends to take much longer than output to recover from recession. Moreover, regional local economies may resume output growth after a recession without recovering in employment (jobless recovery). During the recession, employment fell in all countries besides Poland, though less than proportionally to the decrease in GDP. However, in Estonia was two-digit, whereas in the others it was less than 3 per cent. In Hungary, Lithuania and Estonia some decrease took place already in 2008. In the first half of 2010 employment was declining in all CEE countries besides Slovenia. The highest decline was registered in Baltic Republics and Bulgaria.

3 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).[8] 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).

3.1 Production

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, 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:

$$W_t = \alpha MC_t \frac{Y_t}{L_t}$$

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

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

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.,

$$\max \quad E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \Lambda_{t,\tau} \left\{ (Q_\tau - 1) I_{N\tau} - \mathcal{F}\left(\frac{I_{N\tau} + I_{ss}}{I_{N\tau-1} + I_{ss}}\right)(I_{N\tau} + I_{ss}) \right\}$$

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 τ, $I_{Nt} \equiv I_t - \delta(u_t^k)K_t$ 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 is then

[8] See Galí *et al.* (2007).

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

which describes the Q relation for net investments.

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 ε_p^d is the elasticity of substitution between differentiated domestic goods.

In this 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 are then described by the following expressions:[9]

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

$$\pi_t^d = \left[\gamma_p^d (\pi_{t-1}^d)^{\gamma_{ind}^d (1-\varepsilon_p^d)} + \left(1 - \gamma_p^d\right)\left(\pi_t^{d,*}\right)^{1-\varepsilon_p^d}\right]^{1/(1-\varepsilon_p^d)}$$

where γ_{ind}^d indicates the domestic degree of indexation to past inflation.

The domestic auxiliary variables $\Upsilon_t^{d,p}$ and $\Xi_t^{d,p}$ evolve as:

$$\Upsilon_t^{d,p} = Y_t MC_t + \beta \gamma_p^d E_t \Lambda_{t,t+1} (\pi_{t+1}^d)^{\varepsilon_p^d} (\pi_t^d)^{-\gamma_{ind}^d \varepsilon_p^d} \Upsilon_{t+1}^{d,p}$$

$$\Xi_t^{d,p} = Y_t + \beta \gamma_p^d E_t \Lambda_{t,t+1} (\pi_{t+1})^{\varepsilon_p^d - 1} (\pi_t^d)^{\gamma_{ind}^d (1-\varepsilon_p^d)} \Xi_{t+1}^{d,p}.$$

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, $l = x$, and import, $l = m$, retail firms are described by the following expressions:[10]

$$\pi_t^{l,*} = \frac{\varepsilon_p^l}{\varepsilon_p^l - 1} \frac{\Upsilon_t^{l,p}}{\Xi_t^{l,p}} \pi_t^l, \qquad \forall l = \{x, m\}$$

$$\pi_t^l = \left[\gamma_p^l (\pi_{t-1}^l)^{\gamma_{ind}^l (1-\varepsilon_p^l)} + \left(1 - \gamma_p^l\right)\left(\pi_t^{l,*}\right)^{1-\varepsilon_p^l}\right]^{\frac{1}{1-\varepsilon_p^l}} \qquad \forall l = \{x, m\}$$

[9] The price inflation is $\pi_t^d = P_t/P_{t-1}$; $\pi_t^{d,*}$ is the price inflation of the domestic adjusting firm.

[10] The price inflation is $\pi_t^l = P_t/P_{t-1}$; $\pi_t^{l,*}$ is the price inflation of the export/import adjusting firm.

where ε_p^l is the elasticity of substitution between differentiated l-type goods and γ_{ind}^l indicates the l-type goods' degree of indexation to past inflation.

The export and import auxiliary variables $\Upsilon_t^{l,p}$ and $\Xi_t^{l,p}$ evolve as:

$$\Upsilon_t^{l,p} = Y_t MC_t^l + \beta\gamma_p^l E_t \Lambda_{t,t+1} (\pi_{t+1}^l)^{\varepsilon_p^l} (\pi_t^l)^{-\gamma_{ind}^l \varepsilon_p^l} \Upsilon_{t+1}^{l,p} \qquad \forall = \{x, m\}$$

$$\Xi_t^{l,p} = Y_t + \beta\gamma_p^l E_t \Lambda_{t,t+1} (\pi_{t+1})^{\varepsilon_p^l - 1} (\pi_t^l)^{\gamma_{ind}^l (1-\varepsilon_p^l)} \Xi_{t+1}^{l,p} \qquad \forall = \{x, m\}$$

where $MC_t^x = P_t^d / e_t P_t^x$ and $MC_t^m = P_t^* e_t / P_t^m$ are the export and import marginal costs, respectively, with e_t defining the nominal exchange rate.

3.2 Financial market

3.2.1 Limited–asset market participation

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. Formally, there is a continuum of households in the space $[0,1]$. The household's period preferences are defined as:

$$\mathcal{U}_t = \frac{(C_{t+i} - hC_{t+i-1})^{1-\sigma}}{1-\sigma} - \chi \frac{L_{t+i}^{1+\varphi}}{1+\varphi}$$

where C_t is the aggregate consumption, $h \in [0,1)$ denotes the habits in consumption parameter, χ measures the relative weight of the labor disutility, φ is the inverse Frisch elasticity of labor supply and σ is the relative risk–aversion coefficient.

Non–liquidity constrained households ("dynamic optimizer households" from now on) solve the following intertemporal optimization problem:

$$\max \mathcal{W}_t^O{}_{C_{t+i}^O, L_{t+i}, B_{t+i}, B_{t+i}^*} = E_t \sum_{i=0}^{\infty} \beta^i \left[\frac{(C_{t+i}^O - hC_{t+i-1}^O)^{1-\sigma}}{1-\sigma} - \chi \frac{L_{t+i}^{1+\varphi}}{1+\varphi} \right]$$

$$s.t. \quad C_t^O + B_{t+1} + e_t B_{t+1}^* = W_t L_t + \Pi_t + T_t + R_t B_t + e_t \Phi_t R_t^* B_t^*$$

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, Π_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, Φ_t denotes the risk premium on foreign bond holdings given by

$$\Phi_t = \exp\left[(R_t - R_t^*) - \phi_a A_t + u_t^\phi \right],$$

where $A_t = e_t B_{t+1}^*$ denotes the net foreign assets (NFA) position, ϕ_a denotes the risk premium elasticity to the NFA position and u_t^ϕ is the risk premium shock on foreign bond holdings, which is assumed to follow a first order autoregressive stochastic process $u_t^\phi = u_{uip,t-1}^{\rho_{uip}} e^{\epsilon_{uip,t}}$.

From 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:

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

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

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

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

Instead, LAMP households solve:

$$\max \mathcal{W}_t^L{}_{C_{t+i}^L, L_{t+i}} = E_t \sum_{i=0}^{\infty} \beta^i \left[\frac{(C_{t+i}^L - hC_{t+i-1}^L)^{1-\sigma}}{1-\sigma} - \chi \frac{L_{t+i}^{1+\varphi}}{1+\varphi} \right]$$

$$s.t. \quad C_t^L = W_t L_t + T_t.$$

According to the budget constraint, their optimal consumption is equal to

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

and their marginal utility of consumption is

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

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.,

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

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

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 ν denotes the home bias parameter and η 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 that:

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

3.2.2 The banks' balance sheet constraints

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 θ of bankers survives while a fraction $1-\theta$ exits and is replaced.

Each banker can divert a fraction ζ of funds to its family. 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:

$$V_t = E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} N_{jt+i}$$

Following Gertler and Karadi (2011), 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 the following incentive constraint must hold for the banks to prevent them from diverting funds:

$$V_{jt} \geq \zeta Q_t S_{jt}$$

i.e., the potential loss of diverting assets (l.h.s. of the above equation) should be greater than the gain from doing so (r.h.s. of the above expression). Moreover, V_{jt} can be expressed as

$$V_{jt} = \upsilon_t Q_t S_{jt} + \eta_t N_{jt}$$

where η_t represents the expected discounted value of having an additional unit of net worth and υ_t must be interpreted as the expected discounted marginal gain to the banker of expanding assets $Q_t S_{jt}$ by a unit.

In this framework, the financial intermediary can acquire assets accordingly to his equity capital:

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

where ϕ_t is the private leverage ratio, i.e., the ratio of privately intermediated assets to equity.

As in Gertler and Karadi (2011), [11] the expected discounted marginal gain to the banker of expanding assets, $Q_t S_t$, by a unit is given by

[11] See Gertler and Karadi (2011) for the evolution of υ_t and η_t and a wider discussion about the agency problem.

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

and the expected discounted value of having another unit of N_t keeping fixed S_t

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

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

3.3 Labor market

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 ε_w.

Formally, a typical union chooses the optimal nominal wage W_t^* to maximize a weighted utility function:

$$\max_{W_t^*} \sum_{j=0}^{\infty} (\gamma_w\beta)^j \left\{ W_t^* \left(\frac{W_t^*}{W_{t+j}}\right)^{-\varepsilon_w} L_{t+j}\left[\lambda\varrho_{t+j}^L + (1-\lambda)\varrho_{t+j}^O\right] - \frac{\chi}{1+\varphi}\left[\left(\frac{W_t^*}{W_{t+j}}\right)^{-\varepsilon_w} L_{t+j}\right]^{1+\varphi} \right\}$$

where γ_w is the probability to keep the wage unchanged in the future.

Solving the above problem we obtain the adjustment dynamics for wage inflation[12]

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

$$\pi_t^w = \left[\gamma_w(\pi_{t-1}^w)^{1-\varepsilon_w} + (1-\gamma_w)\left(\pi_t^{w^*}\right)^{1-\varepsilon_w}\right]^{\frac{1}{1-\varepsilon_w}}.$$

Auxiliary variables Υ_t^w and Ξ_t^w evolve according to:

$$\Upsilon_t^w = U_{L,t}L_t + \gamma_w\beta E_t(\pi_{t+1}^w)^{\varepsilon_w}\Upsilon_{t+1}^w$$

$$\Xi_t^w = W_tL_t[\lambda\varrho_t^L + (1-\lambda)\varrho_t^O] + \gamma_w\beta E_t(\pi_{t+1}^w)^{\varepsilon_w-1}\Xi_{t+1}^w.$$

3.4 Aggregation, resource constraint, and government policies

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 ψ indicates the elasticity of investment adjustment cost.

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

$$e_tB_{t+1}^* = e_tP_t^x(C_t^x + I_t^x) - e_tP_t^*(C_t^m + I_t^m) + e_t\Phi_tR_t^*B_t^*$$

12 The wage inflation is $\pi_t^w = W_t/W_{t-1}$; $\pi_t^{w^*} = W_t^*/W_{t-1}$ is the wage inflation of the adjusting union.

where

$$1 + i_t = R_t \frac{E_t P_{t+1}}{P_t}.$$

As in Galì *et al*. (2007), the aggregate consumption is

$$C_t = (1 - \lambda) C_t^O + \lambda C_t^L.$$

The total value of intermediated assets is:

$$Q_t S_t = \phi_t N_t.$$

The law of motion of capital is

$$K_{t+1} = K_t + I_{Nt}.$$

Government expenditures G_t are financed by lump sum taxes

$$G_t = T_t.$$

Finally, the nominal interest rate i_t follows a simple Taylor rule

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

where ρ denotes the degree of interest rate smoothing, κ_π measures the response of the monetary authority to inflation and $\pi_t = P_t / P_{t-1}$ denotes the CPI inflation gross rate.

4 Empirical analysis

4.1 Data and methodology

We estimate our model, using Bayesian techniques, for a group of six countries, namely: Czech Republic, Estonia, Hungary, Lithuania, Poland and Slovakia. Our choice is motivated by the fact that Bayesian methods outperform GMM and maximum likelihood in small samples.[13] 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 algorithm for Monte Carlo integration; for the sake of simplicity, all structural parameters are supposed to be independent of one another.

For each country we perform the estimation by using eleven observable macroeconomic variables: real GDP, real consumption, real investment, export, import, real wage, price inflation, CPI inflation, import inflation, export inflation, and nominal interest rate. All the data are drawn from the OECD database. The dynamics are driven by eleven orthogonal shocks, including monetary policy, productivity, public spending, domestic price mark-up, import price mark-up, export price mark-up, wage mark-up, capital quality, foreign

[13] For an exhaustive analysis of Bayesian estimation methods, see Geweke (1999), An and Schorfheide (2007) and Fernández-Villaverde (2010).

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.[14]

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 β is set to 0.99; the capital share α is 0.33, δ is calibrated to 0.025, implying an annual capital depreciation of 10%; the ratio of public spending over output 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 have been assigned; feedback parameters of the Taylor rule and investment adjustment cost follow a Normal distribution.

4.2 Estimation results

Estimations of the structural parameters of our CEB economies are reported in Table 1 and 2. Tables only report posteriors.[15] The posterior distributions are obtained using the MH algorithm. The mean and posterior percentiles come from two chains of 200,000 draws each from the MH algorithm, for which 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%. 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.[16]

Table 1 – Posterior estimates (structural parameters)

	Czech Rep.	Estonia	Hungary	Lithuania	Slovakia	Poland	mean	s.d.
Deep parameters								
σ	**1.92**	**1.93**	**1.97**	1.69	1.46	**2.22**	1.86	0.26
φ	**2.07**	**1.96**	**3.29**	**2.49**	0.25	0.25	1.72	1.23
h	0.80	**0.89**	**0.87**	0.80	0.79	**0.87**	0.83	0.04

[14] The problems deriving from misspecification are widely discussed in Lubik and Schorfheide (2006) and Fernández-Villaverde (2010).

[15] 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.

[16] Full details on country estimations are reported in Appendix A (see tables A1-A6).

Nominal frictions and indexation								
γ_p^d	**0.86**	**0.84**	0.44	**0.88**	**0.92**	**0.93**	0.81	0.19
γ_p^m	0.44	0.45	**0.79**	0.31	**0.66**	0.41	0.51	0.18
γ_p^x	**0.79**	0.65	**0.73**	0.45	**0.82**	**0.90**	0.72	0.16
γ_w	**0.90**	**0.89**	0.58	**0.84**	**0.94**	0.70	0.81	0.14
γ_{ind}^d	**0.26**	0.17	0.17	**0.18**	0.16	0.16	0.18	0.04
γ_{ind}^m	0.28	0.29	**0.68**	0.26	0.31	0.23	0.34	0.17
γ_{ind}^x	**0.22**	**0.27**	0.18	**0.26**	**0.24**	0.16	0.22	0.04
γ_{ind}^w	0.35	0.29	**0.59**	**0.61**	0.36	**0.51**	0.45	0.14
Real frictions								
λ	0.17	**0.28**	**0.25**	**0.26**	0.14	0.05	0.19	0.09
ψ	**5.91**	5.78	**6.26**	5.58	5.78	5.47	5.80	0.28
η	1.38	**1.90**	**1.91**	1.00	**2.15**	**2.78**	1.85	0.62
$\eta*$	**1.17**	**1.26**	0.61	**1.22**	**1.23**	**1.46**	1.16	0.29
ϕ_a (x10)	**0.09**	0.01	**0.09**	**0.09**	**0.10**	**0.10**	0.08	0.03
z	7.44	**8.37**	6.40	7.13	**8.03**	**10.00**	7.90	1.24
Monetary policy parameters								
κ_π	**2.50**	**2.36**	1.91	**2.46**	1.54	**2.41**	2.20	0.39
κ_y	0.00	0.00	0.00	0.03	**0.17**	0.03	0.04	0.06
$\kappa_{\Delta y}$	**0.08**	0.00	0.03	0.01	**0.08**	0.03	0.04	0.03
$\kappa_{\Delta\Pi}$	**0.33**	**0.29**	0.09	**0.22**	0.08	0.16	0.20	0.10
ρ	**0.43**	**0.23**	0.20	0.20	0.12	0.19	0.23	0.11

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

Apart from Hungary, in all the other countries prices and wages seem to be very sticky as they adjust, on average, every 5-10 quarters. Our estimation suggests that prices and wages are partially indexed to lagged inflation, involving that when 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). Having a fraction of LAMP households of this dimension, entails that positive public spending shock can positively affect public consumption, i.e., no crowding out effects.

The central bank has been aggressive to contrast inflation in all countries, while the response to the output gap, apart in Slovakia, is negligible. The degree of interest rate smoothing is large and in line with the DSGE literature (see, e.g., Smets and Wouters, 2003 and 2007) where it is usually estimated to values greater than 0.7.

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. On the other hand, in Slovakia the standard deviation of the capital quality shock has been around double than the sample mean. Difference among countries are associated also with the AR(1) coefficient 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	**4.73**	**5.85**	**7.80**	4.09	2.63
e_g	19.90	**38.28**	16.70	**23.18**	19.29	21.26	23.10	7.74
e	0.30	**0.42**	0.25	**0.56**	0.32	0.16	0.33	0.14
e_Ψ	2.95	**4.45**	0.63	**4.41**	**7.83**	0.84	3.52	2.69
$e_{\mu pd}$	8.30	8.28	3.55	**13.65**	**17.21**	7.94	9.82	4.84
$e_{\mu pm}$	2.88	3.67	**19.85**	**9.02**	7.66	5.80	8.15	6.19
$e_{\mu px}$	**11.32**	6.89	4.69	8.41	**12.85**	**14.84**	9.83	3.83
$e_{\mu w}$	14.69	18.82	10.25	16.77	**33.58**	**24.59**	19.78	8.25
e_Π	1.15	1.21	**1.92**	**2.67**	1.39	0.99	1.55	0.63
e_{uip}	3.32	**5.76**	3.46	4.19	4.46	**5.64**	4.47	1.05
e_{y*}	4.42	**5.85**	3.85	**7.38**	5.19	**6.21**	5.48	1.28
ρ_a	**0.97**	0.58	**1.00**	**0.89**	0.76	0.73	0.82	0.16
ρ_g	0.79	0.82	0.83	0.79	**0.87**	**0.95**	0.84	0.06
ρ	0.80	0.82	**0.90**	**0.86**	**0.86**	**0.89**	0.85	0.04
ρ_Ψ	0.38	0.12	**0.90**	**0.67**	0.32	**0.84**	0.54	0.31
$\rho_{\mu pd}$	0.10	0.13	**0.89**	0.13	0.12	0.12	0.25	0.31
$\rho_{\mu pm}$	**0.73**	0.59	0.47	**0.83**	0.23	**0.85**	0.62	0.24
$\rho_{\mu px}$	0.14	0.17	**0.83**	**0.86**	0.23	0.13	0.40	0.35
$\rho_{\mu w}$	0.38	0.37	**0.95**	0.42	0.31	0.51	0.49	0.24
ρ_{ui}	0.07	0.14	**0.24**	0.09	**0.34**	**0.35**	0.20	0.12
ρ_{uip}	0.81	0.75	**0.88**	0.73	**0.88**	**0.92**	0.83	0.08
ρ_{y*}	0.80	**0.90**	**0.91**	0.84	**0.90**	**0.93**	0.88	0.05

5 Resilience in Central Europe: Indexes and comparisons

This section constructs some measures of resilience across countries populating the CEB area and investigates the relative performances of these countries. We focus on two dimensions of resilience: resistance and recovery. 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 (Section 5.1). Then, we use our model to investigate the relation between financial shock and CEB resilience (Section 5.2) and, more in general, between the countries' resistance and recovery capabilities and output variabilities (Section 5.3).

5.1 Central Europe regional differences

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)[17] and/or a

[17] Note that not all estimated parameters of Table 1 measure distortions.

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.
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. [18] 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, details are reported in Appendix C.

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.

[18] Information regarding the absolute values is not lost, but it is synthesized in the means that in such a case have to be taken into account in the data analysis (see Noy-Meir 1973).

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). By contrast, 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 C.

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.

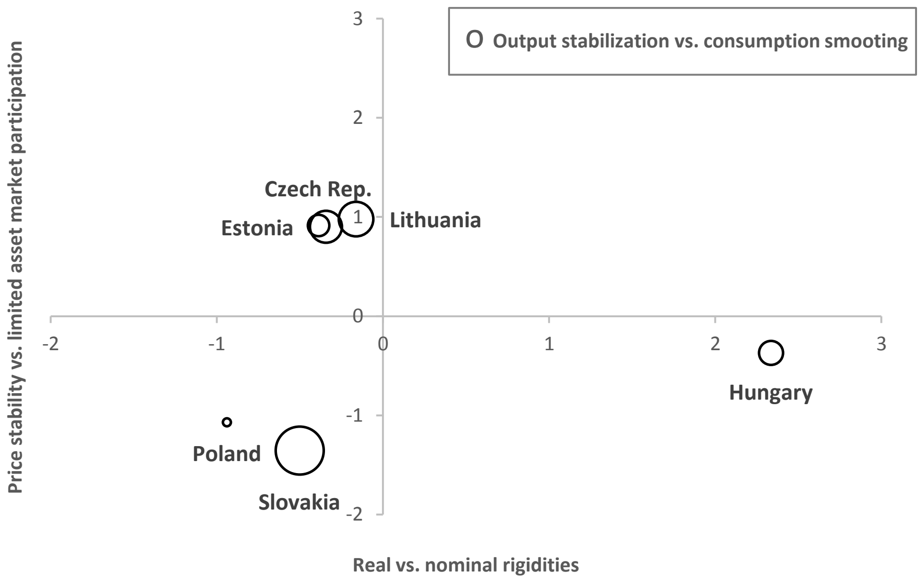

Figure 3 – Centered PCA

5.2 The impact of the financial crisis

The effects of the financial crisis in the six estimated countries, in blue solid line, compared to the CEB benchmark, in red 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, as a consequence 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.

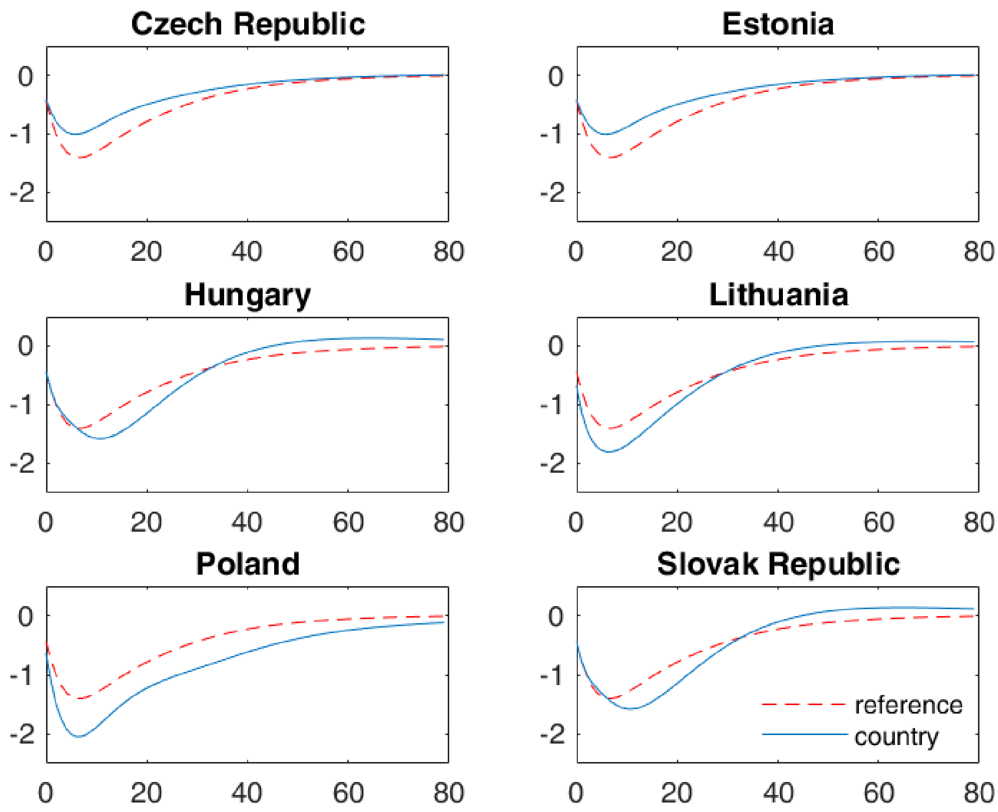

Figure 4 – Output IRF to a capital quality shock

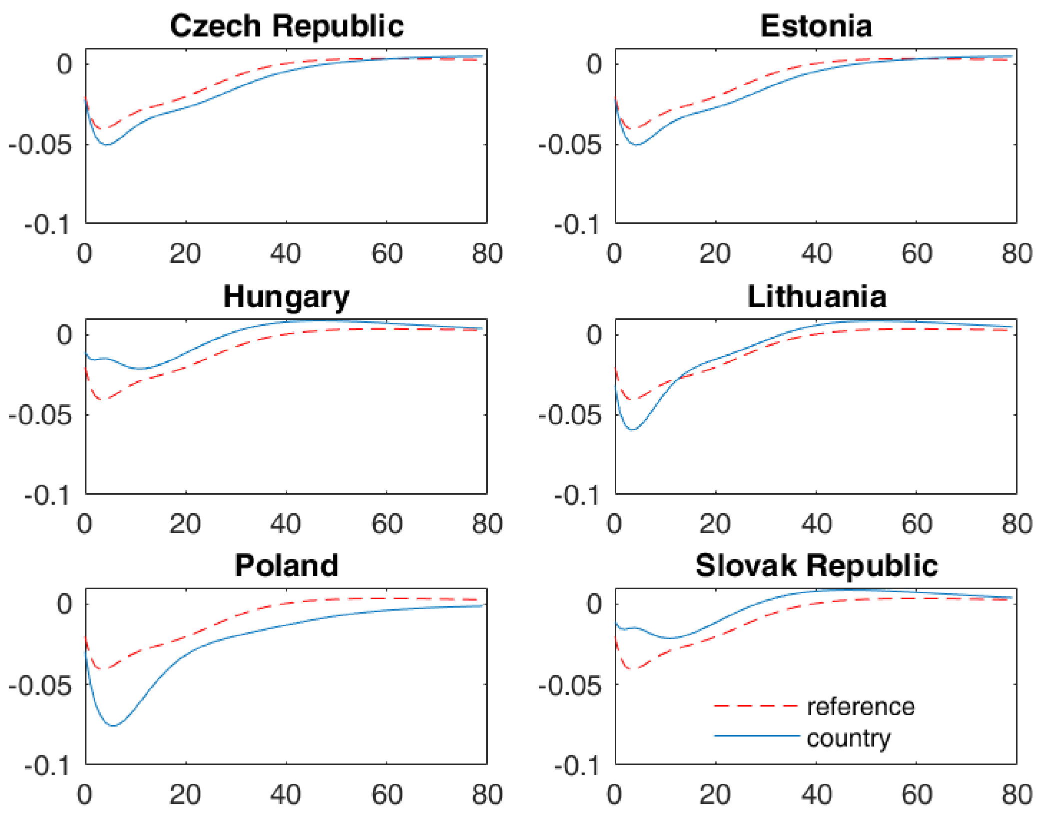

Figure 5 – Output IRF to a net wealth shock

5.3 Resistance and recovery

Finally, we closely study resilience as an ability to absorb external (recovery) shocks and remain immune to them (resistance). The first phenomenon is analyzed using a method based on simulations and related empirical moments. Regarding the recovery capacity, after computing output variance for each country in the sample, we calculate the empirical moments assuming that the stochastic structure is that of the country, while the structure of the deep parameters refers to the CEB region average (see Table 1). Then we calculate the percentage difference between these two measures. The difference, if positive (negative), measures the stronger (weaker) recovery capacity of the country's economic structure for the same stochastic structure than an average hypothetical region. Similarly, we calculate resilience as an ability to immunize from shocks. For each country we calculate the empirical moments assuming that the stochastic structure is the average of the Central Baltic Europe area (Table 2), while the structure of the parameters is country specific (see Table 1). Also in this case, a positive (negative) difference measures a greater (lower) ability to immunize from shocks than an average hypothetical region.

Our results are described in Table 3. As it can be easily noted, Hungary is the most vulnerable country to external shocks, as it has the less effective economic structure to absorb them. However, Hungary is also the most immune country compared to the rest of the economies considered in this analysis. Estonia, instead, is the less vulnerable country to external shocks compared with the remaining economies. In case resistance is considered, Hungary is positioned next to Poland in the race for the less immune country. Given the two polar cases described above, Czech Republic, Lithuania and Slovakia, show slight (strong) recovery capacity compared to Hungary (Estonia). Instead, when ranked by the resistance index, Czech Republic, Lithuania and Slovakia demonstrate lower (greater) immunity than Hungary (Estonia).

Table 3 – Output variability: Recovery and resistance

	Recovery	Resistance
Czech Republic	-0.079	-0.004
Estonia	0.954	-0.386
Hungary	-0.907	0.876
Lithuania	-0.449	0.062
Poland	-0.291	-0.450
Slovakia	-0.239	0.688

6 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 a CEE sub-region (Central Europe and the Baltics, CEB), we analyze the resilience performance to the 2008 financial crisis within countries of this region according to their shock isolation and absorptive capacities.

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 focus on two dimensions of the resilience: resistance and recovery. Specifically, we aim 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).

Accordingly, we study the relative differences across CEB economies using PCA obtaining synthetic orthogonal indexes of these differences in a parsimonious way. Our parameter estimates have been grouped into 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. Finally, we use both to compare the relative recovery (resistance) country performances of a single country to those of a hypothetical economy characterized by a CEB average structural (stochastic) set of estimated parameters. Precisely, considering estimated parameters as variables of a cross-sectional dataset organized by country, we first look at national differences considering as reference a hypothetical country, where there are no distortions and/or unaffected by disturbances; second we use, as reference, a hypothetical average country, built on the estimated parameter means.

By using our Bayesian estimations and non-centered PCA analysis, resistance and recovery have been investigated. CEB countries share similar values for their recovery index, meaning that they have similar economic structures. By contrast, Baltic countries placed at two extreme positions (Lithuania is relatively more flexible than Estonia). The opposite verifies for resistance: Baltic countries share a similar ranking, whereas CEB countries exhibit strong differences (Czech Republic and Hungary are less exposed to disturbances than Slovakia and Poland).

Centered PCA is also performed and three principal components explaining about the 77% of the estimated deep parameter variability have been individuated. The first component measures real vs. nominal stickiness; the second component identifies the preferences for price stability relatively to the financial markets development; the third and last component reveals the preference for output stabilization relatively to consumption smoothing and other sources of output persistence. Hungary positions for its relative price flexibility. It then 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. 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.

Investigating the impact on output of the financial crisis in the Baltics and Central European countries, we find that capital quality and net worth shocks share similar impact on Czech Republic and Estonia, on the one hand, and on Hungary, Lithuania; Poland, and Slovakia, on the other.

Our comparative exercise shows that Hungary is the most vulnerable country to external shocks, as it has the less effective economic structure to absorb them. However, Hungary is also the most immune country compared to the rest of the economies considered, as it is also characterized by low disturbance frequencies. Estonia exhibits instead the lowest vulnerability to external shocks. Given the two polar cases described above, 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).

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.

Appendix A

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]
ρ_{Ψ}	beta (0.5, 0.2)	0.379	[0.083, 0.730]
ρ_{a}	beta (0.5, 0.2)	0.971	[0.954, 0.987]
ρ_{g}	beta (0.5, 0.2)	0.787	[0.717, 0.859]
ρ_{y*}	beta (0.5, 0.2)	0.802	[0.757, 0.848]
ρ_{ui}	beta (0.5, 0.2)	0.065	[0.011, 0.118]
ρ_{uip}	beta (0.5, 0.2)	0.814	[0.769, 0.858]
ρ_{Π}	beta (0.5, 0.2)	0.434	[0.295, 0.566]
σ	norm (1.5, 0.375)	1.916	[1.379, 2.463]
φ	norm (2, 0.75)	2.065	[1.065, 3.055]
h	beta (0.7, 0.1)	0.796	[0.719, 0.878]
ψ	norm (5.5, 0.5)	5.909	[5.125, 6.657]
γ_p^d	beta (0.66, 0.1)	0.861	[0.819, 0.897]
γ_p^m	beta (0.66, 0.1)	0.435	[0.329, 0.536]
γ_p^x	beta (0.66, 0.1)	0.788	[0.724, 0.849]
γ_w	beta (0.66, 0.1)	0.899	[0.850, 0.950]
γ_{ind}^d	beta (0.5, 0.15)	0.258	[0.099, 0.407]
γ_{ind}^m	beta (0.5, 0.15)	0.282	[0.111, 0.450]
γ_{ind}^x	beta (0.5, 0.15)	0.224	[0.087, 0.358]
γ_{ind}^w	beta (0.5, 0.15)	0.347	[0.154, 0.535]
λ	beta (0.3, 0.15)	0.173	[0.126, 0.222]
η	norm (1.5, 0.25)	1.384	[1.099, 1.648]
η*	norm (1.5, 0.25)	1.171	[0.953, 1.400]
ϕ_a	norm (0.01, 0.001)	0.009	[0.008, 0.010]
z	norm (7.2, 2.5)	7.444	[5.332, 9.986]
κ_{π}	norm (1.5, 0.25)	2.497	[2.283, 2.726]
ρ	beta (0.75, 0.1)	0.800	[0.761, 0.836]
κ_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]
ρ_{Ψ}	beta (0.5, 0.2)	0.119	[0.013, 0.220]
ρ_a	beta (0.5, 0.2)	0.582	[0.389, 0.777]
ρ_g	beta (0.5, 0.2)	0.824	[0.766, 0.882]
ρ_{y*}	beta (0.5, 0.2)	0.899	[0.867, 0.932]
ρ_{ui}	beta (0.5, 0.2)	0.139	[0.042, 0.228]
ρ_{uip}	beta (0.5, 0.2)	0.751	[0.690, 0.824]
ρ_{Π}	beta (0.5, 0.2)	0.233	[0.074, 0.383]
σ	norm (1.5, 0.375)	1.930	[1.399, 2.475]
φ	norm (2, 0.75)	1.963	[1.031, 2.860]
h	beta (0.7, 0.1)	0.886	[0.838, 0.937]
ψ	norm (5.5, 0.5)	5.784	[5.021, 6.534]
γ_p^d	beta (0.66, 0.1)	0.836	[0.797, 0.881]
γ_p^m	beta (0.66, 0.1)	0.447	[0.314, 0.603]
γ_p^x	beta (0.66, 0.1)	0.652	[0.546, 0.757]
γ_w	beta (0.66, 0.1)	0.889	[0.857, 0.922]
γ_{ind}^d	beta (0.5, 0.15)	0.171	[0.057, 0.282]
γ_{ind}^m	beta (0.5, 0.15)	0.287	[0.104, 0.464]
γ_{ind}^x	beta (0.5, 0.15)	0.267	[0.112, 0.428]
γ_{ind}^w	beta (0.5, 0.15)	0.288	[0.118, 0.449]
λ	beta (0.3, 0.15)	0.284	[0.224, 0.340]
η	norm (1.5, 0.25)	1.898	[1.546, 2.246]
$\eta*$	norm (1.5, 0.25)	1.259	[0.985, 1.526]
ϕ_a	norm (0.01, 0.005)	0.001	[0.001, 0.001]
z	norm (7.2, 2.5)	8.368	[6.668, 9.999]
κ_{π}	norm (1.5, 0.25)	2.356	[2.175, 2.558]
ρ	beta (0.75, 0.1)	0.820	[0.782, 0.855]
κ_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]
ρ_{Ψ}	beta (0.5, 0.2)	0.903	[0.831, 0.979]
ρ_a	beta (0.5, 0.2)	0.998	[0.998, 0.998]
ρ_g	beta (0.5, 0.2)	0.833	[0.779, 0.893]
ρ_{y*}	beta (0.5, 0.2)	0.907	[0.885, 0.931]
ρ_{ui}	beta (0.5, 0.2)	0.237	[0.104, 0.361]
ρ_{uip}	beta (0.5, 0.2)	0.880	[0.851, 0.910]
ρ_{Π}	beta (0.5, 0.2)	0.198	[0.071, 0.315]
σ	norm (1.5, 0.375)	1.968	[1.397, 2.505]
φ	norm (2, 0.75)	3.294	[2.451, 4.172]
h	beta (0.7, 0.1)	0.870	[0.809, 0.934]
ψ	norm (5.5, 0.5)	6.261	[5.500, 7.006]
γ_p^d	beta (0.66, 0.1)	0.439	[0.347, 0.534]
γ_p^m	beta (0.66, 0.1)	0.793	[0.716, 0.888]
γ_p^x	beta (0.66, 0.1)	0.734	[0.664, 0.807]
γ_w	beta (0.66, 0.1)	0.585	[0.502, 0.665]
γ_{ind}^d	beta (0.5, 0.15)	0.174	[0.052, 0.287]
γ_{ind}^m	beta (0.5, 0.15)	0.677	[0.414, 0.947]
γ_{ind}^x	beta (0.5, 0.15)	0.177	[0.074, 0.272]
γ_{ind}^w	beta (0.5, 0.15)	0.586	[0.371, 0.801]
λ	beta (0.3, 0.15)	0.251	[0.187, 0.311]
η	norm (1.5, 0.25)	1.907	[1.678, 2.110]
$\eta*$	norm (1.5, 0.25)	0.609	[0.454, 0.768]
ϕ_a	norm (0.01, 0.001)	0.009	[0.009, 0.010]
z	norm (7.2, 2.5)	6.404	[3.626, 9.290]
κ_π	norm (1.5, 0.25)	1.912	[1.582, 2.259]
ρ	beta (0.75, 0.1)	0.899	[0.880, 0.922]
κ_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]
ρ_{Ψ}	beta (0.5, 0.2)	0.667	[0.349, 0.934]
ρ_{a}	beta (0.5, 0.2)	0.892	[0.706, 0.989]
ρ_{g}	beta (0.5, 0.2)	0.791	[0.719, 0.855]
ρ_{y*}	beta (0.5, 0.2)	0.844	[0.793, 0.897]
ρ_{ui}	beta (0.5, 0.2)	0.094	[0.017, 0.161]
ρ_{uip}	beta (0.5, 0.2)	0.732	[0.649, 0.813]
ρ_{Π}	beta (0.5, 0.2)	0.205	[0.080, 0.330]
σ	norm (1.5, 0.375)	1.690	[1.149, 2.210]
φ	norm (2, 0.75)	2.495	[1.625, 3.371]
h	beta (0.7, 0.1)	0.798	[0.731, 0.860]
ψ	norm (5.5, 0.5)	5.581	[4.712, 6.387]
γ_p^d	beta (0.66, 0.1)	0.879	[0.837, 0.925]
γ_p^m	beta (0.66, 0.1)	0.313	[0.214, 0.423]
γ_p^x	beta (0.66, 0.1)	0.454	[0.334, 0.582]
γ_w	beta (0.66, 0.1)	0.835	[0.784, 0.890]
γ_{ind}^d	beta (0.5, 0.15)	0.177	[0.062, 0.286]
γ_{ind}^m	beta (0.5, 0.15)	0.262	[0.080, 0.445]
γ_{ind}^x	beta (0.5, 0.15)	0.257	[0.092, 0.420]
γ_{ind}^w	beta (0.5, 0.15)	0.613	[0.397, 0.832]
λ	beta (0.3, 0.15)	0.255	[0.180, 0.331]
η	norm (1.5, 0.25)	1.002	[0.701, 1.262]
$\eta*$	norm (1.5, 0.25)	1.218	[1.218, 1.218]
ϕ_a	norm (0.01, 0.001)	0.009	[0.008, 0.010]
z	norm (7.2, 2.5)	7.126	[4.920, 9.973]
κ_{π}	norm (1.5, 0.25)	2.461	[2.176, 2.737]
ρ	beta (0.75, 0.1)	0.861	[0.830, 0.892]
κ_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]
ρ_{Ψ}	beta (0.5, 0.2)	0.841	[0.693, 0.993]
ρ_a	beta (0.5, 0.2)	0.733	[0.633, 0.820]
ρ_g	beta (0.5, 0.2)	0.945	[0.924, 0.965]
ρ_{y*}	beta (0.5, 0.2)	0.930	[0.907, 0.955]
ρ_{ui}	beta (0.5, 0.2)	0.350	[0.194, 0.493]
ρ_{uip}	beta (0.5, 0.2)	0.920	[0.898, 0.943]
ρ_{Π}	beta (0.5, 0.2)	0.192	[0.056, 0.315]
σ	norm (1.5, 0.375)	2.223	[1.737, 2.720]
φ	norm (2, 0.75)	0.250	[0.250, 0.250]
h	beta (0.7, 0.1)	0.867	[0.811, 0.923]
ψ	norm (5.5, 0.5)	5.465	[4.705, 6.251]
γ_p^d	beta (0.66, 0.1)	0.932	[0.915, 0.948]
γ_p^m	beta (0.66, 0.1)	0.410	[0.273, 0.546]
γ_p^x	beta (0.66, 0.1)	0.896	[0.840, 0.954]
γ_w	beta (0.66, 0.1)	0.700	[0.611, 0.790]
γ_{ind}^d	beta (0.5, 0.15)	0.162	[0.059, 0.261]
γ_{ind}^m	beta (0.5, 0.15)	0.234	[0.064, 0.385]
γ_{ind}^x	beta (0.5, 0.15)	0.161	[0.053, 0.255]
γ_{ind}^w	beta (0.5, 0.15)	0.508	[0.265, 0.756]
λ	beta (0.3, 0.15)	0.054	[0.040, 0.069]
η	norm (1.5, 0.25)	2.782	[2.550, 3.088]
η^*	norm (1.5, 0.25)	1.457	[1.091, 1.799]
ϕ_a	norm (0.01, 0.001)	0.009	[0.009, 0.010]
z	norm (7.2, 2.5)	9.999	[9.999, 10.00]
κ_π	norm (1.5, 0.25)	2.409	[2.110, 2.689]
ρ	beta (0.75, 0.1)	0.890	[0.860, 0.918]
κ_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
$\rho_{\mu pd}$	beta (0.5, 0.2)	0.115	[0.016, 0.202]
$\rho_{\mu pm}$	beta (0.5, 0.2)	0.228	[0.038, 0.426]
$\rho_{\mu px}$	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]
ρ_{Ψ}	beta (0.5, 0.2)	0.315	[0.164, 0.450]
ρ_{a}	beta (0.5, 0.2)	0.764	[0.655, 0.875]
ρ_{g}	beta (0.5, 0.2)	0.871	[0.817, 0.927]
ρ_{y*}	beta (0.5, 0.2)	0.900	[0.866, 0.934]
ρ_{ui}	beta (0.5, 0.2)	0.340	[0.153, 0.518]
ρ_{uip}	beta (0.5, 0.2)	0.883	[0.841, 0.928]
ρ_{Π}	beta (0.5, 0.2)	0.116	[0.019, 0.203]
σ	norm (1.5, 0.375)	1.457	[0.894, 1.998]
φ	norm (2, 0.75)	0.250	[0.250, 0.250]
h	beta (0.7, 0.1)	0.786	[0.690, 0.887]
ψ	norm (5.5, 0.5)	5.783	[4.951, 6.557]
γ_p^d	beta (0.66, 0.1)	0.924	[0.901, 0.949]
γ_p^m	beta (0.66, 0.1)	0.657	[0.535, 0.783]
γ_p^x	beta (0.66, 0.1)	0.818	[0.738, 0.897]
γ_w	beta (0.66, 0.1)	0.939	[0.912, 0.966]
γ_{ind}^d	beta (0.5, 0.15)	0.156	[0.050, 0.258]
γ_{ind}^m	beta (0.5, 0.15)	0.314	[0.112, 0.505]
γ_{ind}^x	beta (0.5, 0.15)	0.236	[0.082, 0.388]
γ_{ind}^w	beta (0.5, 0.15)	0.359	[0.166, 0.565]
λ	beta (0.3, 0.15)	0.143	[0.096, 0.186]
η	norm (1.5, 0.25)	2.149	[1.869, 2.448]
$\eta*$	norm (1.5, 0.25)	1.226	[0.914, 1.550]
ϕ_a	norm (0.01, 0.0005)	0.010	[0.009, 0.011]
z	norm (7.2, 2.5)	8.035	[6.065, 9.999]
κ_{π}	norm (1.5, 0.25)	1.538	[1.222, 1.877]
ρ	beta (0.75, 0.1)	0.855	[0.809, 0.903]
κ_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

In this section we provide 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.

It is interesting to analyze the contribution of the various shocks to the booms and busts in all the regions considered. In this way we can compare which shocks have mainly driven the output growth both in expansions and recessions along our sample. Historical decompositions of the output growth are plotted in Figures 1b-6b considering a semiannual basis. The black solid line depicts the actual series of the GDP growth, while the colored rectangles represent the contribution of each single shock to the output growth. In line of principle, each shock can give a positive or negative contribution. By "Demand" we label shocks to the public spending and foreign GDP, the label "mark-up" groups all the shocks to price and wage mark-up. We further consider in which direction monetary policy, capital quality and TFP shocks affect the GDP fluctuations in our sample for all countries.

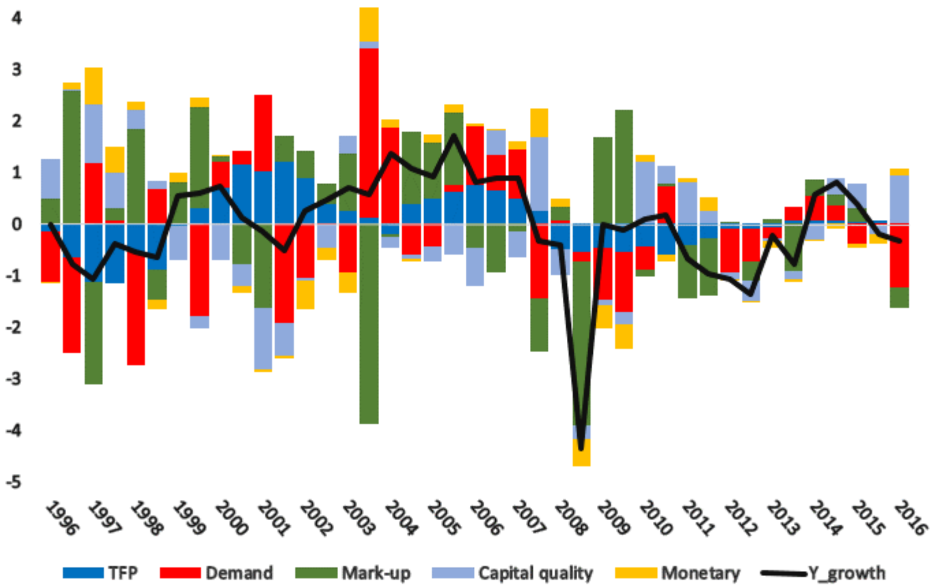

Figure B1 – Czech Republic GDP growth historical decomposition

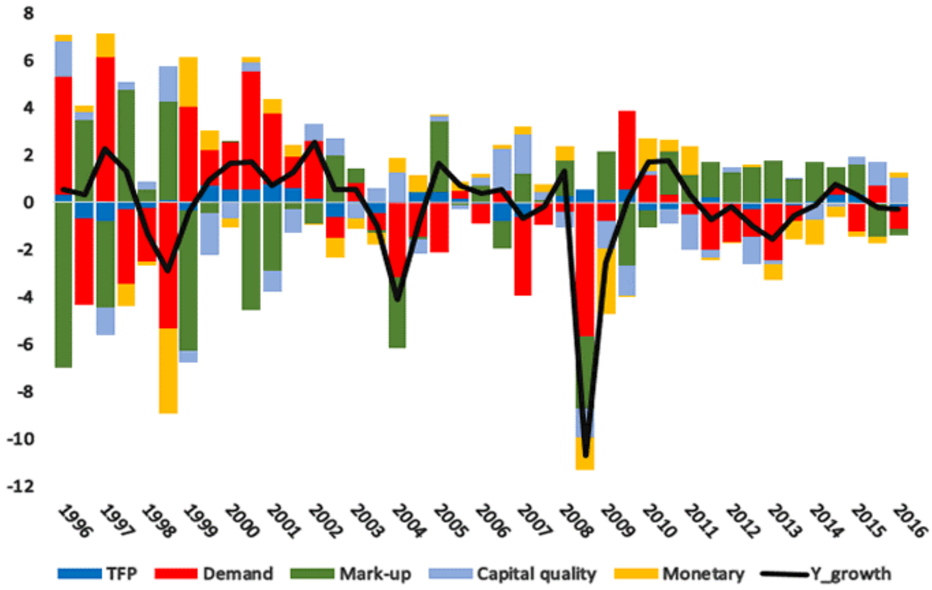

Figure B2 – Estonia GDP historical decomposition

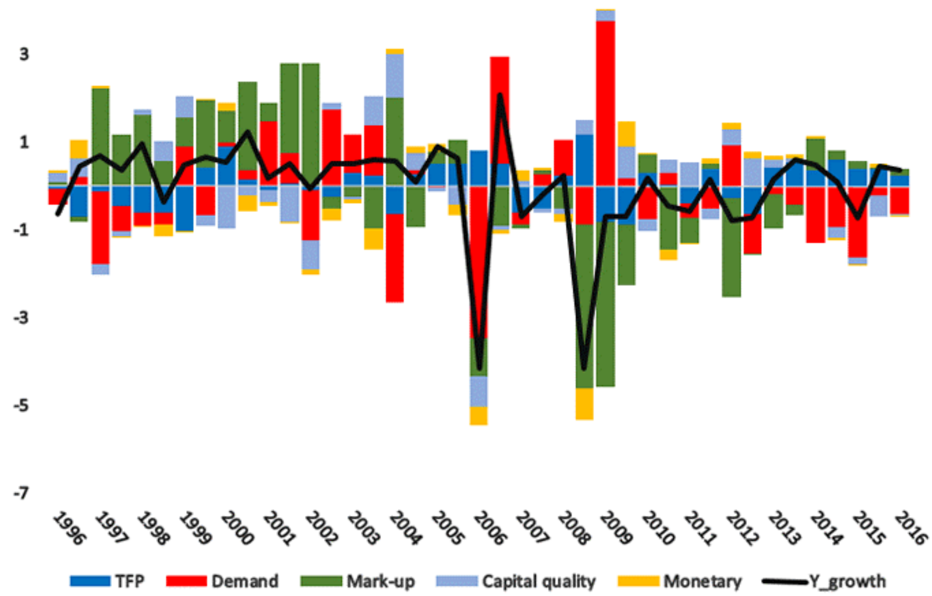

Figure B3 – Hungary GDP historical decomposition

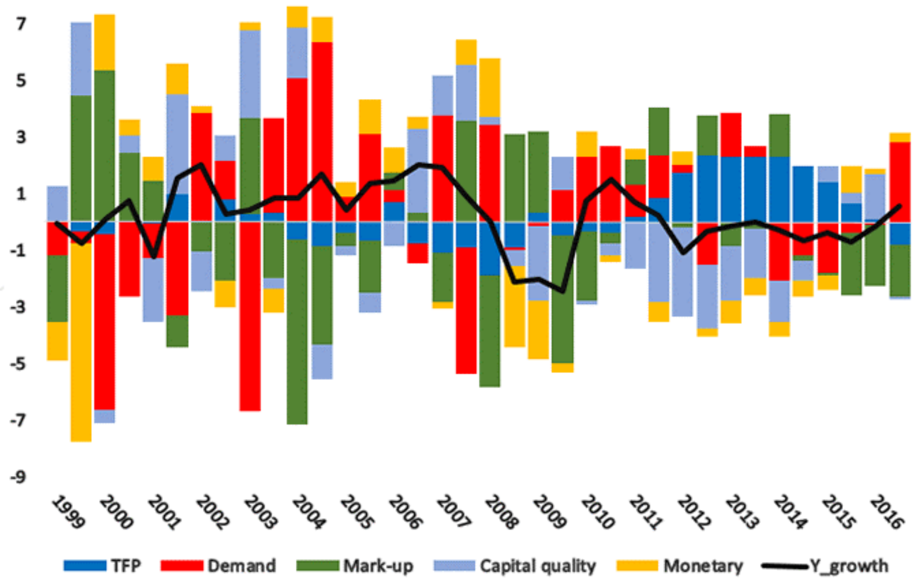

Figure B4 – Lithuania GDP historical decomposition

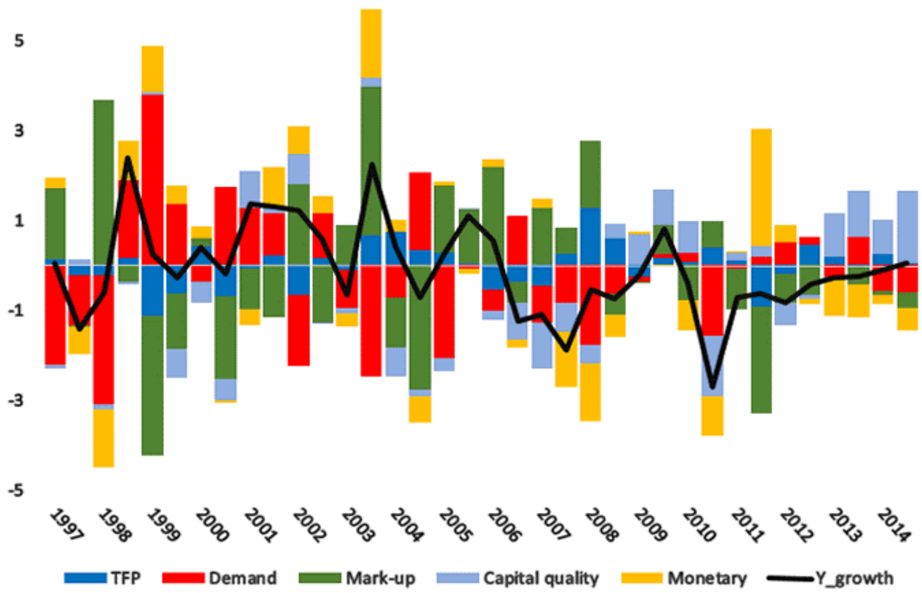

Figure B5 – Poland GDP historical decomposition

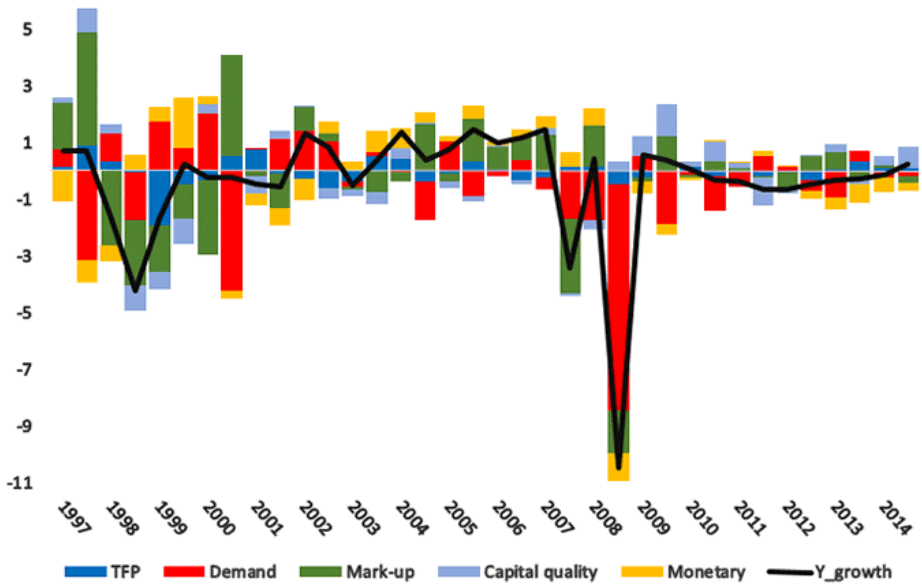

Figure B6 – Slovakia GDP historical decomposition

We begin our investigation from the Czech Republic (Figure 1b). Positive demand shocks, associated with positive TFP shocks have driven the growth in the half-mid of the '2000. The big fall of 2009 was mainly due to negative mark-up shocks, but also capital quality and restrictive monetary policy have played some role in the 2009 fall. In general, mark-up and demand shocks have usually been opposed.

A similar path is observed in Estonia (Figure 2b) and Hungary (Figure 3b). In both countries negative mark-up and demand shock have driven the big recession of the 2009. However, in Estonia monetary policy shocks played also an important role during the big recession of 1998 triggered by the Russian financial crisis, while in Hungary, beyond demand and mark-up shocks, TFP shock often influenced the business cycle fluctuations. In Hungary, the 2006 demand driven recession, was mainly due to fiscal adjustment package and the EU-approved convergence plan launched after the election to cut the budget deficit.

In Lithuania capital quality shocks are estimated to be very important after the 2009 outbreak, partially offset by positive TFP shocks (see Figure 4b).

A negative capital quality shock (associated with falling demand) is also the main driving force for the polish recession of late 2009-early 2010 (Figure 5b). The following recover has been also due to an improvement of the financial conditions. At the beginning of our sample, late '90, the cycle was mainly affected by monetary and demand shocks.

Finally, by looking at the Slovakia (Figure 6b), we see as it experienced a drastic GDP fall since the late 2008, mainly due to a collapse of the demand. This shock was also, together with negative mark-up and capital quality shocks, responsible of the 1998 recession where after election, the new government was obliged to reduce previous period excessive government investment for the purposes of debt consolidation.

Appendix C

Table C1 – Resilience indexes: PCA variable loadings

Recovery		Resistance	
variable	load	variable	load
σ	-0,103	e_a	0,044
φ	-0,018	e	0,068
h	0,578	e_g	0,084
ψ	0,652	$e_{\mu pd}$	0,057
γ_p^d	0,136	$e_{\mu pm}$	0,037
γ_p^m	0,089	$e_{\mu px}$	0,072
γ_p^x	0,146	$e_{\mu w}$	0,068
γ_w	0,184	e_Ψ	0,037
γ_{ind}^d	0,152	e_{y*}	0,121
γ_{ind}^m	0,065	e_{uip}	0,121
γ_{ind}^x	0,160	e_Π	0,069
γ_{ind}^w	0,103	ρ_a	0,145
λ	0,290	ρ_g	0,401
		ρ_{y*}	0,520
		ρ_{ui}	0,047
		ρ_{uip}	0,305
		ρ	0,624

Table C2 – 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
σ	-0,103	0,099	-0,327	0,414	-0,307	-0,274
φ	-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
ψ	0,652	-0,206	-0,231	0,239	0,078	-0,125
γ_p^d	0,136	0,478	0,044	-0,087	-0,084	-0,143
γ_p^m	0,089	-0,287	0,041	0,499	-0,175	0,075
γ_p^x	0,146	0,065	0,417	0,359	0,16	0,166
γ_w	0,184	0,416	-0,285	0,164	-0,017	0,029
γ_{ind}^d	0,152	0,084	-0,157	0,014	0,796	-0,118
γ_{ind}^m	0,065	-0,421	-0,037	0,194	-0,04	-0,015
γ_{ind}^x	0,16	0,244	-0,486	-0,068	-0,19	0,086
γ_{ind}^w	0,103	-0,22	0,072	-0,312	-0,182	-0,738
λ	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 C3 – 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
$e_{\mu pd}$	0,057	-0,244	-0,205	0,45	-0,085	0,13
$e_{\mu pm}$	0,037	0,323	0,067	0,058	-0,531	-0,171
$e_{\mu px}$	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_{Ψ}	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_{Π}	0,069	0,22	-0,353	0,218	-0,191	-0,312
ρ_a	0,145	0,387	-0,009	0,305	0,358	0,064
ρ_g	0,401	-0,14	0,172	-0,055	0,121	-0,036
ρ_{y*}	0,52	-0,025	-0,007	-0,222	-0,195	0,18
ρ_{ui}	0,047	-0,152	0,326	0,099	-0,458	-0,166
ρ_{uip}	0,305	0,043	0,336	0,118	0,089	0,161
ρ	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 C4 – 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
σ	0.024	-0.02	-0.467	0.143	-0.027
φ	0.288	-0.271	-0.005	0	0.063
h	0.115	0.012	-0.388	-0.188	-0.271
ψ	-0.376	0.004	0.063	-0.023	0.062
γ_p^d	0.277	0.225	0.112	0.046	-0.238
γ_p^m	-0.059	0.295	-0.121	0.309	-0.249
γ_p^x	-0.262	-0.116	0.295	-0.012	-0.193
γ_w	-0.02	-0.238	0.046	0.471	-0.034
γ_{ind}^d	0.373	0.072	0	0.027	-0.068
γ_{ind}^m	-0.116	-0.254	0.273	-0.241	-0.145
γ_{ind}^x	0.179	0.04	-0.1	-0.086	0.573
γ_{ind}^w	0.193	-0.287	0.112	-0.247	-0.129
ψ	0.327	-0.023	0.101	0.161	-0.254
η	-0.062	0.334	-0.237	-0.02	-0.208
η^*	-0.374	0.013	-0.072	-0.062	0.039
ϕ_a	0.049	0.197	0.109	0.284	0.468
z	-0.283	0.166	-0.252	-0.049	-0.083
κ_π	-0.126	-0.293	-0.271	0.093	0.167
κ_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
ρ	-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

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List of figures

List of tables

Annexes

Annex 1. Appendix A

Annex 2. Appendix B

Annex 3. Appendix C

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