Journal of Economic Studies

843

An integrated Bayesian-principal component approach to macroeconomic resilience: the case of the Central Europe and Baltic macro-region

Received 6 May 2024
Revised 24 June 2024
3 July 2024
Accepted 5 July 2024

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Abstract

Purpose – In the fashion of Martin (2012), we develop an innovative application to a standard, well-grounded methodology to investigate resilience in two critical dimensions: recovery and resistance. Our novel approach allows us to investigate the resilience performance to the 2008 financial crisis within countries of this macro-region according to their shock isolation and absorptive capacities.

Design/methodology/approach – By individually estimating six open economy DSGE models within the Central Europe and Baltic macro-region, we identify the business-cycle-volatility drivers for each country. Then, we use the outcome of our six estimates to conduct a principal component analysis to determine structural common characteristics required to explain economic resilience in the CEB macro-region.

Findings – In terms of resilience, Central European economies exhibit quite similar paths in terms of recovery, meaning they have similar economic structures. By contrast, Baltic countries behave differently, being outliers in opposite extreme positions. The contrary occurs for resistance: Baltic countries share a similar ranking, whereas Central European economies exhibit substantial differences.

Research limitations/implications – It is important to acknowledge that a limitation of the analysis is that we explicitly consider each country as a stand-alone open economy which are subject to stochastic disturbances. Precisely, we do not model trade or other interactions across countries within the CEB region and with the rest of the world. Consequently, spillover effects in the aftermath of the shock are not accounted for.

Originality/value – We estimate the relative vulnerability or sensitivity of economies within the macro-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 the economic resilience across the region. The approach can be applied to several case studies, parsimoniously.

Keywords Financial crisis, Resilience, Macroeconomic performance, Emerging markets, Bayesian estimations, Principal component analysis

Paper type Research paper

1. Introduction

Post-Communist countries share historical foundations and adopted neoliberal policies after the Berlin Wall fell in 1990. These policies included cutting public spending, promoting trade and capital liberalization, and privatization. The transformation of the Central and Eastern

JEL Classification — E02, E32, E58

We are grateful to Nicola Acocella and Patrizio Tirelli for helpful comments and suggestions and to seminar participants from Regional Studies Association 2017 Central and Eastern Europe Conference. Derivation details and additional tables are available online at the EU/JRC webpage from the working paper version of this study (see Beqiraj *et al.*, 2017).

Journal of Economic Studies
Vol. 52 No. 5, 2025
pp. 843-858

0144-3585
DOI 10.1108/JES-05-2024-0305

European (CEE) region to relaunch the European integration process and guarantee full accession to the EU (European Union) 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, opening the region to deeper exposure to global booms and busts.

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

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

In the context of the unprecedented crisis precipitated by the global spread of the COVID-19 pandemic, the recent conflict in Ukraine, and renewed tensions in the Middle East, a significant body of literature has emerged examining the ways in which the region has responded to the urgent need to foster a robust recovery, while simultaneously enhancing the resilience of economic systems and societies and positioning them for future challenges., (Webb *et al.*, 2022; Constantinescu, 2023).

We adopt a DSGE modeling framework to investigate the economic performance of the Central Europe and Baltic (CEB) macro-region [2], from which we excluded Latvia and Slovenia [3]. We built a small-open economy model for six distinct CEB macro-region economies and estimated them using Bayesian techniques. The model features standard nominal wage and price rigidities, monopolistic competition in the good market, real wage rigidities, and financial frictions. Financial frictions assume the forms of liquidity–constrained households and limited access to the deposits for the bank system (Gertler and Karadi, 2011) [4].

In the fashion of Martin (2012), we also develop an innovative application to a standard, well-grounded methodology to investigate resilience in two critical dimensions: recovery and resistance. The latter can be defined as the relative vulnerability or sensitivity of economies within the CEB region to disturbances and disruptions, whereas the former is the speed and extent of recovery from such a disruption or recession.

The novel methodology has been applied to our Bayesian estimations. We group our parameter estimates 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. Accordingly, we study the relative differences across CEB economies, innovatively applying a Principal Component Analysis (PCA) to our Bayesian estimates, obtaining synthetic orthogonal indexes of these differences parsimoniously [5].

Although some structural parameters within the CEB macro-region seem similar (i.e. those describing habit decision and risk aversion), relatively more significant

heterogeneity exists across countries concerning nominal wage, price rigidities, and financial frictions. Hungary and Poland behave as outliers in the region. As regards the monetary policy feedback rules, the response of central banks is quite aggressive in contrast to inflation in all countries, while the response to the output gap, apart from 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.

In terms of resilience, Central European economies exhibit quite similar paths in terms of recovery, meaning they have similar economic structures. By contrast, Baltic countries behave differently, being outliers in opposite extreme positions. The contrary occurs for resistance: Baltic countries share a similar ranking, whereas Central European economies exhibit substantial differences. Centered PCA stresses the peculiarity of Hungary, reflecting its relative price flexibility. It individuates two groups of countries. The Czech Republic, Estonia, and Lithuania are characterized by a relatively 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 that cannot access the financial markets. However, PCA individuates further differences within the last group: Slovakia (Poland) observes a relatively high (low) preference for output stabilization relative to consumption smoothing.

The EU enlargement, its potential rebound in economic integration, and the consequent convergence process to common living conditions and regulatory framework are in place. Centered PCA, which explains relative country performances concerning the case of an "average" kind of CEB country, can then help emphasize pre-existing differences among countries and identify priority areas of intervention for policy-makers.

The paper is structured as follows: Section 2 introduces our theoretical model, Section 3 presents estimation results, Section 4 discusses CEB economies' resilience, and 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 [6]. The economy is augmented by an imperfect banking sector à la Gertler and Karadi (2011), assuming that firms borrow indirectly from households through the banking sector that operates in an imperfect financial market. Financial frictions are twofold: (1) Only a fraction of the households can access the credit market through financial intermediaries (limited–asset market participation assumption, LAMP henceforth) [7]. (2) 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 economy's supply side is characterized by a competitive retail sector combining 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.

Labor markets are imperfect. Sticky wages are set by monopolistic unions, representing differentiated labor inputs provided by dynamic optimizers and LAMP agents. Labor unions set the nominal wages facing nominal rigidities à la Calvo.

Finally, the monetary authority sets the nominal interest rate according to a simple Taylor rule with interest rate smoothing.

3. Empirical analysis

3.1 Data and methodology

Using Bayesian techniques, we estimate our model for six CEB countries: the 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 [8]. The sample we consider spans from 2002:Q1 to 2016:Q3 when all the countries could be considered as market economies [9].

We estimate each country 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 [10]. 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 markup, import price markup, export price markup, wage markup, capital quality, foreign GDP, risk premium, and CPI inflation.

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 Tables 1 and 2 of the online Appendix B [11].

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, prices and wages are quite sticky in all countries as they adjust, on average, every 5–10 quarters. Our estimation suggests that prices and wages are partially indexed to lag inflation. Therefore, when a shock perturbs the economy, these variables slowly revert to a steady state. The limited asset market participation is estimated at around 20% (except for Poland which 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 from Slovakia, is negligible. The degree of interest rate smoothing is significant in all the region's countries 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).

By investigating the posterior estimations of the stochastic structure, as expected, we observe high autocorrelation for the technology shock. Capital quality shocks are important for mimicking the effects of a financial crisis and their estimates are heterogeneous. Concentrating on the volatility expressed by the standard deviation, capital quality shocks have exhibited a small variance in Hungary and Poland compared with the sample mean. Its standard deviation is instead around double the sample mean in Slovakia. Differences among countries are also associated with the persistence of the shock in capital quality. A high persistence rate is estimated for Hungary, Lithuania, and Poland, whereas the degree of inertia is small in the remaining countries.

3.2.2 The recession drivers. By using our Bayesian estimation, it 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 1990s 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 economy's fluctuations for our sample of estimated countries. Historical decompositions of the output growth for each country are plotted in panels (a)-(f) on a semi-annual 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 markup groups all the shocks to price and wage markup; other disturbances considered are discretionary monetary policies, capital quality, and TFP.

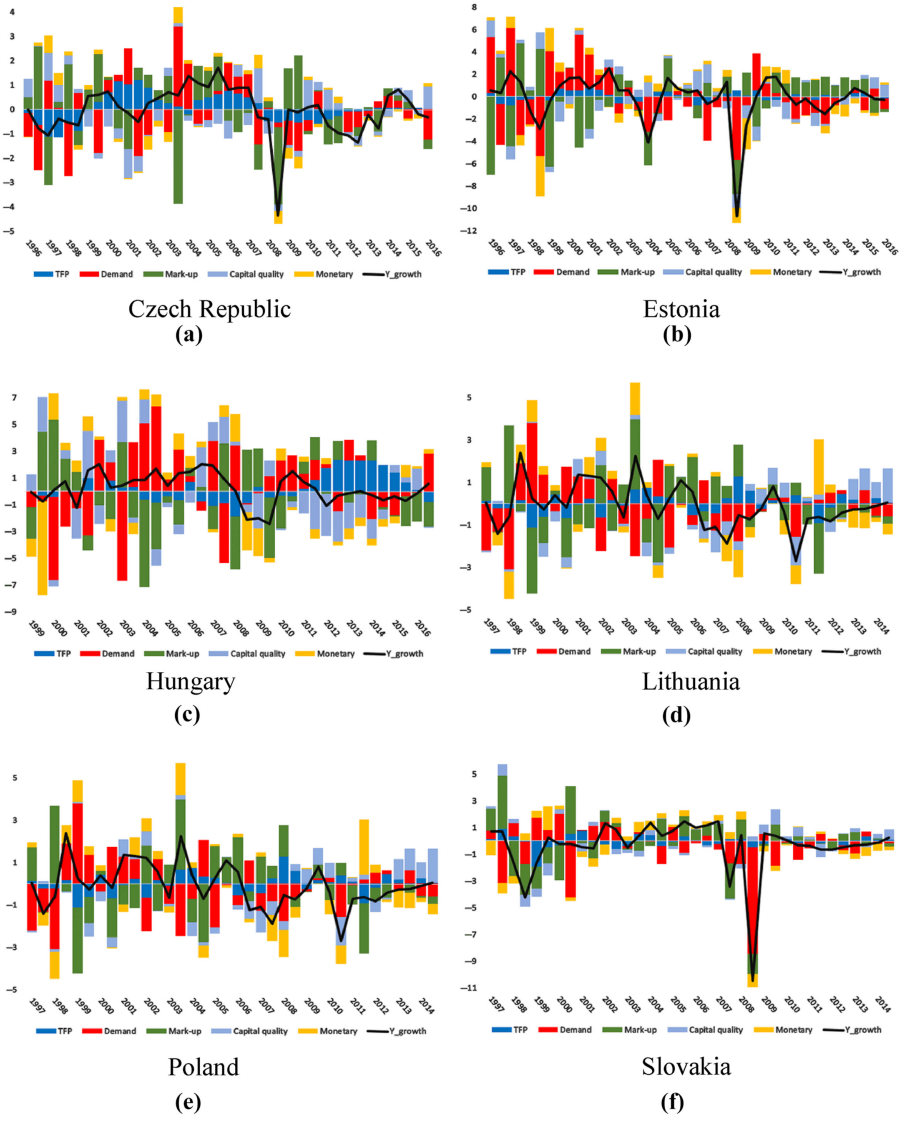

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Figure 1.
GDP growth historical decomposition

In the region, together with Poland, the Czech Republic is one of the economies that suffered less from the crisis [12]. Figure 1(a) shows that demand factors and positive TFP shocks drove the growth in the half-mid of the 2000s. The significant fall of 2009 was mainly due to adverse markup 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 to stop the currency from excessive strengthening and to contrast deflation. The Czech economy imported the global crisis from Western Europe, and supply factors mainly drove its propagation. The Czech Republic's most prominent companies by revenue are automobile manufacturers, which suffered from the lower external demand for intermediate and capital goods in 2008. Instead, the financial system was less vulnerable than its counterparts in the area.

After 2000, Hungary became one of the region's worst-performing countries before it was a regional champion of post-socialist economies (see Figure 1(b)). The spread of the financial crisis revealed the extent of its vulnerabilities. Negative markup and demand shock have driven the big recession of 2008–09. 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 markup and demand shock have driven the big recession of 2007–08 (cf. See Figure 1(c)). Here, the abrupt decrease in the GDP can be related to an unsustainable economic growth model based on foreign loans and domestic consumption, weakened by the dominance of the Nordic banking groups (Raagma, 2010, p. 88). In Estonia, demand factors were among the determinants of the recession of 1998 triggered by the Russian financial crisis; monetary policy shocks also played an important role [13].

Before the financial crisis, Lithuanian GDP experienced strong real growth rates; as a result, the country was often dubbed a Baltic Tiger. However, the country's real GDP contracted by 14.9% in 2009. A mix of internal and external factors drove the slump. Excessive 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 exports also played a relevant role in the weaker performance trade of Lithuania during the crisis, which is structurally very vulnerable from the outside because a large proportion of its economy depends on export-import relations (Burneika, 2010, p. 130) [14].

The Polish case is a sort of outlier, as it is the only CEE country that has not noted an absolute decline in its GDP. Its relative stability is primarily related to the large domestic market and EU funds for financing infrastructure investments and other regional projects. 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 recovery has been due to an improvement in the financial conditions. Looking at the broader perspective, at the beginning of our sample, in the late 1990s, monetary and demand shocks mainly affected the Polish business cycle. However, Poland's economy has been the most resilient among the post-Communist countries. The Polish crisis has been termed a velvet crisis due to pre-existing favorable economic conditions compared to neighboring countries. Among others are a weaker exposure to foreign currencies, a lower export dependence, less growing property bubbles, and a flexible exchange rate regime.

Finally, we look at the case of Slovakia, which joined the EU in 2004 and the Eurozone in 2009. Figure 1(f) shows the dramatic fall in GDP since late 2008. The fall is mainly due to a collapse of the external demand, i.e. the domestic financial sector cannot be counted among the sources of the crisis. As emphasized by Bucek (2010, p. 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, p. 195). Demand disturbances, negative markup, and capital quality shocks were responsible for the 1998 recession when, after the election, the new government was obliged to reduce the previous period's excessive government investment for debt consolidation. After the crisis, Slovakia's economy recovered and exhibited robust economic performance, with international competitiveness, fiscal and financial stability, and ample foreign direct investment as all contributors. GDP growth almost reached 4% 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 countries) by monetary factors. The specific capital quality shock seems more relevant for relatively larger countries with more significant domestic financial markets (Poland and Hungary). However, in the case of Hungary, the effects of financial turmoil were crowed out by improvement in productivity, which characterized the period 2010–2015. The 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 the 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 can cope with and react to shocks or persistent structural changes by either resisting it (absorptive capacity) or by adopting a degree of flexibility and making small changes to the system (adaptive capacity)" (Manca *et al.*, 2017). A functional taxonomy of resilience is provided by Martin (2012), who summarizes it in four dimensions. (1) Resistance as the degree of sensitivity or depth of reaction of regional economy to a recessionary shock; (2) Recovery as the speed and degree of recovery of regional economy from a recessionary shock; (3) Renewal as the extent to which regional economy renews its growth path: resumption of pre-recession path or hysteretic shift to new growth trend.; (4) Re-orientation as the extent of re-orientation and adaptation of regional economy in response to recessionary shock [15].

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 CEB region and, somehow, its ex-post transformative capacity, i.e. the capacity of CEB economies to have implemented in the past crises changes that permit them to cope with the recent global turmoil. Specifically, we estimate the relative vulnerability or sensitivity of economies within the 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 the economic resilience across the CEB region.

Using PCA, we begin by investigating the differences in estimated parameters (Tables 1 and 2 in the online Appendix B) across countries in the CEB region. The main idea of PCA is to reduce the dimensionality of data that may contain correlated variables while retaining as much variability as possible. Our analysis adopts two kinds of PCA: non-centered and centered PCA. The difference 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 in the online Appendix B) [16] or a country unaffected by shocks (if the selected parameters measure shock persistence and variability, cf. Table 2 in the online Appendix B). 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 CEB country.

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

Centered PCA instead focuses on all the structural parameters reported in Table 1 in the online Appendix B. As said, it aims to explain the variability of CEB countries' parameters concerning the case of an "average" kind of CEB country [17]. Here, the variability across the 22 parameters for each country is reduced to a few uncorrelated indexes (three), which 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 Figures 2 and 3 (which report the outcomes of non-centered and centered PCA). We focus on the economic interpretation of PCA [18].

We begin with the non-centered PCA analysis. The first two principal components obtained from two PCAs are the recovery and the resistance index of resilience. The former is obtained from Table 1, considering a subset of parameters associated with nominal and real rigidities, according to which the economic structure diverges from the efficient competitive equilibrium with flexible prices and wages. The latter uses all the estimated parameters from Table 2 from the online Appendix B (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.

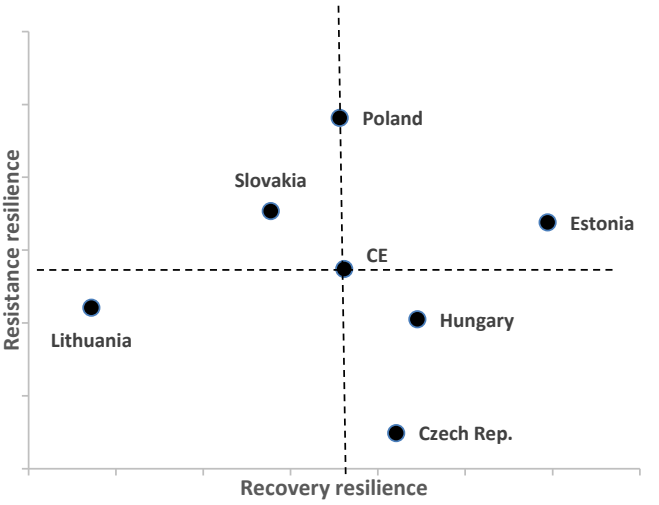

Figure 2.
Recovery and resistance indexes

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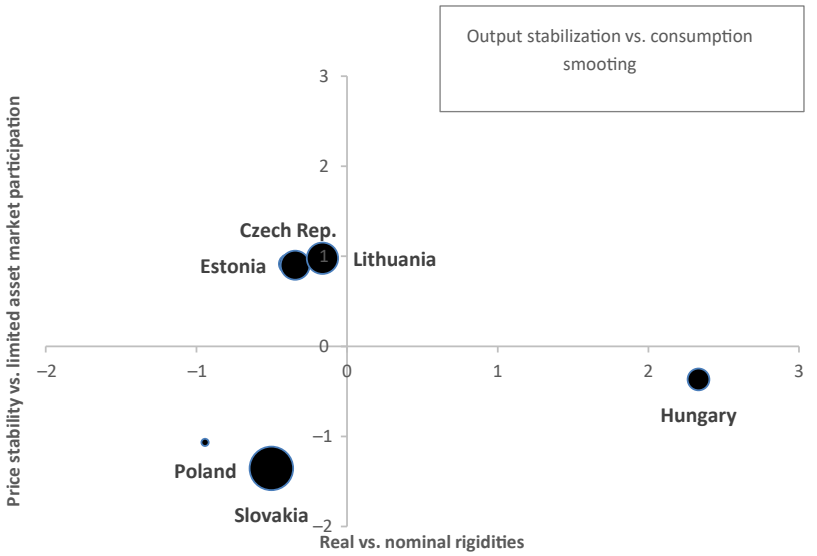

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Figure 3.
Centered PCA

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 similar values for their recovery index, meaning they have similar economic structures. By contrast, Baltic countries are outliers at two extreme positions (Lithuania is relatively more flexible than Estonia). The opposite occurs for the resistance index. Baltic countries rank similarly, whereas Central European countries exhibit significant differences. The Czech Republic and Hungary are less exposed to disturbances than Slovakia and Poland.

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

The first component can be roughly interpreted as a relative measure of real vs nominal rigidities affecting the 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 the consumption variability of households who cannot access 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). In summary, the first component is a rough measure of real rigidities

relative to nominal stickiness; the second component measures the preferences for price stability relative to the financial market's development; and the last component monitors the preference for output stabilization relative 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 Hungary's peculiarity, 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. The Czech Republic, Estonia, and Lithuania are characterized by a relatively high preference for price stability on output and more persistence in the domestic price dynamics.

In contrast, Poland and the Slovak Republic have a relatively small number of households that cannot enter the financial markets, and their inverse of the labor supply elasticity is firmly 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 that 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 relatively high (low) preference for output stabilization relative to consumption smoothing.

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

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 Figure 4, where a different interpretation in terms of the source of the crisis is considered.

In Figure 4 (top panel), we plot the impact of a capital quality shock on the output path. As it can be easily noted, the Czech Republic and Estonia share similar output dynamics and mimic the output path of the benchmark economy. They both observe a less pronounced fall after the shock than in Poland, where a more pronounced fall occurred. Instead, output paths in Hungary, Lithuania, and Slovakia behave similarly in response to a shock in capital quality. Output in these countries experiences a contraction in GDP. Moreover, the fall in GDP is, in the 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 4 (bottom panel) depicts the impact of a net worth shock on output for each 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 has occurred. They also recover to steady state values with some period lags compared to the benchmark country. Instead, Hungary and Slovakia's output paths 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 smoother than the first collapse. The fall in GDP is less intense than the CEB average country, and both countries recover faster at the pre-shock output level. The GDP decline in Poland, because of a net worth shock, is the most evident compared to the other countries within the region. Poland also takes much more time to recover than the benchmark and the other observed countries. Finally, after the initial GDP fall, Lithuania demonstrated a relatively quick recovery ability, overcoming the path of the CEB average country, which was initially less negatively affected by a net worth shock.

5. Conclusions

The recent financial crisis had severe but heterogeneous worldwide impacts. Substantial cross-country disparities in the resistance and recovery capacities have been observed.

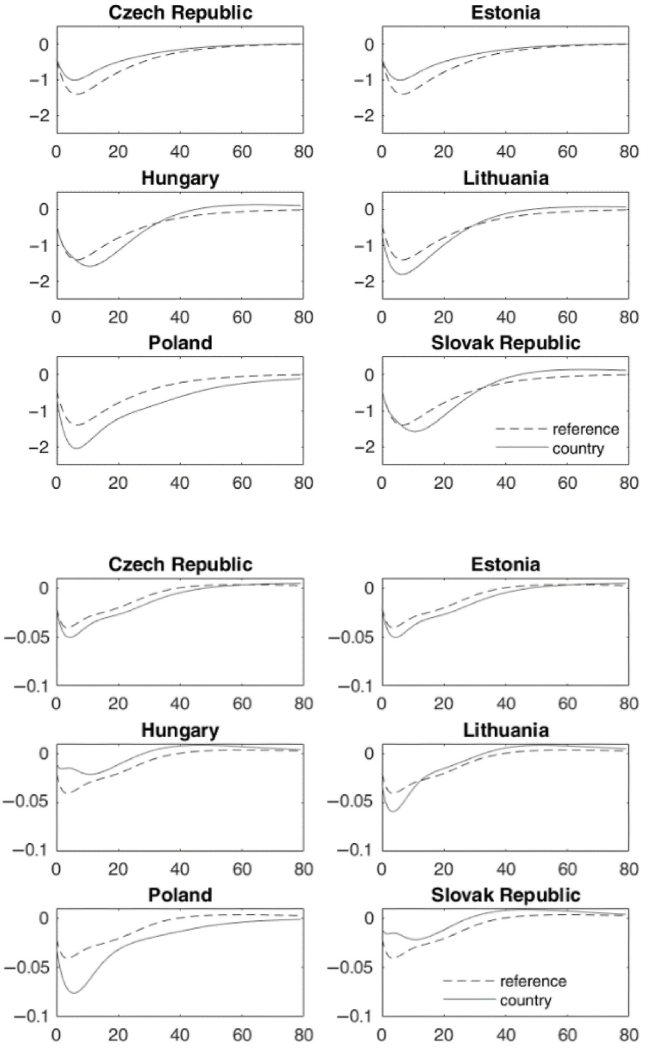

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Figure 4.
Output IRF to a capital quality shock (top panel) and to a net wealth shock (bottom panel), quarterly

Specifically, using PCA on Bayesian estimated parameters for a small-open economy DSGE model, we quantified the relative vulnerability or sensitivity of economies within the CEB macro-region to disturbances and disruptions (resistance) and the speed and extent of recovery from such a disruption or recession (recovery). It is important to acknowledge that a limitation of the analysis is that we explicitly consider each country as a stand-alone open economy which is subject to stochastic disturbances. Precisely, we not model trade or other interactions across countries within the CEB region and with the rest of the world. Consequently, spillover effects in the aftermath of the shock are not accounted for.

Central European countries share similar values for their recovery index, reflecting similar economic structures. By contrast, the two Baltic economies are on opposite sides of recovery:

Lithuania performs relatively better than Estonia. The opposite verifies for resistance, providing evidence of a trade-off between recovery and resistance in the resilience analysis in the region. It is noteworthy that Briguglio (2016) found that the Czech and Slovak Republics, Estonia, Hungary and Lithuania exhibited high vulnerability and resilience scores when adopting the V&R framework [19]. These countries are characterized by specific features which render them particularly exposed to external economic shocks. However, they also exhibit relatively good economic governance, which serves to position them as resilient. Conversely, Poland exhibited, differently from our results, low exposure to shocks but high resilience.

Ifrim *et al.* (2022) found that most CEE countries have shown resilience in either economic output and employment (Czech Republic and Hungary) or in one of these areas (Lithuania and Slovakia). However, Estonia has not recovered in terms of GDP growth rate and employment rate. Analysis using principal component regression reveals that, similarly to our centered PCA analysis, each country's unique social, economic, and institutional frameworks influenced their resilience differently.

The prospect of enlarging the EU to Central European and Baltic countries has reached remarkable progress in macroeconomic stabilization with the transformation from planned to market economies and political, civic, and institutional convergence. Significant differences in the economic structure and consequent resilience performance persist among countries in the CEB region. Evaluating the regional relative performances and establishing in which fields further action is required, e.g. in the labor markets or the development of the financial sector, is paramount, especially for policy-makers.

Despite cross-country differences concerning pre-crisis vulnerability, 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 of the crisis on economic activity.

Notes

1. 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).
2. Our choice follows some International Monetary Fund (IMF) insights. Roaf *et al.* (2014, p. 56), e.g. stress that although Europe remains divided along a "traditional" and historical west-east line, with advanced countries on one side and transition countries on the other, CEB region (Czech Republic, Hungary, Poland, Slovak Republic, Slovenia, Estonia, Latvia, Lithuania) 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.
3. The rationale for excluding those two countries from the CEB region stands on the fact that the global financial crisis in 2008 caused significant instability there. The collapse of a large bank in Latvia and relatively small, targeted recapitalization in Slovenia set these two countries apart from the rest of the CEB region where macroeconomic adjustment proceeded more smoothly than expected and portfolio losses were gradually absorbed, Roaf *et al.* (2014, p. 43).
4. This approach to model credit frictions has become quite popular (e.g. Andreasen *et al.*, 2013), especially to study the effectiveness of unconventional monetary policy in financial crisis (e.g. Gertler and Karadi, 2015).
5. It is worth noting that PCA and similar techniques have been already introduced in estimations including DSGE Bayesian estimation. For instance, dynamic PCA is used to estimate the common component in dynamic factor models by Forni *et al.* (2005). However, the proposed application of PCA to Bayesian estimates is clearly very different and, to the best of our knowledge, has never been applied to resilience.

6. The online Appendix A provides the model details.
7. Among others, the relevance of liquidity constraints as an additional market imperfection has been highlighted by Galí *et al.* (2007), Coenen and Straub (2005), Forni *et al.* (2009), Di Bartolomeo *et al.* (2011).
8. For an exhaustive analysis of Bayesian estimation methods, see An and Schorfheide (2007) and Fernández-Villaverde (2010).
9. We refer to the online Appendix B for further details on the estimation strategy.
10. 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, 2013). Moreover, in the economies of the considered region, the dynamics of domestic financial variables are more related to external factors than domestic ones.
11. Details on country estimations are reported in an on-line appendix (see Beqiraj *et al.*, 2017; Tables A1–A6).
12. 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).
13. 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.
14. Lithuanian exports are about 75% of GDP, more than half of them are sold to six countries: Russia, Latvia, Poland, Germany, Estonia, and Belarus.
15. 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).
16. Note that not all estimated parameters of Table 1 measure distortions.
17. Information regarding the absolute values is not lost, but it is synthesized in the means that in such a case must be considered in the data analysis (see Noy-Meir, 1973).
18. Details are reported in Beqiraj *et al.* (2017: Appendix B).
19. It is a methodological framework for assessing the risk of an economy being harmed by external shocks that juxtaposes the results of the Economic Vulnerability Index and the Economic Resilience Index.

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Online Appendix
The supplementary material for this article can be found online.

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