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One Scheme Fits All: A Central Fiscal Capacity for the EMU Targeting Eurozone, National and Regional Shocks

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JEL Classification: C38, E32, E62, E63

Keywords: central fiscal capacity, Macroeconomic stabilisation, multilevel factor model, Bayesian inference

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One Scheme Fits All: a Central Fiscal Capacity for the EMU Targeting Eurozone, National and Regional Shocks*

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February 5, 2022

Abstract

This paper proposes a central fiscal capacity for the euro area that generates transfers in response to eurozone, country, and region-specific shocks. The main novelty of this fiscal capacity is that it allows a joint response to these three types of shocks within a single scheme. Thus policymakers can decide on the stabilisation of one shock versus the others according to political and economic considerations. Based on NUTS3 regional data over the last two decades, our analysis shows that - with a limited risk of moral hazard - substantial stabilisation could have been achieved in response to the eurozone and regional shocks, while country-specific shocks were less severe and therefore needed less stabilisation. Aggregating the transfers over the three levels, they are in the order of magnitude of the EU's Recovery and Resilience Facility, which was adopted in response to the Covid-19 pandemic.

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1 Introduction

Three major crises in the European Economic and Monetary Union (EMU) over less than fifteen years, i.e., the global financial crisis (GFC), the European sovereign debt crisis and the Covid-19 pandemic, have shown that the common currency area is ill-equipped to handle such large shocks. It would be wishful thinking to assume that the Covid-19 crisis will be the last one. This deficiency in the design of the currency union has, of course, been recognized and given rise to many proposals for a central fiscal capacity (CFC) for the eurozone.

Even during a severe common crisis, there is substantial variation in how individual countries, and the regions within a country, fare. For example, the Covid-19 pandemic had a disproportionately negative effect on Southern Europe and, within this area, on regions relying strongly on contact-intensive sectors, such as tourism. Unlike the United States with its federal tax and transfer system, the eurozone has no central mechanism to attenuate the regional differences in the reaction to shocks. The main contribution of this paper is to propose a CFC in which transfers from a common fund are based on regional output responses to Eurozone-wide, country-specific, and region-specific shocks. The CFC is highly flexible, allowing to cushion all these different shocks within a single scheme, and can be easily modified in response to new crises. The advantage of using growth data is that these are readily available, even at the regional level. We demonstrate the practical implementation of the CFC using regional data from the ARDECO database of the European Commission. To the best of our knowledge this is the first contribution calibrating a CFC on regional data.

The three different levels of the proposed CFC are to some extent reminiscent of already existing arrangements. The first level, which targets eurozone-wide shocks, has a similar nature to the recently established EU's Recovery and Resilience Facility (RRF), which was adopted in response to the Covid-19 pandemic.[1] The RRF, however, is temporary and more focused on financing climate and other investment. The second level, aimed at cushioning national shocks, may have some resemblance to the ESM/IMF official loans, which were activated for countries hit most severely during the European sovereign debt crisis. Finally, the third level, intended to dampen the effects of region-specific shocks, is novel. Its closest analogue in existing arrange-

[1]The RRF entered into force on 19 February 2021. It was launched to finance reforms and investments in EU Member States from the start of the coronavirus pandemic in February 2020 until 31 December 2026. It made available €723.8 billion in total, of which €385.8 billion in loans and €338 billion in grants to EU countries.

ments is the EU Solidarity Fund (ESF), which was "set up to respond to major natural disasters and express European solidarity to disaster-stricken regions within Europe".[2] The main advantage of our proposal is that it encompasses these three levels into one single scheme, thus allowing to give more or less weight to one level versus another according to political and economic considerations. For example, in the case of frequent aggregate or country-specific shocks, policymakers may attach a relatively large weight to the stabilisation of such shocks. By the same token, they may decide to give more weight to the regional component of the CFC when the incidence of regional (idiosyncratic) shocks is higher.

These regional shocks can come from different sources. For example, one can think of a natural disaster hitting a specific region. In addition, the business cycle of a region is often linked to its sectoral specialisation. Therefore, a region will be affected by shocks in the industrial sector to which it has a relatively high exposure (e.g., the automotive sector for Piedmont in Italy, the fishery sector for Galicia in Spain, etc.). Further, regional output may be also affected by global non-eurozone shocks. This could explain, for example, developments in some regions which are very exposed to the US or Chinese economy (e.g., the regions of Amsterdam and Dublin, due to the fact that many multinational corporations have their headquarters there). Importantly, regional stabilisation, as foreseen by our CFC, but largely neglected so far in policy practice and analysis, serves as a useful complement to the eurozone monetary and national fiscal policies, which address shocks that are common across regions. These common policies will suit a wider range of individual regions when the latter feature better aligned business cycles.

Based on 928 NUTS3 eurozone regions from 1999 until 2021, thus including the Covid-19 crisis, we show that our CFC can produce substantial stabilisation at an aggregate borrowing capacity in the order of magnitude of the EU's RRF. The overall borrowing capacity of our CFC is de-facto limited in every year, which is mainly the results of gross transfer flows partially cancelling out, because the regional shocks are uncorrelated within and across countries. We also show that - on average over the last two decades - substantial stabilisation could have been achieved in response to the eurozone and regional shocks, while country-specific shocks were less severe and therefore needed less stabilisation.

[2] See https://ec.uropa.eu/regional_policy/en/funding/solidarity-fund/. While many countries have fiscal-equalization or revenue-sharing schemes for sub-national entities, the difference with the regional stabilisation component in our proposal will be that the latter is steered from the supranational level.

A common criticism on the idea of a CFC is that it may lead to moral hazard.[3] We believe that no transfer scheme can be fully free from moral hazard effects. However, our proposed scheme should be relatively insulated from it, for several reasons. First, policies of individual regions exert a negligible influence on the common factors driving the European and national business cycles. Second, the scheme prevents not only ex-ante redistribution (i.e., the scheme does not redistribute in expected terms), but also ex-post redistribution over longer periods, because the transfers are based on deviations from mean growth at the level of each single region. As a result, the scheme tends to avoid long-lasting transfers into one direction. Indeed, since positive and negative deviations of regional growth from mean growth essentially cancel over time, we observe that (over time) accumulated net transfers to each region are close to zero at the end of our sample.

All in all, while our analysis focuses on the eurozone, the findings of this paper could potentially also inform policymakers on the construction of centralised fiscal capacities in other federations, such as the US, and in emerging economies, such as China or Brasil.

The rest of the paper is organized as follows. Section 2 discusses some existing proposals for a CFC for the EMU, Section 3 presents the data, Section 4 lays out our methodology, while Section 5 presents and discusses the estimation results of the transfer scheme and demonstrates its stabilising effects. Finally, Section 6 concludes.

2 Proposals for a fiscal capacity for the EMU

Several proposals for a CFC have been made in the academic literature and in the policy debate. Some go back to before the euro came into existence, for example Marjolin (1975) and Padoa-Schioppa (1987). At the time, however, it was quite generally believed that macroeconomic stabilisation would be achieved through market mechanisms and that EMU by itself would lead to more business cycle synchronisation within the euro-area (EA) (Allard et al., 2013). After the EMU took off, however, it became clear that these mechanisms were imperfect and that the currency union was not complete, thus giving rise to reports on further completion.

[3] Moral hazard issues associated with a central stabilisation capacity are discussed in several contributions, for example Koester and Sondermann (2018), Burriel et al. (2020) and Beetsma et al. (2021). Wyplosz (2020) takes the position that emergencies, such as those arising from the coronavirus pandemic, dominate moral hazard issues.

This lack of completeness is aggravated by the fact that cross-border private risk-sharing remains limited.[4] The "Four Presidents' Report" of Van Rompuy et al. (2012) envisages the gradual creation of a CFC, while the "Five Presidents' Report" of Juncker et al. (2015) discusses a euro-area stabilisation function that rules out permanent transfers through the convergence of economic structures beforehand, so as to encourage governments to follow sound fiscal policies. In its reflection paper, the European Commission (2017) sketches options for a euro-area macroeconomic stabilisation function, such as a scheme to protect investment during downturns and an unemployment reinsurance scheme. The case for a CFC was also recently made in contributions by officials of the IMF (see Berger et al., 2019, and Arnold et al., 2018) and by the European Fiscal Board (2018).[5] Although the RRF is a response to the coronavirus crisis, it is temporary and mainly aimed at structural reforms and investment, in particular in climate transition and digitalisation, implying there is still a need for a CFC aimed at economic stabilization.[6]

Other proposals have been made both by academic researchers and specialists.[7] Most focus on some form of unemployment reinsurance, for example Beblavý et al. (2015), Dolls et al. (2017), Beblavý and Lenaerts (2017), Carnot et al. (2017) and Abraham

[4] This is shown in early work, e.g., by Sorensen and Yosha (1998) and confirmed in more recent work by, e.g., the European Central Bank (2018). Cimadomo et al. (2020) demonstrate some improvement in cross-border consumption risk sharing in the eurozone due to IMF/ESM official assistance programmes, but also owing to increased cross-border of financial assets holdings (see, also, Milano, 2017). Farhi and Werning (2017) show that, due to private agents failing to internalise the beneficial macroeconomic stabilisation effects of their investment decisions, some degree of public risk-sharing remains desirable even in the presence of complete markets. Hettig and Mueller (2018) point to another interesting externality that could be taken care of by a CFC. Within a New-Keynesian currency-union model, they show that, with monetary policy constrained by the effective lower bound, absence of fiscal coordination induces governments to unduly hold back public spending for fear of a terms-of-trade appreciation, which would undermine demand for domestic products when there is economic slack.

[5] De Haan and Kosterink (2018) identify the circumstances under which a CFC may be most effective.

[6] Indeed, in a intervention at an ECB conference on 2 December 2021, the EU Commissioner for Economy, Paolo Gentiloni, claimed that the EU should have resources to help stabilise economies in a crisis, especially after the EU's post-pandemic recovery fund ends in 2026. See: https://www.ecb.europa.eu/pub/conferences/html/20211202_5th_fiscal_policy_conference.en.html.

[7] For an overview, see Favaque and Huart (2017), while De Grauwe (2018) provides a conceptual discussion. Buti and Messori (2021) make the case that in the current EMU architecture a CFC is necessary to alleviate the stabilising burden on monetary policy and for fiscal policy to adhere to the fiscal rules.

et al. (2017).[8] Beetsma et al. (2021) propose a scheme in which a country whose exports are hit by a shock get compensated to the extent that the decline in exports is driven by a decline in world trade in the relevant sectors in which the country is active. Bénassy-Quéré et al. (2018) instead suggest that pre-qualified countries would be allowed to borrow from the ESM. However, various contributions are critical about the need for a CFC and whether it will do more harm than good, for example Feld and Osterloh (2013) and Feld (2018). Closer to this paper is Enderlein et al. (2013), in which transfers would flow to and from a fund depending on a country's relative cyclical position, and Furceri and Zdzienicka (2015), where transfers are based on country-specific GDP shocks. However, none of the above contributions explore stabilisation at the regional level. Recently, Canova and Pappa (2021), using similar data, assess the likely macroeconomic effects of the RRF. However, they do not engineer a fiscal capacity in which transfers are calibrated according to the different (aggregate, national or regional) origin of the shocks, which is instead the focus of this paper.[9]

3 Data

We use eurozone NUTS3 regional statistics from the ARDECO database of the European Commission. This database includes annual statistics on demography, labour market, capital formation and regional gross domestic product (GDP). Data is provided at constant prices with base year 2015. We collect regional GDP for the 949 NUTS3 eurozone regions from 1999 until 2021.[10] After removing the so-called "extraregions", which are non-geographical economic territories (e.g. airspace, territorial waters, embassies, consulates, military bases, etc.), and which are included in the NUTS classification as these territories are subject to the Treaty establishing the

[8] The popular support for such a scheme will typically depend on its design (e.g., Burgoon et al., 2020 and Beetsma et al., 2022). show that this support can be substantial, even among populations in countries with a reputation of scepticism towards these types of schemes.

[9] Hauptmeier et al. (2020) also employ the ARDECO database. They explore how monetary policy impacts on sub-national inequality in the EU. An important commonality with our paper is the role of instruments designed at the central level of the EU or the eurozone for the functioning of the regional economies.

[10] The vintage of ARDECO database used in the analysis is dated May 5, 2021, and was downloaded on June 21, 2021. This version of the database includes estimates (forecasts) for 2021. We have decided to use these data for 2021, because, although they are preliminary, they provide some interesting insights on the pandemic period.

European Community,[11] we are left with 939 NUTS3 regions (Table 1). We further leave Cyprus, Malta and Luxembourg out of our analysis as these countries consist of only one region, which prevents us from disentangling country-specific and regional shocks. Moreover, we omit seven overseas territories from our analysis due to their geographical distance from the eurozone.[12] Hence, we retain 928 eurozone regions for our empirical analysis.

There is considerable variation in the number of regions in each country and in the size of the regions, both within and across countries. Against this backdrop, we use regional real GDP in per capita terms as this provides a demographic correction for the size of a region in terms of its population.[13] In the following, for conciseness, we refer to regional real per-capita GDP simply as "regional GDP". Table 1 shows that regional GDP differs quite considerably over regions and countries. To avoid that our proposed transfer scheme responds to structural differences, we use demeaned growth rates in the empirical analysis. In particular, we compute the deviation of regional GDP growth from its historical average. We then use the ensuing demeaned series for the estimation of shocks and the calibration of our CFC.

[11]See Regions in the European Union, Nomenclature of territorial units for statistics NUTS 2010/EU-27, Annex 1 (12), pp. 138-139. https://ec.europa.eu/eurostat/documents/3859598/5916917/KS-RA-11-011-EN.PDF.

[12]For France, the overseas territories are Guadeloupe, Martinique, French Guiana, La Réunion and Mayotte. For Portugal, these territories are the Azores and Madeira.

[13]Our robustness analysis will show that the number of regions in a country, e.g., moving from the NUTS3 to the NUTS2 classification, does not significantly influence the main results.

Table 1: NUTS3 regional summary statistics.

Country	# Regions	Population ($\times 10^6$) Mean	Population ($\times 10^6$) Std. Dev.	Reg. GDP ($\times 10^3$) Mean	Reg. GDP ($\times 10^3$) Std. Dev.
AT	35	0.24	0.28	33.98	8.70
BE	44	0.25	0.23	28.76	9.40
CY	1	0.79		22.26	
DE	401	0.20	0.23	32.02	13.94
EE	5	0.27	0.18	11.23	5.15
EL	52	0.21	0.23	16.01	4.74
ES	59	0.76	1.06	21.52	4.45
FI	19	0.28	0.32	34.15	6.31
FR	101	0.64	0.49	27.76	10.36
IE	8	0.55	0.31	40.25	17.57
IT	110	0.54	0.58	26.44	7.13
LT	10	0.31	0.23	8.60	2.82
LU	1	0.51		87.75	
LV	6	0.36	0.17	8.64	4.35
MT	2	0.21	0.25	15.26	5.25
NL	40	0.41	0.32	34.90	9.13
PT	25	0.42	0.58	15.06	3.38
SI	12	0.17	0.13	15.90	3.94
SK	8	0.67	0.09	12.58	7.14
Total	939	332.65	7.12	28.20	12.77

Notes:
(i) NUTS3 regional statistics from the ARDECO database of the European Commission, vintage 5 May 2021. Figures are calculated over the sample period 1999-2021.
(ii) The table displays country averages (across regions within a country) and standard deviations, calculated over regions within a country, and averaged over time.
(iii) AT = Austria, BE = Belgium, CY = Cyprus, DE = Germany, EE = Estonia, EL = Greece, ES = Spain, FI = Finland, FR = France, IE = Ireland, IT = Italy, LT = Lithuania, LU = Luxembourg, LV = Latvia, MT = Malta, NL = the Netherlands, PT = Portugal, SI = Slovenia, and SK = Slovakia.

Figure 1 shows the distribution of regional GDP growth for the 16 eurozone countries in our sample. Average values are depicted in blue. Although for many countries some common business cycle among its regions can be observed (visible through country-wide shifts in the frequency distribution of regional growth rates), there exists substantial heterogeneity in regional growth rates around the country averages. Differences in regional growth rates within a country appear to have been larger during the GFC of 2009 than during the Covid crisis year of 2020. A potential explanation is the strong commonality of the Covid shock, which hit all parts of a country, while the GFC may have been relatively harsher on regions with a concentration in the financial industry. This observation suggests that a transfer scheme should be flexible enough to cushion different types of shocks. Not surprisingly, from a purely statistical point of view, countries with a larger number of regions tend to have regions with more extreme growth rates.

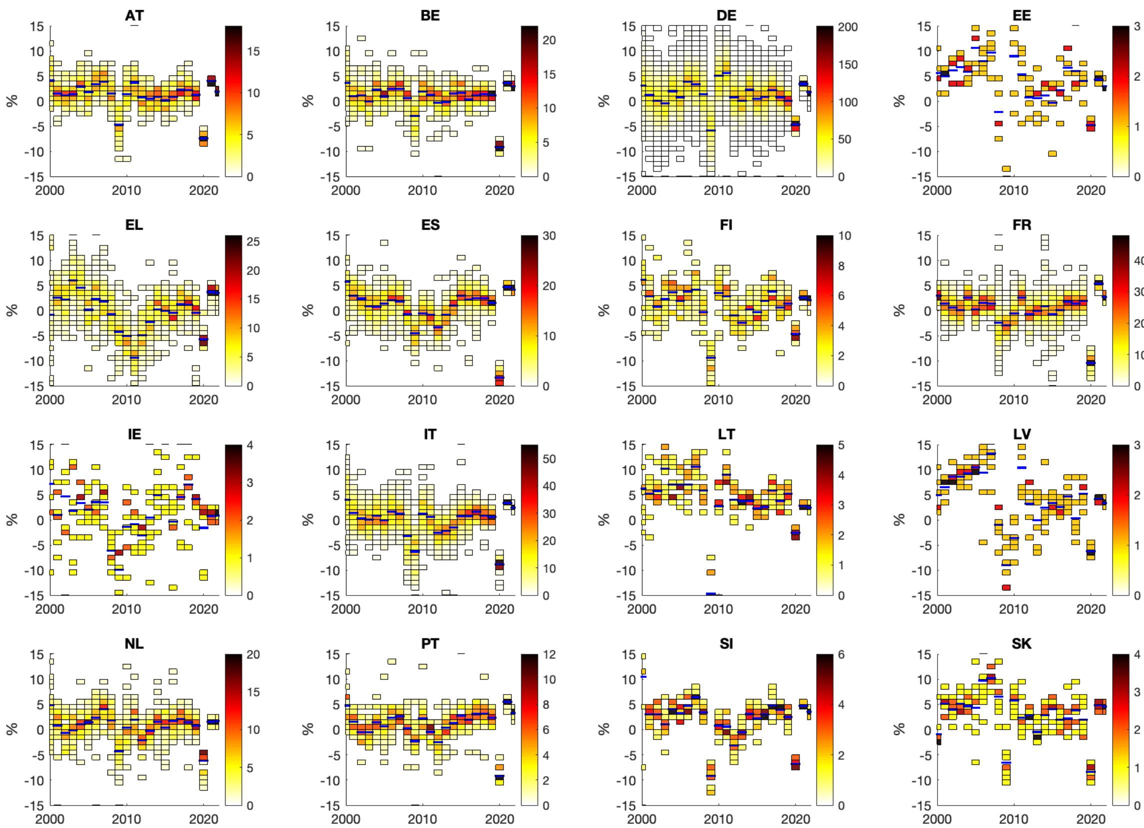


Figure 1: Distribution of regional real per-capita GDP growth rates by year. Average values in every year are in blue. Sample: 1999-2021. Source: European Commission's ARDECO dataset.

4 Model

As outlined in the Five Presidents Report (Juncker et al., 2015), a central fiscal capacity should be a business cycle stabilisation tool and not target structural imbalances. Our proposal complies with this basic principle as it targets divergence from the individual regions' average growth paths. Our approach consists of two stages. First, we decompose regional growth using a multilevel dynamic factor model which allows for eurozone-, national-, and regional shocks. Second, we calibrate a transfer scheme that can dampen shocks originating from any of these three levels in a flexible manner, steered by financial restrictions or political preferences.

4.1 Dynamic factor model

Our model is based on that of Kose et al. (2003), but more general in the sense that we allow for a richer factor structure. We model the demeaned GDP growth of region r in country c in year t, $y_{r,c,t}$,[14] with a 3-level dynamic factor model, for $r \in \mathcal{R}_c$ the region set of country c with $|\mathcal{R}| = N_c^R$, where N_c^R is the number of regions in country c, and $c \in \mathcal{C}$ the country set with $|\mathcal{C}| = N^C$, where N^C is the number of countries.[15] Growth rates and, more specifically, their co-movements, are explained by latent unobserved factor levels: a euro-area common factor level, F_t^{EA}, a country-specific factor level, F_t^c, and an idiosyncratic regional factor, $\varepsilon_{r,c,t}$. We use the term "factor level" as each level could contain multiple factors. For instance, the eurozone level could have one factor, or more than one factor. Denote the number of factors in factor level k, $k \in \{EA, \mathcal{C}\}$, by N_k^F. Region r's exposure to each of the factors is determined by the loadings $\lambda_{r,c}^{EA}$ and $\lambda_{r,c}^c$, $\forall r, c$.[16] Note that $\lambda_{r,c}^{EA}$ and $\lambda_{r,c}^c$ may be vectors if the factor levels F_t^{EA} and F_t^c contain multiple factors. That being the case, denote the l^{th} entry in the k^{th} factor level's loading vector by $\lambda_{r,c}^{k,l}$ for region r in country c, and $l \in \left\{1, 2, \ldots, N_k^F\right\}$. Factors are modelled as AR(1) processes,

[14] Growth rates are demeaned over the time dimension. Hence, structural differences in growth rates should not have an effect on the transfer flows. Alternatively, one could include an intercept in our regression model below.

[15] Del Negro (2002) also adopts a three-layers dynamic factor model to disentangle output and consumption movements in the US in response to national, regional, or state-specific business cycle shocks. For related approaches using factor models for business cycle analysis, see also Giannone et al. (2008), Doz et al. (2011) and D'Agostino et al. (2016).

[16] The residual, idiosyncratic effect on regional growth could be interpreted as a factor with loading one.

and are assumed to be orthogonal. Formally:

$$y_{r,c,t} = \sum_{l=1}^{N_{EA}^F} \lambda_{r,c}^{EA,l} F_t^{EA,l} + \sum_{l=1}^{N_c^F} \lambda_{r,c}^{c,l} F_t^{c,l} + \varepsilon_{r,c,t} \tag{1}$$

$$F_t^{k,l} = \theta_{k,l} F_{t-1}^{k,l} + \upsilon_{k,l,t}, \forall k \in \{EA, \mathcal{C}\} \tag{2}$$

$$\varepsilon_{r,c,t} = \phi_{r,c}\varepsilon_{r,c,t-1} + u_{r,c,t} \tag{3}$$

$$\mathbb{E}\left[\upsilon_{k,l,t}\upsilon_{k,l,t}\right] = \sigma_{k,l}^2 \tag{4}$$

$$\mathbb{E}\left[u_{r,c,t}u_{q,c,t-s}\right] = \begin{cases} \sigma_{r,c}^2 & q = r \wedge s = 0, \forall r, c \\ 0 & \text{otherwise} \end{cases} \tag{5}$$

As should be clear from equation (1), no region r in country c is exposed to any factor in another country d's factor level (except for the euro-area factors). More formally, $\lambda_{r,c}^{d,l} = 0$, $\forall l \in \left\{1, 2, \ldots, N_F^d\right\}$, $d \neq c$ and $d \neq EA$.

Differently from Kose et al. (2003), who assume that the global, regional and national business cycles can be explained by one factor each, we allow for multiple factors in the euro-area and country levels. Any variation left unexplained by a single factor in a level would lead to misspecification in the sense that this residual variation would be explained by the factor level below. Albeit of less importance when modelling business cycles, this potential misspecification could have considerable implications for the transfer scheme. For instance, when - for some budgetary or political reasons - the scheme attaches a higher relative weight to the country-level shocks, any unexplained variance at this level will need to be explained by the regional factor level, which only cushions region-specific shocks. Hence, if the scheme is relatively more geared towards cushioning country-level shocks and, therefore, less towards regional shocks, part of the variability in growth is left uncushioned by our CFC.

4.1.1 Identification, normalization, and variance decomposition

The scale, sign and loading of the factors are not uniquely identified. Taking the negative of a factor and multiplying its loading by minus one yields a statistically identical decomposition. The same is the case if we rescale a factor and rescale its loading by the reciprocal number. Moreover, if a factor level consists of multiple factors, all permutations of the factor ordering within the level yield identical decompositions. As is common in the literature, for every factor level we restrict the loadings of the first regions (exposed to those factors) to be positive. To exclude symmetry, we restrict the first number (equal to the number of factors in the factor level) of rows of the loadings matrix to be lower triangular, such that the first region is only exposed to the first factor, the second to the first and second factors, etc. The exact restrictions can be found in Appendix A.1.

The scale of the factors is pinned down by setting $\sigma^2_{k,l}$ equal to a constant. In the following we assume that $\sigma^2_{k,l} \equiv 1, \forall(k,l)$.The variance of each observation is then given by:

$$\begin{aligned}
\mathbb{V}\text{ar}\left[y_{r,c,t}\right] &= \mathbb{V}\text{ar}\left[\lambda^{EA}_{r,c}F^{EA}_t + \lambda^c_{r,c}F^c_t + \varepsilon_{r,c,t}\right] \\
&= \sum_{l=1}^{N^F_{EA}} \left(\lambda^{EA,l}_{r,c}\right)^2 \mathbb{V}\text{ar}\left[F^{EA,l}_t\right] + \sum_{l=1}^{N^F_c} \left(\lambda^{c,l}_{r,c}\right)^2 \mathbb{V}\text{ar}\left[F^{c,l}_t\right] + \mathbb{V}\text{ar}\left[\varepsilon_{r,c,t}\right] \\
&= \sum_{l=1}^{N^F_{EA}} \frac{\left(\lambda^{EA,l}_{r,c}\right)^2}{1-\left(\theta_{EA,l}\right)^2} + \sum_{l=1}^{N^F_c} \frac{\left(\lambda^{c,l}_{r,c}\right)^2}{1-\left(\theta_{c,l}\right)^2} + \frac{\sigma^2_{r,c}}{1-\phi^2_{r,c}} \qquad (6)
\end{aligned}$$

The proportion of the variance explained by each factor is obtained by dividing every term in (6) by $\mathbb{V}\text{ar}\left[y_{r,c,t}\right]$.

4.1.2 Estimation conditional on given factor structure

The estimation procedure follows the Bayesian approach by Otrok and Whiteman (1998), and Kose et al. (2003).[17] The priors are conjugate and stated in Appendix A.2.1. The posteriors are given in Appendix A.2.2.

In the estimation procedure, we adapt the algorithm proposed by Jackson et al. (2015), in turn based on Kose et al. (2003), in two ways. First, to satisfy the sign restrictions, the authors sample the $\lambda_{r,c}$-vectors (in our case consisting of $\lambda^{EA}_{r,c}$ and $\lambda^c_{r,c}$) from a multivariate normal distribution until the vector satisfies the constraints. If the true factor loadings are small, which is typically the case with standardised data, there exists a (high) probability that a factor loading draw obeys the constraints even though the factor draw itself might be mirror-imaged. Then, if in the next draw the mean of $\lambda_{r,c}$ is negative, the algorithm will mirror the factor draw so as to obtain the correct decomposition. Subsequently, taking the average over the draws, both the factor and loading estimates converge to zero. Instead, we opt to sample each entry of the $\lambda_{r,c}$-vector individually, which is possible since the factors are orthogonal. If a specific entry has to satisfy a sign restriction, we replace the normal distribution by its truncated (by zero from below) counterpart.

[17] Due to the large number of parameters a Bayesian approach is much faster than its frequentist counterpart.

Second, for data sets with a small time dimension, the algorithm might fail in drawing factors that are completely orthogonal. As a result, the variance decomposition can be biased. As a solution, after every factor draw in each factor level, we orthogonalize the draw with respect to previously sampled factors in that level. For instance, the second eurozone factor is orthogonalized to the first eurozone factor by deploying the annihilator matrix. More specifically, the orthogonalized second eurozone factor is given by $F^{EA,2,orth} = (I - F^{EA,1}(F^{EA,1'}F^{EA,1})^{-1}F^{EA,1'})F^{EA,2}$ where $F^{EA,2}$ is the original factor draw. Similarly, for each country's factor level, factors are projected to the matrix space that is orthogonal to the previously sampled factors in that level and the complete eurozone factor level. If the factors are in fact already orthogonal, their matrix spaces do not intersect, and hence the annihilator matrix equals the identity matrix making the transformation inoperative. However, if the matrix spaces overlap, the previously sampled factors contain common information that should only be contained in these previously sampled factors. In that case, the transformation eliminates the intersection of the matrix spaces.

We estimate a range of potential models, which vary in the numbers of factors per level. We allow the eurozone and country factor levels to consist of zero to three potential factors. We then rank the models according to their average Bayesian Information Criterion (BIC).

4.2 The transfer scheme

4.2.1 The European policymaker's decision

The decision to implement a specific transfer scheme is a trade-off between its benefits in terms of macroeconomic stabilisation and its potential costs in terms of political support and financial resources. One can think of this political decision-making process as an optimization problem at the central European level where the goal is to reduce regional growth variation against acceptable costs. This "optimal" scheme can be seen as targeting the minimization of the average regional output volatility, once the macroeconomic effects of the transfers are factored in. These effects are captured by the region-specific fiscal multiplier $g_{r,c}$. We also consider a cost $f(T^{EA}, T^{C}, T^{R})$ associated with the transfers, which can be viewed as a political cost associated with getting agreement on the redistribution across regions and countries after shocks have materialised. Formally, the European social planner chooses the optimal level of the transfers $T^{EA,*}, T^{C,*}, T^{R,*}$ minimising the following loss function:

$$(T^{EA,*}, T^{C,*}, T^{R,*}) = \text{argmin } L(T^{EA}, T^{C}, T^{R}) \tag{7}$$

where,

$$\begin{aligned} L(T^{EA}, T^{C}, T^{R}) &= \sum_{c \in \mathcal{C}} \sum_{r \in \mathcal{R}_c} \mathbb{V}\text{ar} \left(y_{r,c,t} + \sum_{i \in \{EA,C,R\}} g_{r,c} T^{i}_{r,c,t} \right) \\ &+ f\left(T^{EA}, T^{C}, T^{R}\right) \\ &= \sum_{c \in \mathcal{C}} \sum_{r \in \mathcal{R}_c} \left[\mathbb{V}\text{ar}\left(y_{r,c,t}\right) + g^2_{r,c} \sum_{i \in \{EA,C,R\}} \mathbb{V}\text{ar}\left(T^{i}_{r,c,t}\right) \right. \\ &\left. + g_{r,c} \sum_{i \in \{EA,C,R\}} \mathbb{C}\text{ov}\left(y_{r,c,t}, T^{i}_{r,c,t}\right) \right] + f\left(T^{EA}, T^{C}, T^{R}\right) \end{aligned} \tag{8}$$

Note that the first term in the above expression contains the regional variance of output growth including the transfers associated with the different levels in percent of regional GDP. Although the current loss function is the aggregate of the regional growth variances, introducing country- or region-specific weights, e.g., based on the ECB capital key, is straightforward. We chose the simplest weight, being unity for each region, so as to simplify this illustrative exercise. Appendix A.3 presents the optimization problem where the transfers are assumed to be a function of the shocks at the different levels.

4.2.2 A linear transfer scheme

Under some specific assumptions on the minimisation problem above, the transfers boil down to the following expressions:[18]

$$T^{EA}_{r,c,t} = -\gamma^{EA} \sum_{l=0}^{N^F_{EA}} \lambda^{EA,l}_{r,c} F^{EA,l}_t \tag{9}$$

$$T^{C}_{r,c,t} = -\gamma^{C} \sum_{l=0}^{N^F_{c}} \lambda^{c,l}_{r,c} F^{c,l}_t \tag{10}$$

$$T^{R}_{r,c,t} = -\gamma^{R} \epsilon_{r,c,t} \tag{11}$$

This scheme possesses a number of desirable characteristics for a CFC, some of which have also been highlighted in the Five Presidents Report (2015).

The first property is *counter-cyclicality*, which is obtained by imposing $\gamma^{EA}, \gamma^C, \gamma^R > 0$. In other words, a negative (EA, C,or R) shock hitting one region will be partially compensated by a positive transfer, whose size will depend on γ^i, for $i \in \{EA, C, R\}$. The counter-cyclicality of the scheme is visible by substituting the expressions for the transfers into $y_{r,c,t} + \sum_{i\in\{EA,C,R\}} g_{r,c} T^i_{r,c,t}$:

$$y^T_{r,c,t} = (1 - g_{r,c}\gamma^{EA}) \sum_{l=1}^{N^F_{EA}} \lambda^{EA,l}_{r,c} F^{EA,l}_t + (1 - g_{r,c}\gamma^{C}) \sum_{l=1}^{N^F_{c}} \lambda^{c,l}_{r,c} F^{c,l}_t + (1 - g_{r,c}\gamma^{R})\varepsilon_{r,c,t} \tag{12}$$

where $y^T_{r,c,t}$ regional growth when the transfer is included. Full stabilisation would in theory be achieved, conditional on fiscal multipliers equal to unity, when setting $\gamma^{EU} = \gamma^C = \gamma^R = 1$, or more generally, when $g_{r,c}\gamma^i = 1$, for $i \in \{EA, C, R\}$. However, full stabilisation seems rather unrealistic, because for conventional values of the multiplier $g_{r,c}$ it would require transfers across regions and countries likely too large to be politically feasible. A second reason is that the larger is the CFC, the more likely it is that it affects individual behaviour, leading to a potential breakdown of the above relationship between the size of the transfers and and their effect on regional growth.

[18] Specifically, we assume that the transfer is a linear function, i.e., $\tau^i\left(x|\gamma^i\right) \equiv -\gamma^i x$, where x depends on the eurozone, country-specific and regional factors. The complete derivation is found in Appendix A.3.

Second, the scheme avoids *permanent transfers* when it is a linear function of the shocks. Since our scheme targets deviations from the trend growth path, transfers are not aimed at reducing structural income differences. The expected transfer to each region is zero, hence there is no ex-ante redistribution, as formally stated in the following proposition:

Proposition 1. ***Ex-ante neutrality.*** *Assume that the transfers are a linear function of the shocks. For every region r in country c, the expected transfer in each CFC level $i \in \{EA, C, R\}$ at every time point t equals zero, i.e. $\mathbb{E}\left[T^i_{r,c,t}\right] = 0$. Hence, for any $T > 1$, the expected time aggregates of the transfers are also zero, i.e. $\mathbb{E}\left[\sum_{t=1}^{T} T^i_{r,c,t}\right] = 0$.*

Proof. First, define $\lambda^R_{r,c} = 1$, $N^F_R = 1$, and $F^{R,1}_{r,c,t} = \varepsilon_{r,c,t}$, $\forall(r, c)$. Then we can generally write $T^i_{r,c,t} = -\gamma^i \lambda^i_{r,c} \sum_{l=1}^{N_i^F} F^{i,l}_{r,c,t}$. Taking the expected value yields $\mathbb{E}\left[T^i_{r,c,t}\right] = -\gamma^i \lambda^i_{r,c} \mathbb{E}\left[\sum_{l=1}^{N_i^F} F^{i,l}_{r,c,t}\right] = -\gamma^i \lambda^i_{r,c} \sum_{l=1}^{N_i^F} \mathbb{E}\left[F^{i,l}_{r,c,t}\right] = 0$, given that $\mathbb{E}\left[F^{i,l}_{r,c,t}\right] = 0$, i.e., the factors have mean zero. Hence, it follows for any $T > 1$ that $\mathbb{E}\left[\sum_{t=1}^{T} T^i_{r,c,t}\right] = \sum_{t=1}^{T} \mathbb{E}\left[T^i_{r,c,t}\right] = 0$. □

Third, our scheme is *flexible*. The scheme can be calibrated, through specific γ^i settings, to target dominant shocks or to satisfy specific political preferences. The eurozone-wide NextGenEU, to the extent that it provides some stabilisation, can be seen as a scheme with a relative high value of γ^{EA} as well as relatively high values of γ^C, while the European Economic Recovery program during the GFC featured only relatively high values of γ^C, but a relatively low value of γ^{EA}. Regional output shocks, such as those caused by natural disasters, could be dampened by setting a relatively high γ^R.

Fourth, the scheme is *complementary* to sound national and regional fiscal policies and minimises concerns about *moral hazard*. Regions are merely exposed to, but cannot influence, the latent eurozone- and national business cycles. Regional exposure to these cycles, determined by the loadings, is calculated over a long time-window. Regions cannot adapt their preceding growth path, or deviations therefrom, to benefit from current-period transfers. The regional component is the only level potentially vulnerable to moral hazard in a material way. However, this will only happen if the transfer they are expecting from the CFC outweighs the cost of lower GDP. In practice, it is not likely that regional governments on purpose generate local recessions, because the costs will be generally higher than the benefits from the scheme. Moreover, like in other transfer scheme proposals, to mitigate moral hazard one could attach conditionality constraints to the part of the transfers determined by the regional shock.

Fifth, the idiosyncratic regional shocks $\varepsilon_{r,c,t}$ are uncorrelated across regions and countries, making it unlikely that the aggregate transfer volume associated with these shocks to or from an individual country is large at any moment.

Finally, because transfers are based on deviations from mean growth, positive transfers to a region in specific years (in response to negative shocks to that region) will be compensated over time by negative transfers in response to positive shocks to the same region. This is a particularly desirable property, as the regional level is most vulnerable to moral hazard.

4.2.3 Theoretical stabilisation properties

In this subsection we explore the contribution of each individual level of our CFC to regional GDP growth stabilisation, based on the theoretical framework presented earlier. We define the stabilisation effect as the percentage reduction in the volatility of the original raw regional growth process, once the transfers generated by the scheme are added to the original series. Formally, the stabilisation effect of each level $i \in \{EA, C, R\}$ is defined as:

$$\begin{aligned} s_{r,c}^{i} &= \frac{std\left(y_{r,c,t} + g_{r,c}T_{r,c,t}^{i}\right)}{std\left(y_{r,c,t}\right)} - 1 \\ &= std\left(\tilde{y}_{r,c,t} + g_{r,c}\tilde{T}_{r,c,t}^{i}\right) - 1 \end{aligned} \tag{13}$$

where $\tilde{y}_{r,c,t}$ denotes the standardised series and $\tilde{T}_{r,c,t}^{i}$ the transfers associated with the standardised data series. The simplification from the first to second line is trivial and can be found in Appendix A.4.

Proposition 2. *The stabilisation effect of level $i \in \{EA, C, R\}$ equals:*

$$s_{r,c}^{i} = \sqrt{1 + \left((g_{r,c}\gamma^{i})^{2} - 2g_{r,c}\gamma^{i}\right)\nu^{i}} - 1 \tag{14}$$

where ν^i is the fraction of regional output variance explained by level i. For example, if $i = EA$, $\nu^{EA} = \mathbb{V}\text{ar}\left[\sum_{l=1}^{N_{EA}^F} \lambda_{r,c}^{EA,l} F_t^{EA,l}\right]$.

The derivation can be found in Appendix A.4. The stabilising effect of our scheme at level i is a function of the fiscal multiplier $g_{r,c}$, the level-specific smoothing parameter γ^i, and the level-specific explained variance, ν^i. Further, note that the stabilising effect is a bi-variate convex function in $g_{r,c}$ and γ^i. Therefore, the marginal stabilising effect decreases for larger $g_{r,c}$ and/or γ^i up to the point where $g_{r,c}\gamma^i = 1$, at which point the stabilisation at this level is maximized. This is illustrated in Figure 2, which shows the theoretical stabilising effectiveness of the model (i.e., $s_{r,c}^i$) as a function of $g_{r,c}$ and γ^i (a lower level in the graph means more stabilization).[19] The convexity of the stabilising function can be explained by the fact that, for regions with high fiscal multipliers, sufficiently large transfers lead to a reversal of the deviation from the long-term growth target (an "overshooting"). For example, suppose that a region's deviation from its long-term growth path is completely explained by the idiosyncratic level, i.e., $\nu^R = 1$, and that the policymaker sets $\gamma^R = 1$. In case the fiscal multiplier of that region equals one, the policymaker achieves full stabilisation for that region with a transfer $T_{r,c,t}^R = -\epsilon_{r,c,t}$. However, when the region's multiplier is higher than one, the regional growth will overshoot the long term growth level. For example, in case of a multiplier of two, there will be a full overshoot, i.e., the absolute value of the distance to the long-term growth path will be unchanged by the transfer. This is shown in the zero value for the stabilising effect in Figure 2 when $g_{r,c} = 2$ and $\gamma^i = 1$.

Note that the $g_{r,c}\gamma^i = 1$ in Figure 2 puts a natural bound on the size of γ^i, for given value of the multiplier. For example, for a region with a relatively high fiscal multiplier, say 1.5, the maximum value of γ to avoid overshooting in terms of stabilisation, therefore decreasing marginal stabilisation effects, is 2/3. For smaller fiscal multipliers, say less than one, the scheme would benefit from a higher γ^i without incurring marginally decreasing stabilisation effects.[20] In our illustration below, we show that, for $\gamma^i = 0.5$ for all i, the scheme would generate transfers in the order of magnitude of the RRF.

[19] In Figure 2, we assume that level i explains 33% of the variance, i.e., $\nu^i = 0.33$.

[20] See Caldara and Kamps (2017) for a discussion on the estimation of fiscal multipliers and Castelnuovo and Lim (2018) for a survey.

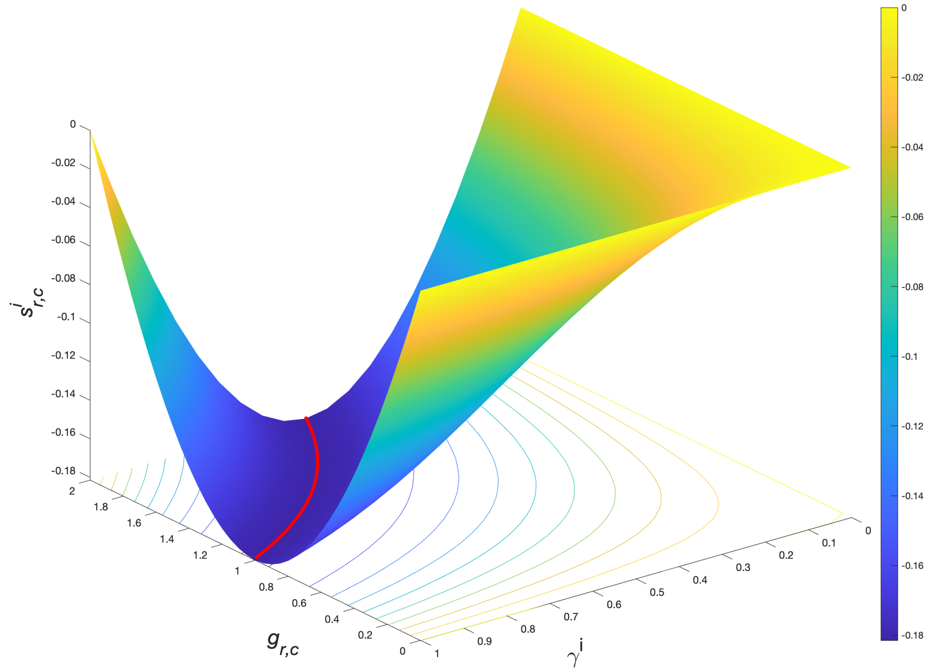


Figure 2: Amount of stabilisation $s^i_{r,c}$ by CFC level i, expressed as a reduction of the average regional GDP variance, as a function of the parameter γ^i and the regional multiplier $g_{r,c}$. A value of zero along the vertical axis would indicate no stabilisation, a value of -1 would indicate full stabilisation of regional GDP around its mean GDP growth rate. The calculation in this graph is performed under the assumption that the fraction of GDP variance explained by layer i is $\nu^i = .33$. The maximum stabilisation provided by this level of our CFC is attained at $g_{r,c}\gamma^i = 1$, which is represented by the red contour.

5 Results

5.1 Eurozone, national and regional business cycles

Before we estimate our factor model, we normalize the regional GDP growth rates, i.e., by subtracting the regional mean and dividing by the standard deviation for each region. The results from the estimation are then transformed back such that they display the regional heteroskedasticity. Estimates are based on 5000 posterior draws with a burn-in of 2000, and a thinning factor of 5, so as to end up with 1000 posterior draws. The model selection algorithm indicates as the optimal model one in which each level always consists of one factor, except in the case of the country-specific level for France which indicates two factors. However, the simplest model with each level always containing only one factor performs very similarly, with a BIC score difference of around 2%. We opt for this simplest model, as there is no clear economic argument to include two country-factors only for France.

5.1.1 Decomposition of regional GDP growth

Figure 3 depicts, for each country, the average GDP growth rate rate over the regions in that country and its decomposition into the EA factor, the country factor and the region-specific factor. A few facts are worth highlighting. First, the eurozone factor primarily extracts the common components of the GFC in 2009 and the Covid-19 pandemic in 2020. The factor has a very strong role in explaining regional real GDP growth in Germany.[21] Second, in some other countries the eurozone factor plays a minor role. This is, for example, the case of Greece. For this country, the country factor is by far the most important driver of regional output. Its contribution traces GDP growth very closely. This can be explained by the fact that Greece was particularly exposed to the sovereign debt crisis. Other countries, including Spain, Ireland, Italy, Latvia, Portugal and Slovenia, also feature a country-specific factor which can be associated to the sovereign debt crisis, although the impact is smaller than for Greece.[22] Finally, the contribution of the region-specific shocks to the total is close to zero for most countries. However, this is an average effect across the regions in a country. If one looks at specific regions, the contribution of this factor can be sizeable.

[21] In our robustness analysis, we explore whether the number and size of the regions may drive the results. For example, Germany turns out to have a large number of NUTS3 regions, of a relatively small size (Table 1). Our robustness test indicates that results are not significantly affected by the size and number of regions. In particular, we perform the following exercises: 1. we test an alternative specification, including the aggregation of NUTS3 into NUTS2 regions for the large countries so as to obtain a balanced sample; 2. we scale the data by their EA population or GDP shares such that larger regions receive a higher weight; and 3. we include two factors in the country level for the large countries. A more elaborate description of these robustness tests can be found in Appendix B.1.

[22] Irish growth in 2015 is an outlier. This is explained by the fact that in that year a change in tax legislation led to an international relocation towards Ireland of output produced by intellectual property, see https://www.oecd.org/sdd/na/Irish-GDP-up-in-2015-OECD.pdf. We re-estimated the model where we proportionally scale back the growth rates of the Irish regions such that the 2015 Irish average GDP growth rate equals 6.4%, which is its 2015 net national income growth. Since 2015 is the base year, no further transformation is needed to obtain real numbers. The results are virtually identical.

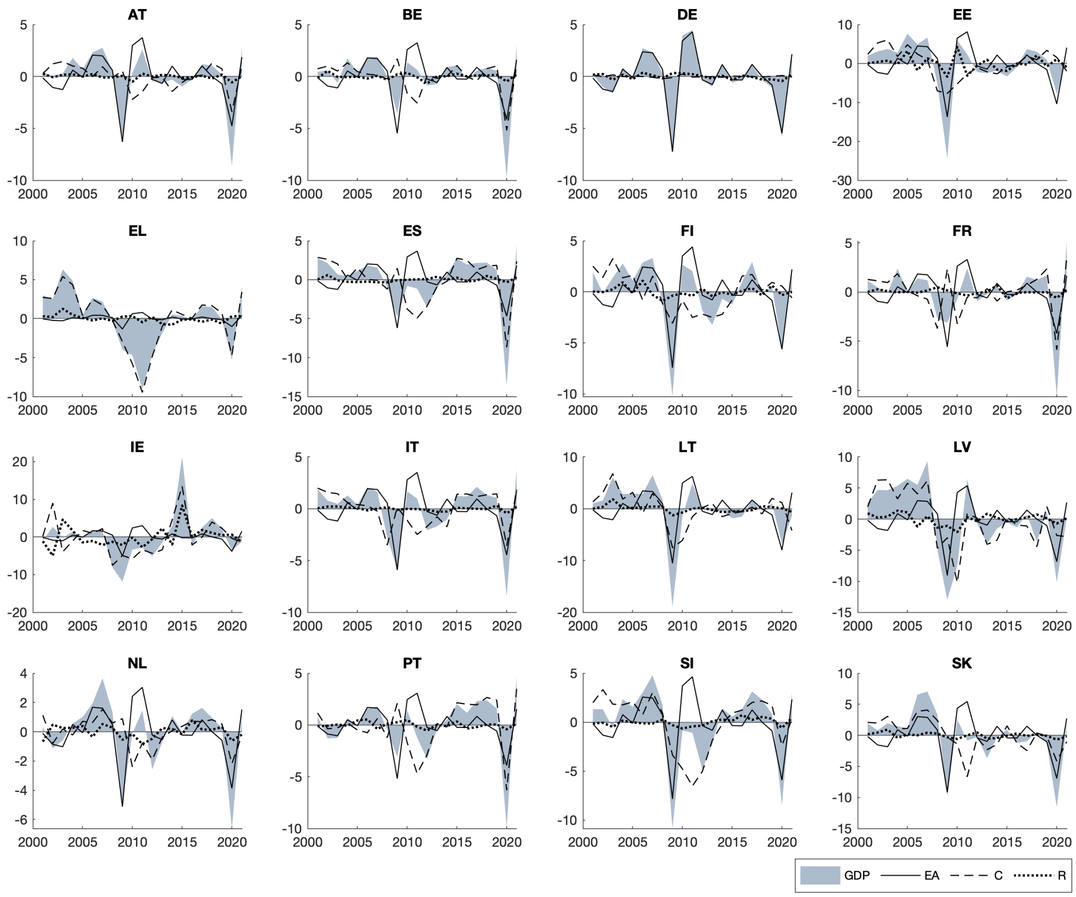


Figure 3: Regional GDP growth decomposed into eurozone, country, and idiosyncratic components, averaged over regions within a country.

5.1.2 Composition in contribution to regional variance

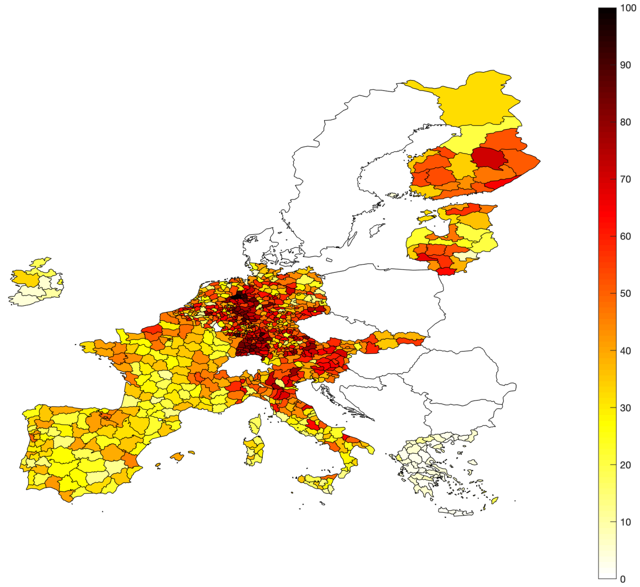
Table 2 reports, for each country, the percentage of the regional growth rate variance explained by the eurozone-, country-, and idiosyncratic factors. These are, again, results averaged over all regions within a country. The percentages explained by the eurozone factor are particularly high for Germany and Austria, confirming what was already highlighted in Figure 3. Also consistent with this figure, the largest contribution of the country factor is for Greece.

Table 2: Regional growth variance explained by the euro area factor, the country-specific factor, and the idiosyncratic regional component (percentages)

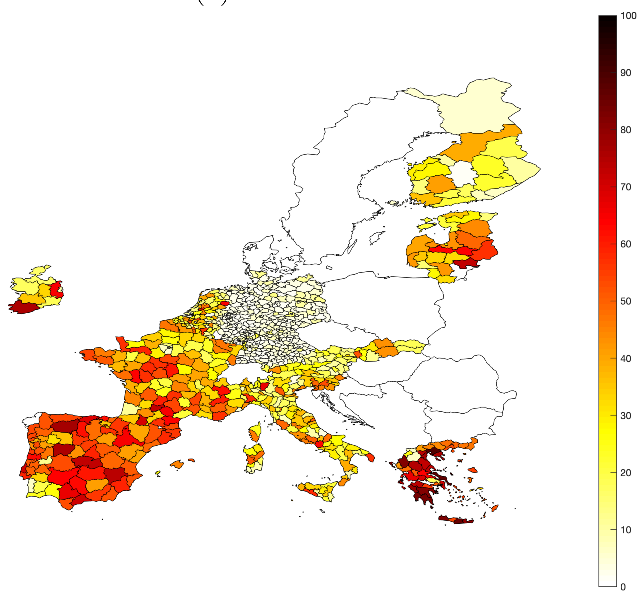
Country	F^{EA}	F^{C}	ε
AT	50.71	18.00	31.29
BE	41.85	26.28	31.87
DE	51.11	3.52	45.37
EE	42.55	28.26	29.18
EL	3.71	62.46	33.83
ES	29.66	51.23	19.11
FI	44.67	18.46	36.87
FR	32.59	38.15	29.26
IE	12.34	33.72	53.94
IT	38.25	27.28	34.48
LT	46.52	37.20	16.27
LV	26.03	47.16	26.81
NL	37.45	23.53	39.02
PT	28.96	43.24	27.80
SI	48.59	38.84	12.57
SK	43.47	29.81	26.72
EA	41.23	21.75	37.01

Note: Entries are country averages of regional growth variance explained by each level, in percentages. AT = Austria, BE = Belgium, CY = Cyprus, DE = Germany, EE = Estonia, EL = Greece, ES = Spain, FI = Finland, FR = France, IE = Ireland, IT = Italy, LT = Lithuania, LU = Luxembourg, LV = Latvia, MT = Malta, NL = the Netherlands, PT = Portugal, SI = Slovenia, and SK = Slovakia.

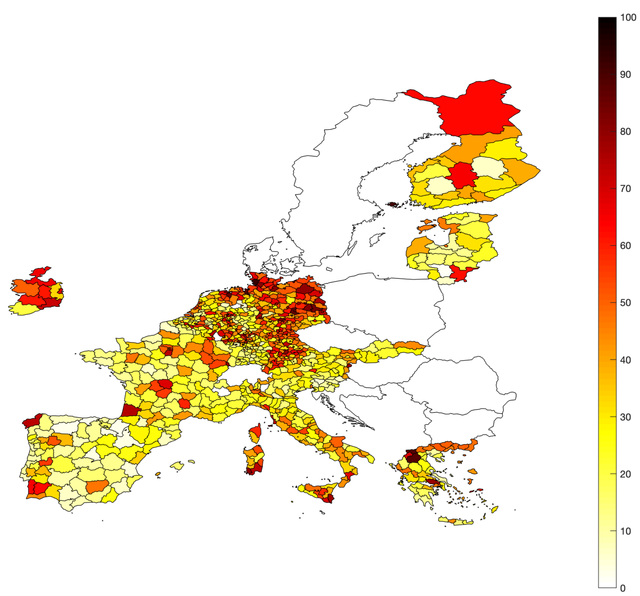
The variance decomposition in Table 2 only provides an aggregate perspective at the country level, but does not give information on individual regions. Therefore, Figure 4 depicts a heat map of the percentage explained variance by each level for all NUTS3 regions. The eurozone factor explains most of the variance of most regions in the Western part of Germany, a number of regions in Austria, Northern Italy, the Netherlands, Belgium, and some regions in the Eastern part of France. Interestingly, the eurozone factor also plays a large role in some of the Baltic regions. According to the model and the data, these regions would thus form the core of the eurozone economy. It corresponds to some extent to what is traditionally considered as the core (the Benelux, France, Germany and Austria). The second level, the country factor, explains most of the total variance of the Greek and Spanish regions, and a number of regions in West France. The country factor also seems to be prominent in parts of Ireland (Dublin and Cork), Rome and adjacent regions in the middle of Italy, Lithuania and Latvia. The regional factor is important in some parts of the eurozone outskirts. This is the case for most of Ireland and some regions of Greece, the South of Italy and Portugal. Interestingly, also most of Eastern Germany and the North-East of the Netherlands fall into this group. This may not be surprising. These areas are less developed and less active in competing on the EU internal market.



(a) Eurozone factor.



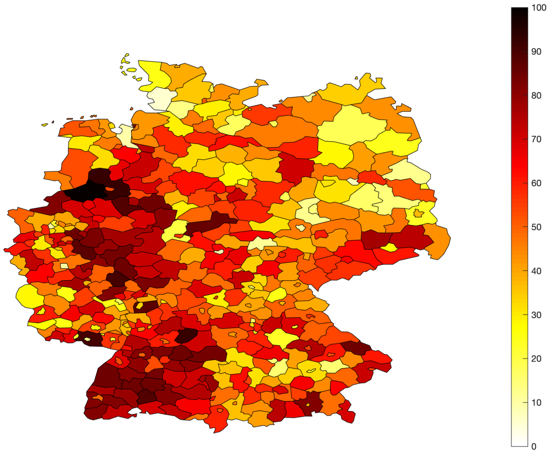
(b) Country factor.



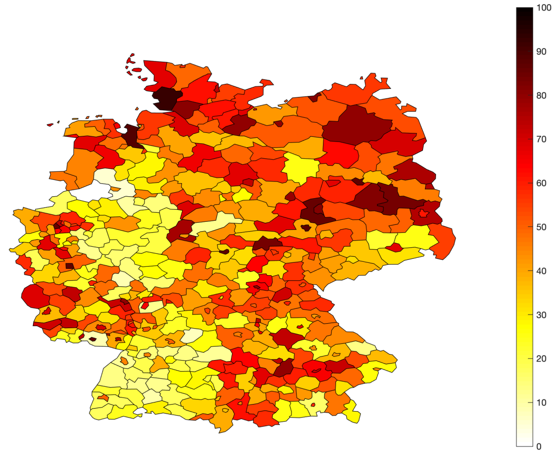
(c) Idiosyncratic factor.

Figure 4: Variance explained by each level, in percentages.

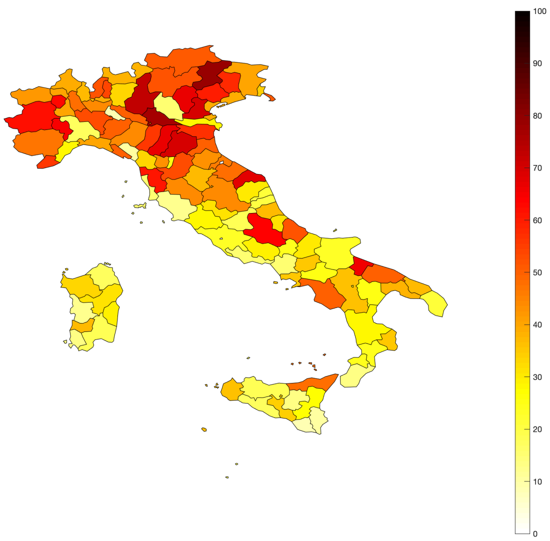
It is interesting to zoom in a bit further on Germany and Italy. Figure 5 shows more clearly the regional differences in the relative roles of the eurozone and the regional factors for these two countries. Indeed, the Western part of Germany and Northern Italy clearly belong to the core of the eurozone economy, while Eastern Germany and the South of Italy are more driven by the regional shocks.



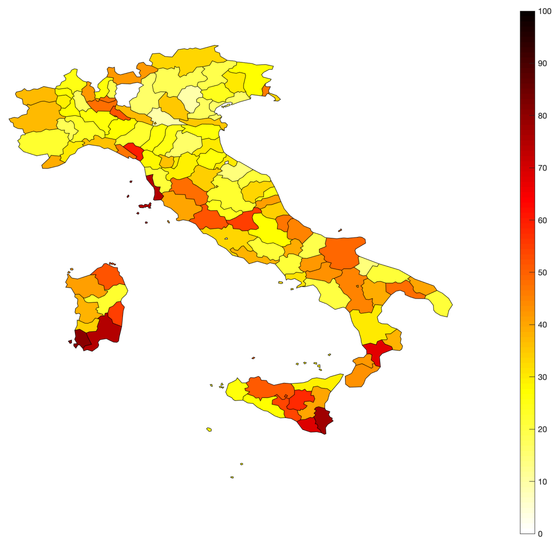
(a) Germany, Eurozone factor.



(b) Germany, Idiosyncratic factor.



(c) Italy, Eurozone factor.



(d) Italy, Idiosyncratic factor.

Figure 5: Variance explained by the eurozone and the regional factors in Germany and Italy.

5.2 The transfer scheme

5.2.1 Transfers based on 2021 vintage

Our analysis is based on the 2021 data vintage of ARDECO, which includes data from 1999 until 2021 (provisional). We have decided to include also the estimate for 2021 because, although preliminary, this will allow us to derive some insights on how the scheme would have operated in the pandemic period. The transfers presented below are generated by our linear scheme (equations 9 to 11) where, for illustrative purposes, we set $\gamma^{EA} = \gamma^{C} = \gamma^{R} = 0.5$.

Figure 6 depicts the transfers generated by each level of our scheme as well as the (shaded) total transfer received or paid by the country, aggregated over the regions of each country. Every country would have received transfers to cushion EMU-wide large shocks, in particular those associated with the GFC and the Covid-19 pandemic. The transfers generated by this first level of the scheme are on average about 4% of GDP around these crises. Transfers prompted by country-specific factors predominantly flow to countries that were disproportionately hit by the eurozone sovereign debt crisis. These transfers are especially visible for countries that received ESM official loans, i.e., Greece, Ireland and, to a lesser extent, Spain. Not surprisingly, the transfers associated with the region-specific shocks are roughly zero as these are orthogonal to each other and to any other factors. However, this does not mean that this transfer level is ineffective in stabilising the region-specific shocks. In fact, the third level of our CFC explains around 37% of the variation of GDP growth at the eurozone level, as shown in Table 2.[23]

Figure 7 shows the distribution of the regional transfers for Germany and Italy by sample year. The colours indicate the frequency mass of the different amounts of transfers at each level, with black indicating the highest frequency. This figure clearly shows the contrast between the commonality of the first two levels of the scheme, which lead to transfers of relatively comparable order of magnitude paid to or received by the regions, and the third level at which regional shocks are cushioned. However, more interestingly, although the average transfer associated with the re-

[23] The limited length of the sample restricts us from doing a fully-fledged rolling window analysis in which we assess the stability of the transfers for the subsequent data vintages. Such an analysis would implicitly account for the effect of a changing long-run (potential) GDP growth rate on the transfers. However, a limited exercise, in which starting with 2015 we iteratively expand the sample period with one year, shows that the transfers are relatively stable. Moreover, the transfers become more stable with the expansion of the sample period.

gional shock is close to zero on average, in virtually all the years the range of transfers at this level is larger than the range of transfers associated with the first two levels. The "netting" effect of the transfers associated with the region-specific shocks is an attractive feature of our CFC, as it reduces the need for the CFC to borrow on the capital market. Extensive use of the capital market might be politically sensitive, as the resources obtained in this way are used for (ex-post) temporary cross-border redistribution.

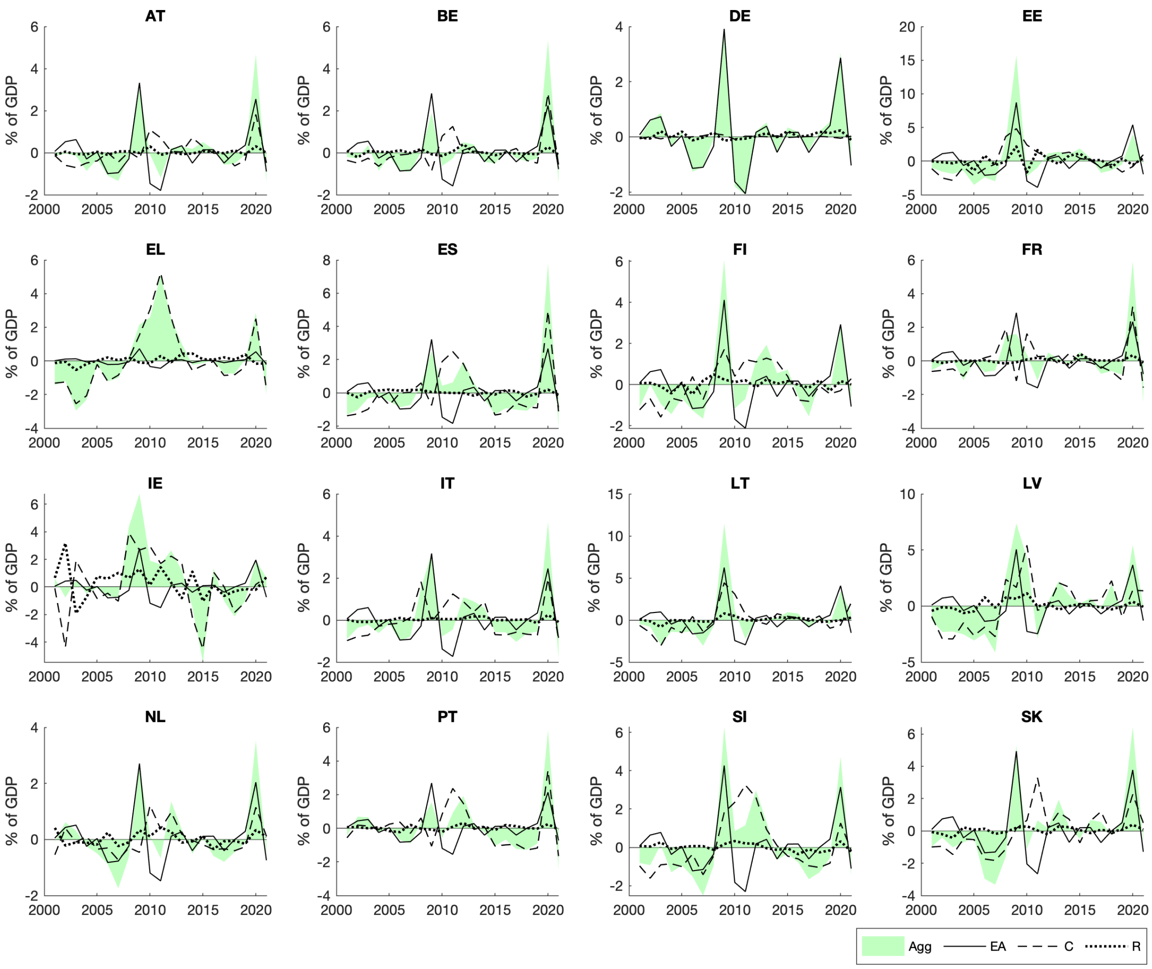
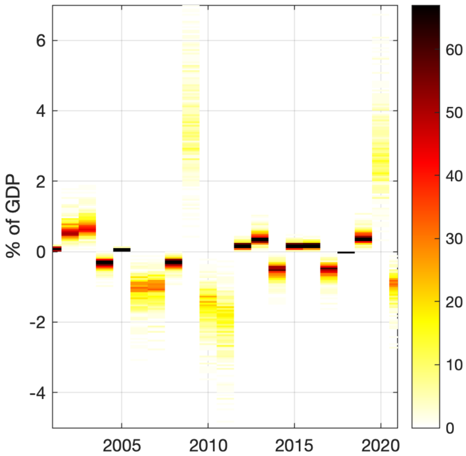
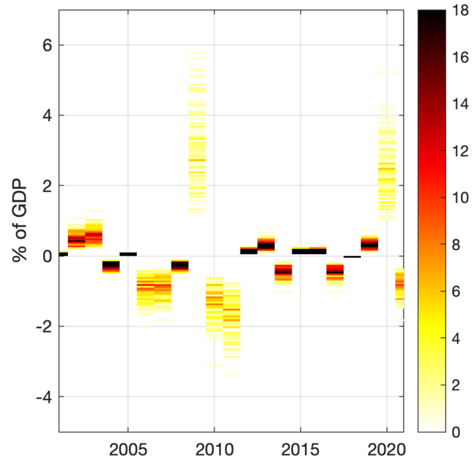


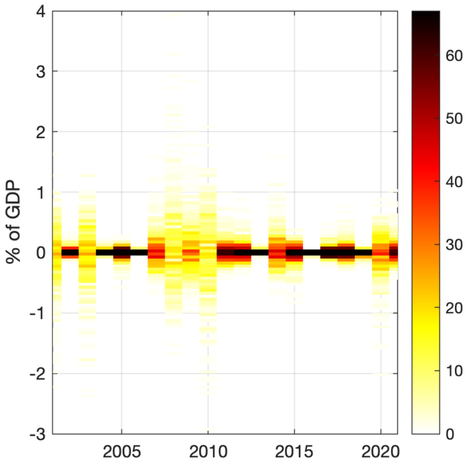
Figure 6: Country transfers by level and aggregate, in percent of country GDP.



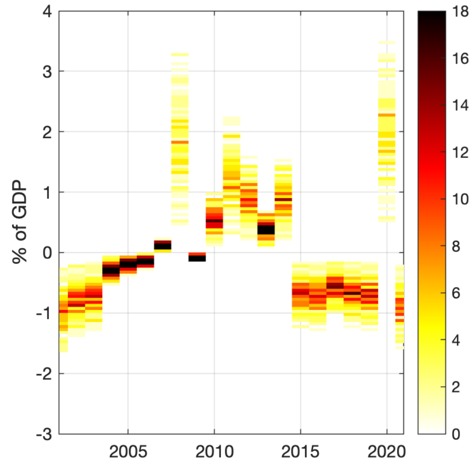
(a) Germany, Eurozone factor.



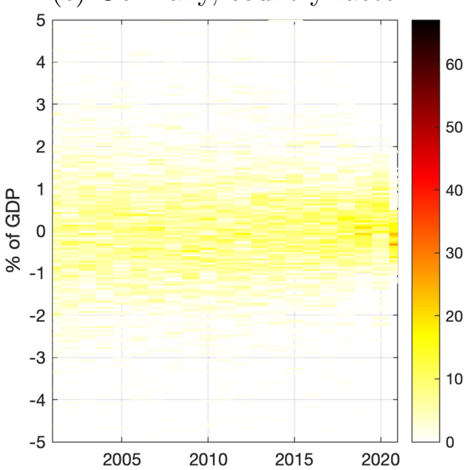
(b) Italy, Eurozone factor.



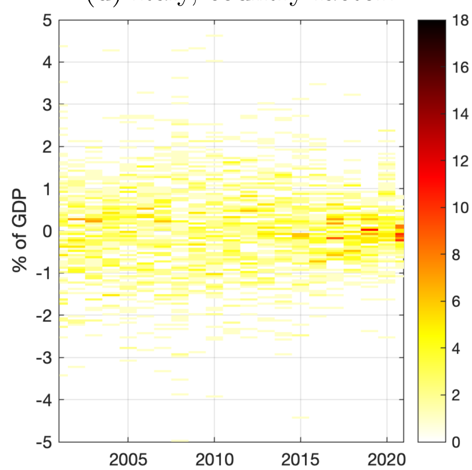
(c) Germany, country factor.



(d) Italy, country factor.



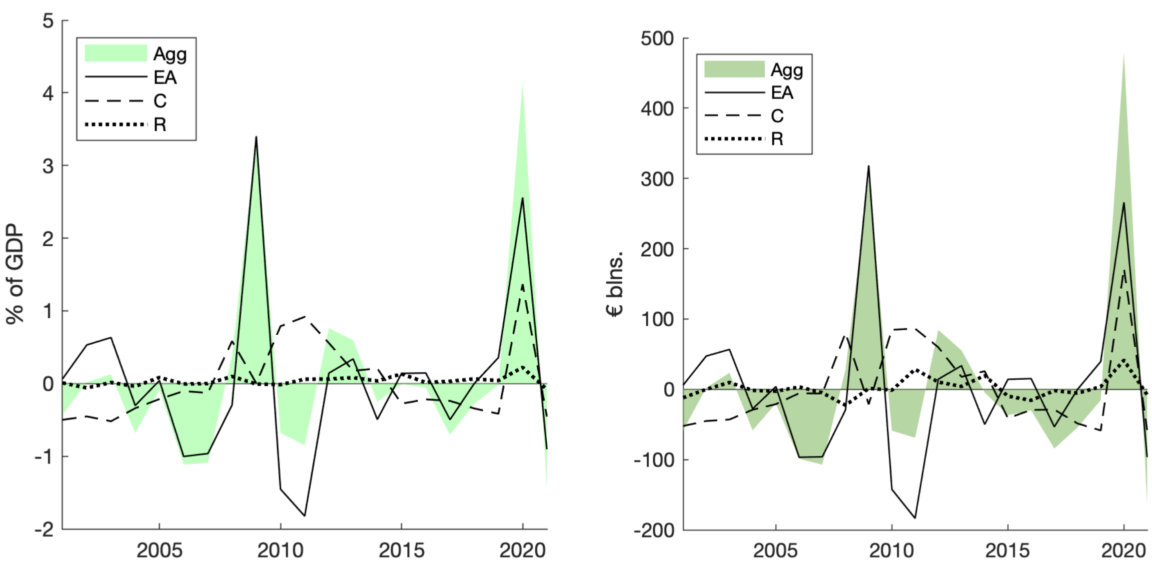
(e) Germany, regional factor.



(f) Italy, regional factor.

Figure 7: Regional distribution of transfers, in percent of regional GDP.

Panel (a) of Figure 8 depicts the transfers to the eurozone regions in percent of GDP, averaged over the whole eurozone, while Panel (b) shows those transfers in euros. Because the system does not need to be balanced on an annual basis, we observe that there is a substantial positive net flow of transfers in the years 2009 and 2020, the years when, respectively, the GFC and the Covid-19 pandemic struck hardest. This positive net flow in 2009 is "financed" by a negative net flow of transfers in the relatively good years preceding the GFC and the two years after 2009 when economies were rebounding and growth rates were higher than normal. The 2020 net positive flow is in part compensated by net outflows during the years in the run-up to Covid-19 and in 2021 when economies are rebounding. It is interesting to observe that the net positive flows in 2009 plus 2020 are of roughly the same order of magnitude as the NGEU. The net negative flows, the total "contributions" rarely exceed 100 billion euros in a year. In percent of GDP the maximum negative flow is around 1 percent in a year.



(a) In percent of euro area GDP.

(b) Monetary values.

Figure 8: Annual net transfers, EA aggregates.

Figure 9 depicts, by country, the transfers aggregated over the country's regions, cumulated over the years since the start of the sample period. The figure also depicts the transfers by level calculated in this way. This figure highlights that the transfers are stable in the sense that the cumulative transfers converge to roughly zero at the end of the period. The figure confirms the findings discussed above: typically, in the run-up to the GFC regions make net payments to the CFC, while substantial positive transfers are received by the regions during the GFC. A similar, though less stark, pattern with build-down of cumulative transfers arises in the years preceding the Covid-19 pandemic. Countries that experienced a double dip recession during the sovereign debt crisis tend to receive net transfers during this period.

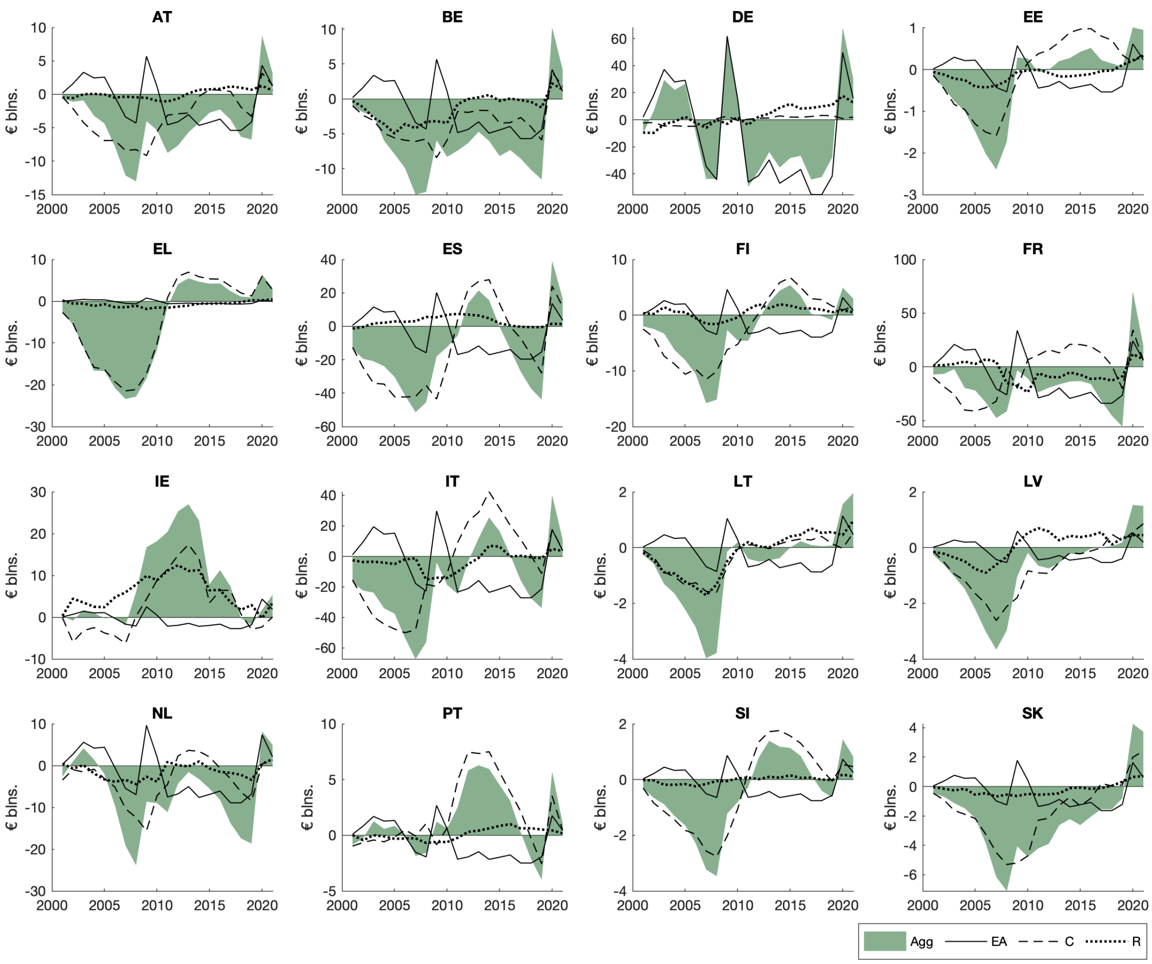


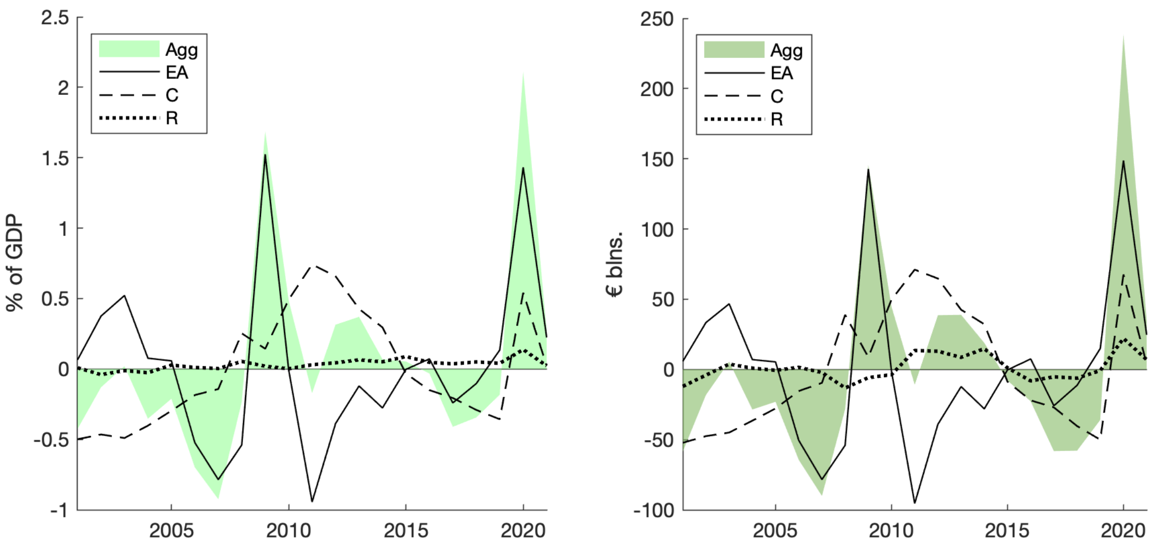
Figure 9: Cumulative net transfers, country aggregates, monetary values.

5.2.2 Robustness

Smoothed transfers

The deep negative shocks created by the GFC and Covid-19 were followed by periods of above average growth, leading on average to negative transfers, because our CFC requires regions to make net payments during periods of unusually high growth, even when this growth is merely the result of the elimination of a large overcapacity created by a crisis. Such an unfortunate timing of net payments would hamper recovery from severe shocks. In this subsection, we consider the case in which transfers are smoothed over the years. More specifically, actual transfers in period t are a weighted average of the original transfers from $t-s$ up to and including t, $s \in \mathbb{N}$, with weights $w_k = 1/2^k \times \sum_{i=0}^{s} 1/2^i$, $k \in (t-s, t-s+1, \ldots, t)$.[24] In the following we use $s = 3$.

Figure 10 displays the smoothed transfers aggregated at the eurozone level. Not surprisingly, compared with Figure 8, the peaks in the transfers, both positive and negative, are smaller. Importantly, in the first year of recovery from the GFC, aggregate transfers are close to zero, while the year following the Covid-19 shock they are still positive. This suggests that the smoothing of the transfers is beneficial to countries restoring from a severe shock.



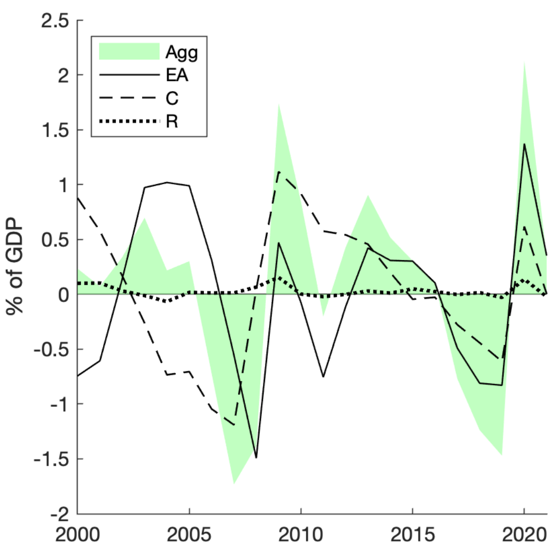
(a) In percent of euro area GDP.

(b) Monetary values.

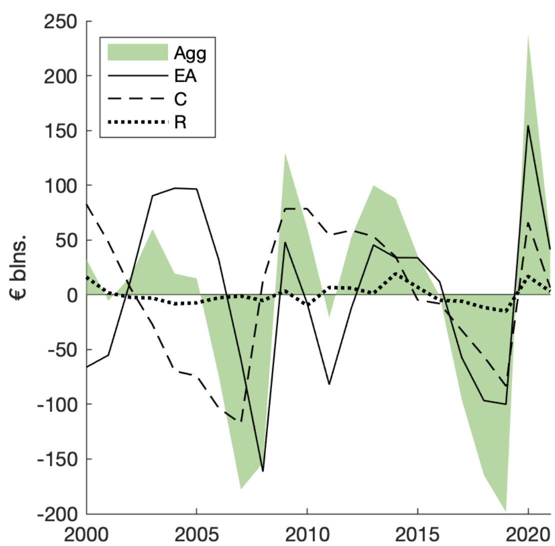
Figure 10: Smoothed annual total EA transfers.

[24] The multiplication term assures that the weights add up to unity.

Transfers calibrated on per-capita output gap
An alternative to basing the CFC on regional growth rates would be to calibrate it on regional output gaps. This would avoid the problem of negative transfers resulting from bounce back growth after a highly negative shock. A disadvantage of using the output gap is that it is not directly observed. Indeed, output gaps are calculated based on potential output, and are frequently revised as new data come in. Real-time measurement error is likely even larger at the regional than at the country level. Nevertheless, we apply our CFC to output gaps calculated as deviations from region-specific trends estimated through the Hodrick-Prescott filter. The estimates are consistent with those of the baseline model in terms of the variance explained by each level.[25] Transfers differ somewhat from the baseline pattern due to the higher persistence of the output gap compared to deviations of growth from their trend, although they remain qualitatively similar.



(a) In percent of euro area GDP.



(b) Monetary values.

Figure 11: Output gap driven annual transfers, EA aggregates.

5.3 Stabilising effects in the 1999-2021 sample

In this subsection we explore the contribution of each individual level of our CFC to the regional GDP growth stabilisation. More specifically, we separately calibrate each level of our scheme for different γ values and assess their stabilising effect. In

[25]Note that we retain one time observation more by avoiding using growth rates.

this exercise, we assume for illustrative purposes that the regional multiplier $g_{r,c}$ is equal to one, for all regions and countries.[26]

Table 3 reports, for different values of γ and for each level of our scheme, the empirical stabilising effect as a percentage of the standard deviation of regional growth (averaged over all its regions) for each country, as well as for the entire eurozone. We calculate the stabilising effect as the percentage decrease in the standard deviation of the growth rate when the transfers are added to the raw output data. The table reports an average reduction in volatility of -11.78%, -21.28%, and -29.79%, for $\gamma^{EA} = 0.25$, $\gamma^{EA} = 0.5$, and $\gamma^{EA} = 1$, respectively. This is close to the theoretical numbers calculated using (14). In addition, the table confirms that the marginal stabilising effect of an increase in γ^i is decreasing, also also shown in the theoretical counterpart of Figure 2.

Table 3 indicates that - on average - the CFC's stabilising effects of the EA and the regional layer are of roughly the same magnitude, while the stabilising effect of the country layer is roughly half that of the other two levels. This is due to the fact that the country-specific factors explain less of the regional growth variation than do the EA and regional factors.

The relative importance of the stabilising effect of the three levels differs across the countries, in line with the cross-country differences in the variance decomposition highlighted earlier. For instance, the CFC level cushioning euro area shocks is highly effective in Germany, but virtually ineffective in the case of Greece. We observe the opposite for the country-specific level.

[26] Although heterogeneity in fiscal multipliers will influence the stabilisation properties, deviations of the multiplier from one will affect neither ex-ante nor ex-post redistribution among countries, as positive and negative transfers will cancel at the regional level in the long run (see Proposition 1).

Table 3: Stabilisation of each individual level for different γ^i values, in percentages.

Level:	Eurozone aggregate			Country-specific			Regional		
γ^i :	0.25	0.5	1	0.25	0.5	1	0.25	0.5	1
AT	-11.92	-21.90	-31.96	-3.93	-6.91	-9.55	-7.56	-13.73	-20.04
BE	-9.51	-17.24	-24.52	-5.83	-10.35	-14.42	-7.91	-14.39	-20.88
DE	-11.98	-22.12	-32.62	-0.71	-1.31	-2.11	-10.90	-20.12	-30.05
EE	-10.07	-18.25	-26.29	-6.71	-12.09	-17.66	-6.74	-12.42	-19.47
EL	-0.41	-0.69	-0.82	-14.97	-28.04	-41.69	-8.52	-15.58	-23.07
ES	-6.60	-11.67	-16.07	-11.88	-21.59	-30.34	-4.74	-8.47	-11.87
FI	-10.46	-19.05	-27.59	-4.24	-7.12	-8.07	-9.26	-17.02	-25.92
FR	-7.32	-13.05	-18.26	-8.76	-15.81	-22.43	-7.09	-12.88	-18.77
IE	-2.16	-3.77	-5.09	-7.14	-13.24	-20.43	-14.53	-27.35	-41.93
IT	-8.72	-15.77	-22.50	-6.28	-11.27	-16.07	-8.19	-14.87	-21.79
LT	-10.77	-19.55	-27.81	-7.69	-13.65	-18.22	-5.15	-9.22	-13.17
LV	-5.72	-10.09	-13.94	-10.84	-19.70	-28.40	-7.03	-12.87	-19.70
NL	-8.56	-15.45	-22.06	-5.06	-9.07	-12.95	-9.72	-17.86	-26.44
PT	-6.41	-11.36	-15.76	-11.08	-19.69	-25.38	-6.82	-12.38	-18.01
SI	-11.42	-20.75	-29.64	-9.78	-16.82	-19.41	-3.59	-6.39	-9.20
SK	-9.92	-17.92	-25.37	-6.47	-11.46	-15.80	-6.98	-12.59	-18.45
EA	-9.51	-17.37	-25.17	-4.99	-9.03	-12.84	-9.00	-16.50	-24.43

Note: the table reports, for different values of γ - and assuming that the regional multiplier $g_{r,c}$ is equal to one - the stabilising effect of the fiscal capacity scheme. Specifically, the table reports the percentage reduction in the average regional volatility of output, once the transfers calibrated according to γ^i for each layer are factored in.

Due to the netting behaviour, as can also be seen from Figures 6 to 9, the amount of funds needed at the EA level to implement the CFC level associated with dampening the effect of the regional factor is close to zero, despite the fact that on average this level of the CFC is almost as effective as that dealing with the EA factor. By helping to align regional business cycles, the regional level of the CFC strengthens the eurozone and national policy transmission mechanisms, and as such it should be considered a useful complement to the eurozone central monetary policy and national fiscal policies, which address common shock components. These common policies will suit a wider range of regions when the business cycles of the latter are better aligned.

6 Conclusion

This paper has presented a proposal for a central fiscal capacity that can be implemented at the euro area (or EU) level, where transfers are based on the exposure of the cyclical component of regional output growth to area-wide factors, country-specific factors and regional-idiosyncratic factors. The stabilisation of region-specific shocks has so far not received much attention in the literature, even though these shocks can be substantial.

Calibrating the model over the period 1999-2021, it emerges that the proposed CFC has a number of desirable features. First, the scheme can be flexibly calibrated according to economic considerations or political preferences, for example by giving more or less weight to the eurozone factor compared to the other factors. Second, cumulated over time, transfers tend to zero at the end of the sample period. This is the result of transfers being based on deviations from mean growth, hence positive and negative transfers will roughly cancel over time. Third, transfers are positive and sizeable during when it is most needed, e.g., during deep crises such as the GFC and the Covid-19 pandemic. In these periods, the CFC would need to borrow on the capital market or use funds accumulated earlier. Instead, in periods with above average growth, the CFC may accumulate funds or pay off its debts. Fourth, substantial stabilisation can already be obtained with a borrowing capacity comparable to that of NextGenEU. Finally, stabilisation of the euro area and the regional factors is on average about equally effective, while stabilisation of the country factor is on average about half as effective, because country-specific shocks turn out to be less destabilising over this sample. Because the regional factors are mutually orthogonal, substantial stabilisation of regional shocks can be achieved with very little aggregate financing need.

Our proposal for a CFC fits well within the current discussion in the EU. Various international institutions view a CFC as a beneficial complement to the EU fiscal architecture. The value-added of a CFC would be particularly high in the presence of extreme shocks when at the same time governments find it difficult to borrow on the capital market. Deploying the CFC in these circumstances would be more effective than counting on the indirect stimulus from countries with fiscal space, if these are prepared to expand at all. However, the eventual political feasibility of a future CFC will crucially depend on how well the current RRF will be implemented. The latter is quite widely viewed as the embryo of a potential CFC. Hence, the functioning of the RRF will affect the perceived relevance of moral hazard for a CFC, as well as confidence in EU facilities in general.

All in all, while our analysis focuses on the Eurozone, the findings of this paper could potentially also provide useful insights on the construction of centralised fiscal capacities in other federations.

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A Model specifics and derivations

A.1 Dynamic factor model identification restrictions

To exclude symmetry when the eurozone level consists of multiple factors ($l > 0$), we impose $\lambda_{r,c}^{EA,l} = 0$ if $c = 1 \wedge l > r, r \in \left\{1, 2, \ldots, N_{EA}^{F} - 1\right\}$. In words, of the first country the first region is only exposed to the first factor in the level, the second only to the first and second factors, etc. If this restriction is left out, the factors and loading vectors can be swapped while obtaining an identical decomposition.

To uniquely pin down the signs of the loadings and the factors, we impose $\lambda_{r,c}^{EA,l} > 0$ if $c = 1 \wedge l = r, r \in \left\{1, 2, \ldots, N_{EA}^{F}\right\}$. Hence, in case the eurozone factor level consists of two factors, we restrict the first region's loading to the first factor in the level to be positive, the second region's loading to the second factor to be positive, etc. Analogously, for the country factor levels we impose $\forall c \in \mathcal{C}$ and $r \in \left\{1, 2, \ldots, N_{c}^{F}\right\}$ that $\lambda_{r,c}^{c,l} > 0$, if $r = l$, and $\lambda_{r,c}^{c,l} = 0$, if $l > r$.

A.2 Sampler distributions

A.2.1 Priors

$$\lambda_{r,c}^{k,l} \sim \mathcal{N}\left(\bar{\lambda}_{r,c}^{k,l}, \bar{\Lambda}_{r,c}^{k,l}\right), \forall k, l, r, c \tag{15}$$

$$\theta_{k,l} \sim \mathcal{TN}_{(-1,1)}\left(\bar{\theta}_{k,l}, \bar{\Theta}_{k,l}\right), \forall k, l \tag{16}$$

$$\phi_{r,c} \sim \mathcal{TN}_{(-1,1)}\left(\bar{\phi}_{r,c}, \bar{\Phi}_{r,c}\right), \forall r, c \tag{17}$$

$$\sigma_{r,c}^{2} \sim IG\left(\frac{\bar{\nu}_{r,c}}{2}, \frac{\bar{\delta}_{r,c}}{2}\right), \forall r, c \tag{18}$$

where the second and third lines denote truncated normal densities over the interval $(-1, 1)$ and the fourth line an inverted-gamma distribution.

A.2.2 Posteriors

Define $\mathbf{Y} \equiv \left\{\left(y_{r,c,1}, y_{r,c,2}, \ldots, y_{r,c,T}\right), r \in \left\{1, 2, \ldots, N_{c}^{R}\right\}, c \in \left\{1, 2, \ldots, N_{C}\right\}\right\}$ as the set of observed regional growth rates, and $\mathbf{F} \equiv \left\{\left(F_{1}^{k}, F_{2}^{k}, \ldots, F_{T}^{k}\right) | k \in \{EA, \mathcal{C}\}\right\}$ as the set of unobserved latent factor levels. Denote by ψ the full set of parameters.

Given the conjugate priors the posterior parameter distributions yield:

$$\left(\lambda_{r,c}^{k,l}|\mathbf{Y},\mathbf{F},\{\psi\setminus\lambda_{r,c}^{k,l}\}\right)\propto\mathcal{N}\left(\widehat{\lambda}_{r,c}^{k,l},\widehat{\Lambda}_{r,c}^{k,l}\right),\forall k,l,r,c \tag{19}$$

$$\left(\theta_{k,l}|\mathbf{Y},\mathbf{F},\{\psi\setminus\theta_{k,l}\}\right)\propto\Psi\left(\theta_{k,l}\right)\mathcal{N}\left(\widehat{\theta}_{k,l},\widehat{\Theta}_{k,l}\right)\mathbb{1}(|\theta_{k,l}|<1),\forall k,l \tag{20}$$

$$\left(\phi_{r,c}|\mathbf{Y},\mathbf{F},\{\psi\setminus\phi_{r,c}\}\right)\propto\Psi\left(\phi_{r,c}\right)\mathcal{N}\left(\widehat{\phi}_{r,c},\widehat{\Phi}_{r,c}\right)\mathbb{1}(|\phi_{r,c}|<1),\forall r,c \tag{21}$$

$$\left(\sigma_{r,c}^{2}|\mathbf{Y},\mathbf{F},\{\psi\setminus\sigma_{r,c}^{2}\}\right)\propto IG\left(\frac{\widehat{\nu}_{r,c}}{2},\frac{\widehat{\delta}_{r,c}}{2}\right),\forall r,c \tag{22}$$

where,

$$\begin{aligned}
\widehat{\lambda}_{r,c}^{k,l}&=\widehat{\Lambda}_{r,c}^{k,l}\left(\left(\bar{\Lambda}_{r,c}^{k,l}\right)^{-1}\bar{\lambda}_{r,c}^{k,l}+\sigma_{r,c}^{-2}(\tilde{F}_{r,c}^{k,l})'\tilde{y}_{r,c}\right)\\
\widehat{\Lambda}_{r,c}^{k,l}&=\left(\left(\bar{\Lambda}_{r,c}^{k,l}\right)^{-1}+\sigma_{r,c}^{-2}(\tilde{F}_{r,c}^{k,l})'\tilde{F}_{r,c}^{k,l}\right)^{-1}\\
\Psi\left(\theta_{k,l}\right)&=\sqrt{1-\theta_{k,l}^{2}}\ \exp\left(-\frac{\left(1-\theta_{k,l}^{2}\right)}{2}\left(F_{1}^{k,l}\right)^{2}\right)\\
\widehat{\theta}_{k,l}&=\widehat{\Theta}_{k,l}\left(\left(\bar{\Theta}_{k,l}\right)^{-1}\bar{\theta}_{k,l}+U_{k,l}'u_{k,l}\right)\\
\widehat{\Theta}_{k,l}&=\left(\left(\bar{\Theta}_{k,l}\right)^{-1}+U_{k,l}'U_{k,l}\right)^{-1}\\
\Psi\left(\phi_{r,c}\right)&=\sqrt{1-\phi_{r,c}^{2}}\ \exp\left(-\frac{\left(1-\phi_{r,c}^{2}\right)}{2\sigma_{r,c}^{2}}\left(y_{r,c,1}-\sum_{l=1}^{N_{EA}^{F}}\lambda_{r,c}^{EA,l}F_{1}^{EA,l}-\sum_{m=1}^{N_{c}^{F}}\lambda_{r,c}^{c,m}F_{1}^{c,m}\right)^{2}\right)\\
&=\sqrt{1-\phi_{r,c}^{2}}\ \exp\left(-\frac{\left(1-\phi_{r,c}^{2}\right)}{2\sigma_{r,c}^{2}}\left(y_{r,c,1}-\lambda_{r,c}^{EA,1}F_{1}^{EA,1}-\lambda_{r,c}^{c,1}F_{1}^{c,1}\right)^{2}\right)\\
\widehat{\phi}_{r,c}&=\widehat{\Phi}_{r,c}\left(\left(\bar{\Phi}_{r,c}\right)^{-1}\bar{\phi}_{r,c}+\sigma_{r,c}^{-2}E_{r,c}'e_{r,c}\right)\\
\widehat{\Phi}_{r,c}&=\left(\left(\bar{\Phi}_{r,c}\right)^{-1}+\sigma_{r,c}^{-2}E_{r,c}'E_{r,c}\right)^{-1}\\
\widehat{\nu}_{r,c}&=\bar{\nu}_{r,c}+T\\
\widehat{\delta}_{r,c}&=\bar{\delta}_{r,c}+||\tilde{y}_{r,c}-\tilde{x}_{r,c}\beta_{r,c}||^{2}
\end{aligned}$$

and,

$$\tilde{y}_{r,c} = \begin{bmatrix} \frac{1}{1-\phi_{r,c}^2} y_{r,c,1} \\ (1-\phi_{r,c}L)\, y_{r,c,2} \\ \vdots \\ (1-\phi_{r,c}L)\, y_{r,c,T} \end{bmatrix}$$

$$\tilde{F}_{r,c}^{k,l} = \begin{bmatrix} \frac{1}{1-\phi_{r,c}^2} F_1^{k,l} \\ (1-\phi_{r,c}L)\, F_2^{k,l} \\ \vdots \\ (1-\phi_{r,c}L)\, F_T^{k,l} \end{bmatrix}$$

$$u_{k,l} = \left(F_2^{k,l}, \dots, F_T^{k,l}\right)'$$

$$U_{k,l} = \left(F_1^{k,l}, \dots, F_{T-1}^{k,l}\right)'$$

$$e_{r,c} = (e_{r,c,2}, \dots, e_{r,c,T})'$$

$$E_{r,c} = (e_{r,c,1}, \dots, e_{r,c,T-1})'$$

$$e_{r,c,t} = y_{r,c,t} - \sum_{l=1}^{N_{EA}^F} \lambda_{r,c}^{EA,l} F_t^{EA,l} - \sum_{m=1}^{N_c^F} \lambda_{r,c}^{c,m} F_t^{c,m}$$

where L is the lag-operator. Note that we can sample each loading individually due to the orthogonality of all factors in the observation equation. Further, for higher-order AR-processes sampling can be easily adapted, see Otrok and Whiteman (1998).

The conditional distribution of the latent factors is given by:

$$
\begin{aligned}
F^{k,l} &\sim \mathcal{N}\left(f_{k,l}, H_{k,l}\right) \qquad (23)\\
f_{k,l} &= H_{k,l}\left[\sum_{c\in\mathcal{C}}\sum_{r\in\mathcal{R}_c}\frac{\left(\lambda^{k,l}_{r,c}\right)^2}{\sigma^2_{r,c}}S_{r,c}\tilde{e}^{l}_{r,c}\right]\\
H_{k,l} &= \left[S_{k,l}+\sum_{c\in\mathcal{C}}\sum_{r\in\mathcal{R}_c}\frac{\lambda^{k,l}_{r,c}}{\sigma^2_{r,c}}S_{r,c}\right]^{-1}\\
S_{k,l} &= \begin{bmatrix}
1 & -\theta_{k,l} & 0 & \dots & \dots & \dots & 0\\
-\theta_{k,l} & 1+\theta^2_{k,l} & -\theta_{k,l} & 0 & \cdots & \cdots & 0\\
0 & -\theta_{k,l} & 1+\theta^2_{k,l} & -\theta_{k,l} & 0 & \cdots & 0\\
\vdots & \vdots & \ddots & \ddots & \ddots & \ddots & \vdots\\
\vdots & \vdots & \ddots & \ddots & \ddots & \ddots & -\theta_{k,l}\\
0 & 0 & \cdots & \cdots & \cdots & -\theta_{k,l} & 1
\end{bmatrix}\\
S_{r,c} &= \begin{bmatrix}
1 & -\phi_{r,c} & 0 & \dots & \dots & \dots & 0\\
-\phi_{r,c} & 1+\phi^2_{r,c} & -\phi_{r,c} & 0 & \cdots & \cdots & 0\\
0 & -\phi_{r,c} & 1+\phi^2_{r,c} & -\phi_{r,c} & 0 & \cdots & 0\\
\vdots & \vdots & \ddots & \ddots & \ddots & \ddots & \vdots\\
\vdots & \vdots & \ddots & \ddots & \ddots & \ddots & -\phi_{r,c}\\
0 & 0 & \cdots & \cdots & \cdots & -\phi_{r,c} & 1
\end{bmatrix}\\
\tilde{e}^{k,l}_{r,c} &= (\tilde{e}^{k,l}_{r,c,1}, \tilde{e}^{k,l}_{r,c,2}, \dots, \tilde{e}^{k,l}_{r,c,T})'\\
\tilde{e}^{k,l}_{r,c,t} &= y_{r,c,t} - \sum_{m=1}^{N^F_{EA}}\mathbb{1}\left[k\neq EA \vee l\neq m\right]\lambda^{EA,m}_{r,c}F^{EA,m}_t - \sum_{n=1}^{N^F_c}\mathbb{1}\left[k\neq c\vee l\neq n\right]\lambda^{c,n}_{r,c}F^{c,n}_t
\end{aligned}
$$

A.3 Transfer scheme optimization

To establish the optimal transfers, we first derive a consistent policy function. Define a general transfer as a function, dependent on parameter vector γ^i, of a region's exposure to common and/or idiosyncratic shocks, i.e. $T^i_{r,c,t} \equiv \sum_{l=1}^{N^F_i}\tau^i\left(\lambda^{i,l}_{r,c}F^{i,l}_t|\gamma^i\right)$. The policymaker is now faced with pinning down the policy functions $\tau^i(\cdot|\gamma^i)$ by optimizing over γ^i, per level $i\in\{EA, C, R\}$. In the following, we suppress in the notation the dependence of $\tau^i(\cdot)$ on γ^i. Now, the loss function of the decision makers operating the CFC reads:

$$
\begin{aligned}
L\left(\gamma^{EA,*},\gamma^{C,*},\gamma^{R,*}\right) = \sum_{c\in\mathcal{C}} \frac{1}{N_c^R} \sum_{r\in\mathcal{R}_c} \Bigg[& \mathbb{V}\text{ar}\left(y_{r,c,t}\right) + g_{r,c,t}^2 \sum_{i\in\{EA,C,R\}} \mathbb{V}\text{ar}\left(\sum_{l=1}^{N_i^F} \tau^i\left(\lambda_{r,c}^{i,l} F_t^{i,l}\right)\right) \\
& + 2 g_{r,c,t} \sum_{i\in\{EA,C,R\}} \mathbb{C}\text{ov}\left(y_{r,c,t}, \sum_{l=1}^{N_i^F} \tau^i\left(\lambda_{r,c}^{i,l} F_t^{i,l}\right)\right) \Bigg] \\
& + f\left(\left\{\sum_{c\in\mathcal{C}} \sum_{r\in\mathcal{R}_c} \sum_{t=1}^{T} \sum_{l=1}^{N_i^F} \tau^i\left(\lambda_{r,c}^{i,l} F_t^{i,l}\right)\right\}_{i\in\{EA,C,R\}}\right)
\end{aligned} \tag{24}
$$

Note that:

$$
\begin{aligned}
\sum_{i\in\{EA,C,R\}} \mathbb{V}\text{ar}\left(\sum_{l=1}^{N_i^F} \tau^i\left(\lambda_{r,c}^{i,l} F_t^{i,l}\right)\right) &= \sum_{i\in\{EA,C,R\}} \sum_{l=1}^{N_i^F} \mathbb{V}\text{ar}\left(\tau^i\left(\lambda_{r,c}^{i,l} F_t^{i,l}\right)\right) \\
&\underset{\text{Delta-method}}{\approx} \sum_{i\in\{EA,C,R\}} \sum_{l=1}^{N_i^F} \left(\tau^{i'}\left(\underbrace{\mathbb{E}\left[\lambda_{r,c}^{i,l} F_t^{i,l}\right]}_{=0}\right)\right)^2 \mathbb{V}\text{ar}\left(\lambda_{r,c}^{i,l} F_t^{i,l}\right) \\
&\approx \sum_{i\in\{EA,C,R\}} \sum_{l=1}^{N_i^F} \left(\tau^{i'}\left(0\right)\right)^2 \frac{\left(\lambda_{r,c}^{i,l}\right)^2}{1-\theta_{i,l}^2}
\end{aligned} \tag{25}
$$

and:

$$\sum_{i\in\{EA,C,R\}} \mathbb{C}\text{ov}\left(y_{r,c,t}, \sum_{l=1}^{N_i^F} \tau^i\left(\lambda_{r,c}^{i,l} F_t^{i,l}\right)\right) =$$

$$\sum_{i\in\{EA,C,R\}} \mathbb{C}\text{ov}\left(\sum_{l=1}^{N_{EA}^F} \lambda_{r,c}^{EA,l} F_t^{EA,l} + \sum_{m=1}^{N_c^F} \lambda_{r,c}^{c,m} F_t^{c,m} + \varepsilon_{r,c,t}, \sum_{l=1}^{N_i^F} \tau^i\left(\lambda_{r,c}^{i,l} F_t^{i,l}\right)\right) =$$

$$\sum_{l=1}^{N_{EA}^F} \mathbb{C}\text{ov}\left(\lambda_{r,c}^{EA,l} F_t^{EA,l}, \tau^{EA}\left(\lambda_{r,c}^{EA,l} F_t^{EA,l}\right)\right) + \sum_{m=1}^{N_c^F} \mathbb{C}\text{ov}\left(\lambda_{r,c}^{c,m} F_t^{c,m}, \tau^{C}\left(\lambda_{r,c}^{c,m} F_t^{c,m}\right)\right) +$$

$$\mathbb{C}\text{ov}\left(\varepsilon_{r,c,t}, \tau^R\left(\varepsilon_{r,c,t}\right)\right) =$$

$$\sum_{l=1}^{N_{EA}^F} \mathbb{E}\left[\tau^{EA'}\left(\lambda_{r,c}^{EA,l} F_t^{EA,l}\right)\right] \mathbb{V}\text{ar}\left(\lambda_{r,c}^{EA,l} F_t^{EA,l}\right) + \sum_{m=1}^{N_c^F} \mathbb{E}\left[\tau^{C'}\left(\lambda_{r,c}^{c,m} F_t^{c,m}\right)\right] \mathbb{V}\text{ar}\left(\lambda_{r,c}^{c,m} F_t^{c,m}\right) +$$

$$\mathbb{E}\left[\tau^{R'}\left(\varepsilon_{r,c,t}\right)\right] \mathbb{V}\text{ar}\left(\varepsilon_{r,c,t}\right) =$$

$$\sum_{l=1}^{N_{EA}^F} \mathbb{E}\left[\tau^{EA'}\left(\lambda_{r,c}^{EA,l} F_t^{EA,l}\right)\right] \frac{\left(\lambda_{r,c}^{EA,l}\right)^2}{1-\theta_{EA,l}^2} + \sum_{m=1}^{N_c^F} \mathbb{E}\left[\tau^{C'}\left(\lambda_{r,c}^{c,m} F_t^{c,m}\right)\right] \frac{\left(\lambda_{r,c}^{c,m}\right)^2}{1-\theta_{c,m}^2} +$$

$$\mathbb{E}\left[\tau^{R'}\left(\varepsilon_{r,c,t}\right)\right] \frac{\left(\sigma_{r,c}^2\right)^2}{1-\phi_{r,c}^2} \tag{26}$$

A.3.1 Optimization with linear policy function

With a linear transfer function, as deployed in the main text, i.e. $\tau^i\left(x|\gamma^i\right) \equiv -\gamma^i x$, the optimization problem boils down to:

$$(\gamma^{EA}, \gamma^C, \gamma^R) = \text{argmin } L(\gamma^{EA}, \gamma^C, \gamma^R) \tag{27}$$

$$
\begin{aligned}
L(\gamma) &= \sum_{c\in\mathcal{C}} \frac{1}{N_c^R} \sum_{r\in\mathcal{R}_c} \mathbb{V}\text{ar}\left(y_{r,c,t} + g_{r,c,t} \sum_{i\in\{EA,C,R\}} T_{r,c,t}^i \right) + f\left(\left\{ \sum_{c\in\mathcal{C}} \sum_{r\in\mathcal{R}_c} \sum_{t=1}^{T} \sum_{l=1}^{N_i^F} -\gamma^i \lambda_{r,c}^{i,l} F_t^{i,l} \right\}_{i\in\{EA,C,R\}} \right) \\
&= \sum_{c\in\mathcal{C}} \frac{1}{N_c^R} \sum_{r\in\mathcal{R}_c} \left[\left(1 - g_{r,c,t}\gamma^{EA}\right)^2 \sum_{l=1}^{N_{EA}^F} \frac{\left(\lambda_{r,c}^{EA,l}\right)^2}{1-\left(\theta_{EA,l}\right)^2} + \left(1 - g_{r,c,t}\gamma^{C}\right)^2 \sum_{m=1}^{N_c^F} \frac{\left(\lambda_{r,c}^{c,m}\right)^2}{1-\left(\theta_{c,m}\right)^2} + \frac{\left(1 - g_{r,c,t}\gamma^{R}\right)^2 \sigma_{r,c}^2}{1-\phi_{r,c}^2} \right] \\
&+ f\left(\left\{ \sum_{c\in\mathcal{C}} \sum_{r\in\mathcal{R}_c} \sum_{t=1}^{T} \sum_{l=1}^{N_i^F} -\gamma^i \lambda_{r,c}^{i,l} F_t^{i,l} \right\}_{i\in\{EA,C,R\}} \right) \\
&= \left(1 - g_{r,c,t}\gamma^{EA}\right)^2 \sum_{c\in\mathcal{C}} \frac{1}{N_c^R} \sum_{r\in\mathcal{R}_c} \sum_{l=1}^{N_{EA}^F} \frac{\left(\lambda_{r,c}^{EA,l}\right)^2}{1-\left(\theta_{EA,l}\right)^2} + \left(1 - g_{r,c,t}\gamma^{C}\right)^2 \sum_{c\in\mathcal{C}} \frac{1}{N_c^R} \sum_{r\in\mathcal{R}_c} \sum_{m=1}^{N_c^F} \frac{\left(\lambda_{r,c}^{c,m}\right)^2}{1-\left(\theta_{c,m}\right)^2} \\
&+ \sum_{c\in\mathcal{C}} \frac{1}{N_c^R} \sum_{r\in\mathcal{R}_c} \frac{\left(1 - g_{r,c,t}\gamma^{R}\right)^2 \sigma_{r,c}^2}{1-\phi_{r,c}^2} + f\left(\left\{ \sum_{c\in\mathcal{C}} \sum_{r\in\mathcal{R}_c} \sum_{t=1}^{T} \sum_{l=1}^{N_i^F} -\gamma^i \lambda_{r,c}^{i,l} F_t^{i,l} \right\}_{i\in\{EA,C,R\}} \right) \qquad (28)
\end{aligned}
$$

A.4 Stabilisation properties of the transfer scheme

Denote standardised series by $\tilde{y}_{r,c,t}$ and the transfers calibrated on the standardised data estimation results by $\tilde{T}_{r,c,t}$. Then we can rewrite the stabilisation statistic as:

$$
\begin{aligned}
s_{r,c}^i &= \frac{std\left(y_{r,c,t} + g_{r,c,t} T_{r,c,t}^i\right)}{std\left(y_{r,c,t}\right)} - 1 \\
&= \frac{std\left(\sigma_{r,c}\tilde{y}_{r,c,t} + \sigma_{r,c} g_{r,c} \tilde{T}_{r,c,t}^i\right)}{std\left(\sigma_{r,c}\tilde{y}_{r,c,t}\right)} - 1 \\
&= \frac{\sigma_{r,c} std\left(\tilde{y}_{r,c,t} + g_{r,c,t} \tilde{T}_{r,c,t}^i\right)}{\sigma_{r,c} \underbrace{std\left(\tilde{y}_{r,c,t}\right)}_{=1}} - 1 \\
&= std\left(\tilde{y}_{r,c,t} + g_{r,c,t} \tilde{T}_{r,c,t}^i\right) - 1
\end{aligned}
$$

For illustrative purposes we derive the stabilising effect of a CFC that cushions eurozone-wide shocks:

$$
\begin{aligned}
s^{EA}_{r,c} &= std\left(\tilde{y}_{r,c,t} + g_{r,c,t}\tilde{T}^{EA}_{r,c,t}\right) - 1 \\
&= \sqrt{\mathbb{V}\mathrm{ar}\left[(1 - g_{r,c,t}\gamma^{EA})\sum_{l=1}^{N^F_{EA}} \lambda^{EA,l}_{r,c} F^{EA,l}_t\right] + \mathbb{V}\mathrm{ar}\left[\sum_{l=1}^{N^F_c} \lambda^{c,l}_{r,c} F^{c,l}_t\right] + \mathbb{V}\mathrm{ar}\left[\varepsilon_{r,c,t}\right]} - 1 \\
&= \sqrt{1 + \left((g_{r,c,t}\gamma^{EA})^2 - 2g_{r,c,t}\gamma^{EA}\right)\mathbb{V}\mathrm{ar}\left[\sum_{l=1}^{N^F_{EA}} \lambda^{EA,l}_{r,c} F^{EA,l}_t\right]} - 1
\end{aligned}
$$

where in going from the second to the third line we have used the assumption that the three decomposition terms sum up to unity as the growth rate is standardised. Define ν^i as the explained variance by the i^{th} layer. For example, $\nu^{EA} = \mathbb{V}\mathrm{ar}\left[\sum_{l=1}^{N^F_{EA}} \lambda^{EA,l}_{r,c} F^{EA,l}_t\right]$ in the expression above. Then, we can write:

$$
s^i_{r,c} = \sqrt{1 + \left((g_{r,c}\gamma^i)^2 - 2g_{r,c}\gamma^i\right)\nu^i} - 1
$$

Notice that when all CFC levels are deployed simultaneously and feature the same γ^i, i.e. $\gamma^{EA} = \gamma^C = \gamma^R = \gamma^*$, the stabilisation can be simplified to:

$$
\begin{aligned}
s^*_{r,c} &= std\left(\tilde{y}_{r,c,t} + g_{r,c,t}\sum_{i\in\{EA,C,R\}} \tilde{T}^i_{r,c,t}\right) - 1 \\
&= \sqrt{\mathbb{V}\mathrm{ar}\left[(1 - g_{r,c}\gamma^*)\sum_{l=1}^{N^F_{EA}} \lambda^{EA,l}_{r,c} F^{EA,l}_t + (1 - g_{r,c}\gamma^*)\sum_{l=1}^{N^F_c} \lambda^{c,l}_{r,c} F^{c,l}_t + (1 - g_{r,c}\gamma^*)\varepsilon_{r,c,t}\right]} - 1 \\
&= \sqrt{(1 - g_{r,c}\gamma^*)^2 \underbrace{\mathbb{V}\mathrm{ar}\left[\sum_{l=1}^{N^F_{EA}} \lambda^{EA,l}_{r,c} F^{EA,l}_t + \sum_{l=1}^{N^F_c} \lambda^{c,l}_{r,c} F^{c,l}_t + \varepsilon_{r,c,t}\right]}_{=\mathbb{V}\mathrm{ar}[\tilde{y}_{r,c,t}]=1}} - 1 \\
&= -g_{r,c}\gamma^*
\end{aligned}
$$

Note that $s^*_{r,c}$ is equal to $s^i_{r,c}$ when level i explains 100% of the variation in the decomposition model, i.e. for $\nu_i = 1$. This is not surprising as $s^*_{r,c}$ can be perceived as a stabilisation scheme that dampens shocks arriving from a single process, which is a mixture of the underlying processes, hence explaining 100% of the variation. Figure 14 shows this conditional linear relation.

Define $C \equiv 1 + \left((g_{r,c}\gamma^i)^2 - 2g_{r,c}\gamma^i\right)\nu^i$. Assuming $\gamma^i, g_{r,c}, v^i > 0$, the first- and second-order derivatives w.r.t. γ^i are given by (derivatives w.r.t. $g_{r,c}$ are analogous):

1. $$\frac{\partial}{\partial\gamma^i}s^i_{r,c} = \frac{\partial}{\partial\gamma^i}C^{1/2} = (g_{r,c}\gamma^i - 1)g_{r,c}\nu^i C^{-1/2}\begin{cases} < 0 & \iff g_{r,c}\gamma^i < 1 \\ = 0 & \iff g_{r,c}\gamma^i = 1 \\ > 0 & \iff g_{r,c}\gamma^i > 1 \end{cases}$$

2. $$\frac{\partial^2}{(\partial\gamma^i)^2}s^i_{r,c} = \frac{\partial}{\partial\gamma^i}(g_{r,c}\gamma^i - 1)g_{r,c}\nu^i C^{-1/2} = g^2_{r,c}\nu^i C^{-1/2} - (g_{r,c}\gamma^i - 1)^2(g_{r,c}\nu^i)^2 C^{-3/2}$$
$$= g^2_{r,c}\nu^i C^{-1/2}\left[1 - (g_{r,c}\gamma^i - 1)^2\nu^i C^{-1}\right]\begin{cases} = 0 & \iff \nu^i = 1 \\ > 0 & \iff \nu^i < 1 \end{cases}$$

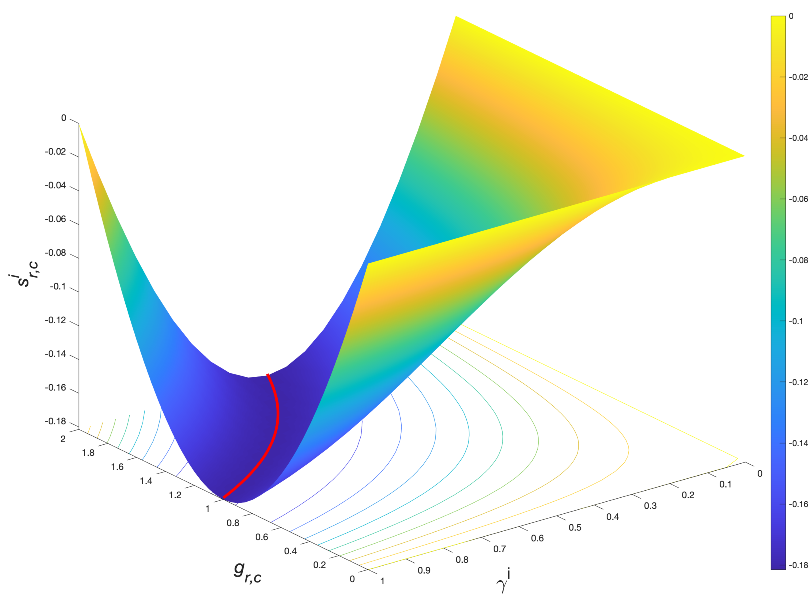

Figure 12: $v^i = .33$

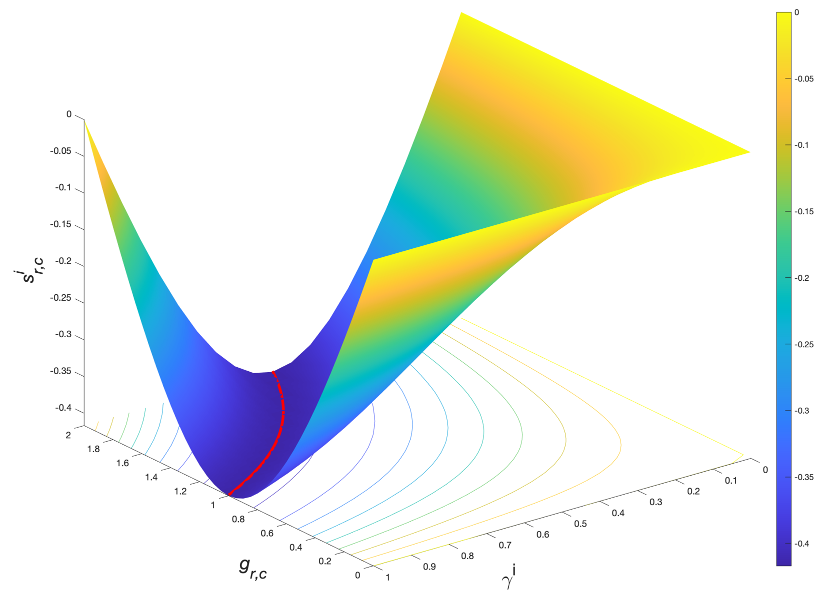

Figure 13: $v^i = .66$.

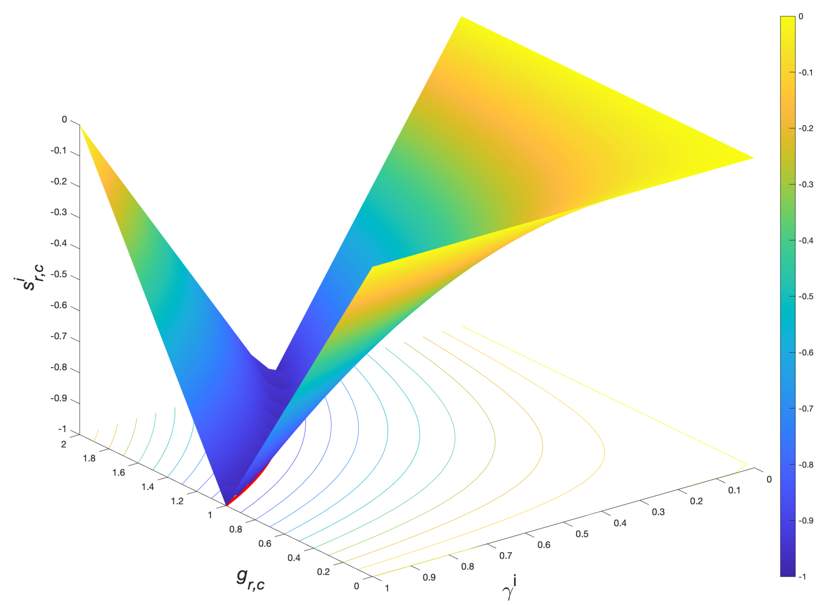

Figure 14: $v^i = 1$

B Robustness tests

B.1 DFM robustness tests

We investigate the robustness of our baseline results in a number of ways. All robustness results can be found below. These results are qualitatively identical to the baseline results. First, we assess whether the results are affected by the fact that some countries feature in proportion to their size a relatively large number NUTS3 regions. We do this by replacing the NUTS3 regions by the NUTS2 regions for Germany, Italy, France, Greece, and Spain. Second, the BIC scores suggest more than one country-specific factor for France, which may be explained by the fact that the degree of variation in growth is relatively large for this country. While the effect on the BIC scores is small, we explore a variant with two factors in the French country-specific level. Third, because the sizes of the regions in our sample vary, we also consider a variant in which we weigh the size of each region's per-capita real GDP growth rate $y_{r,c,t}$ by its share of the EU population, $POP_{r,c,t}/\sum_{r,c} POP_{r,c,t}$. We do not standardize the data in this case as this would largely undo the transformation. Finally, we also consider a variant based on real GDP weights.

B.1.1 Replacing NUTS3 by NUTS2 regions for large countries

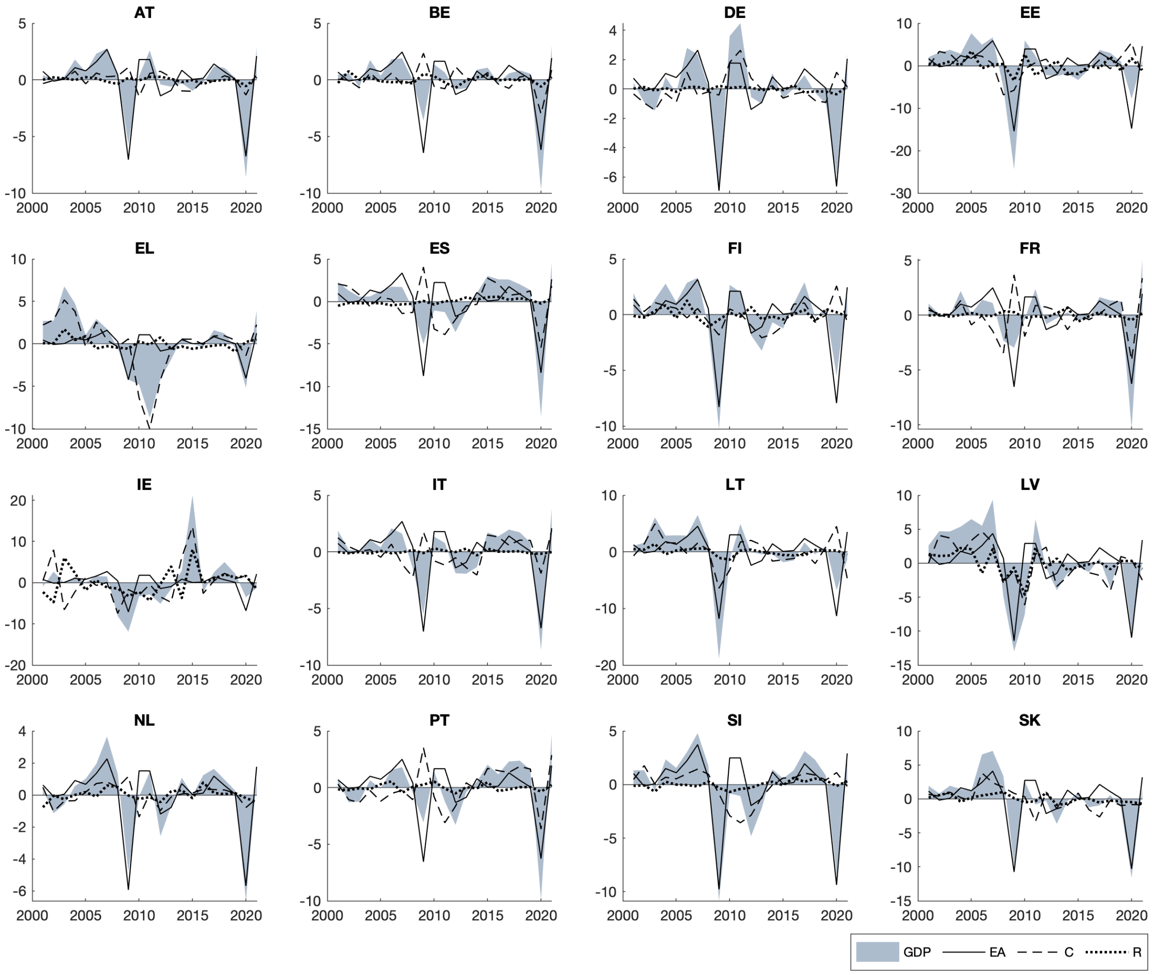

Figure 15: Regional growth decomposed into eurozone, country, and idiosyncratic components, averaged over regions per country.

B.1.2 Two country factors for France

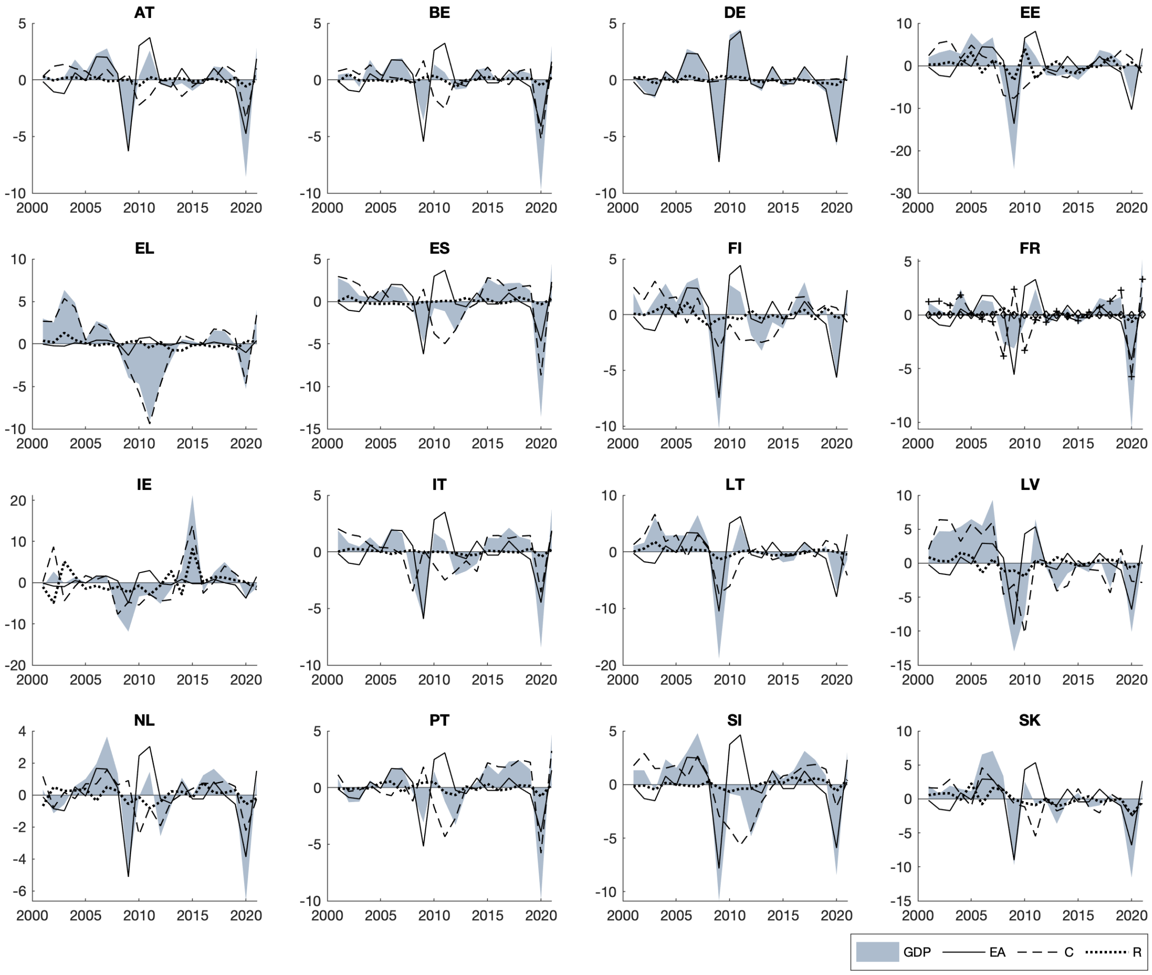

Figure 16: Regional growth decomposed into eurozone, country, and idiosyncratic components, averaged over regions per country.

B.1.3 Weighting by population contribution

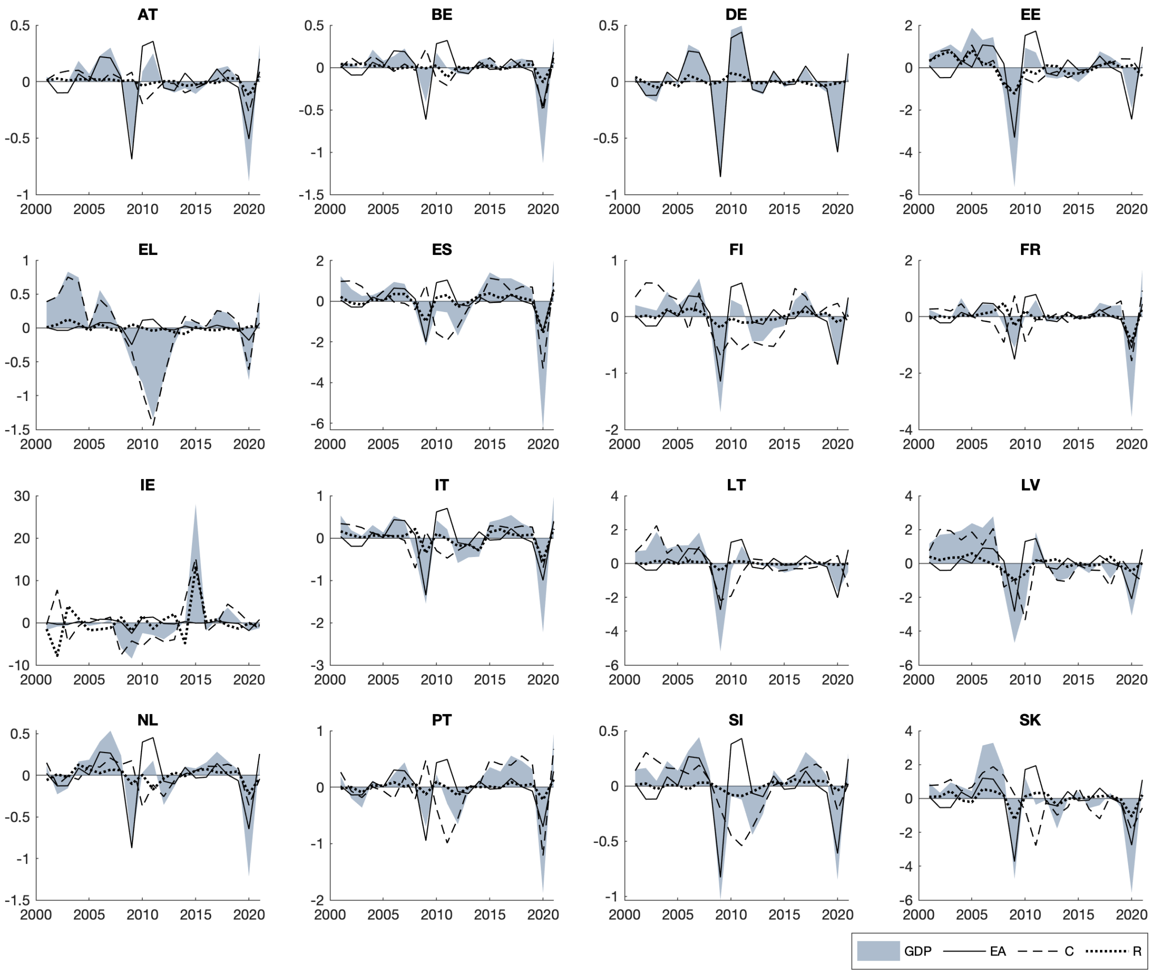

Figure 17: Regional growth decomposed into eurozone, country, and idiosyncratic components, averaged over regions per country.

B.1.4 Weighting by GDP contribution

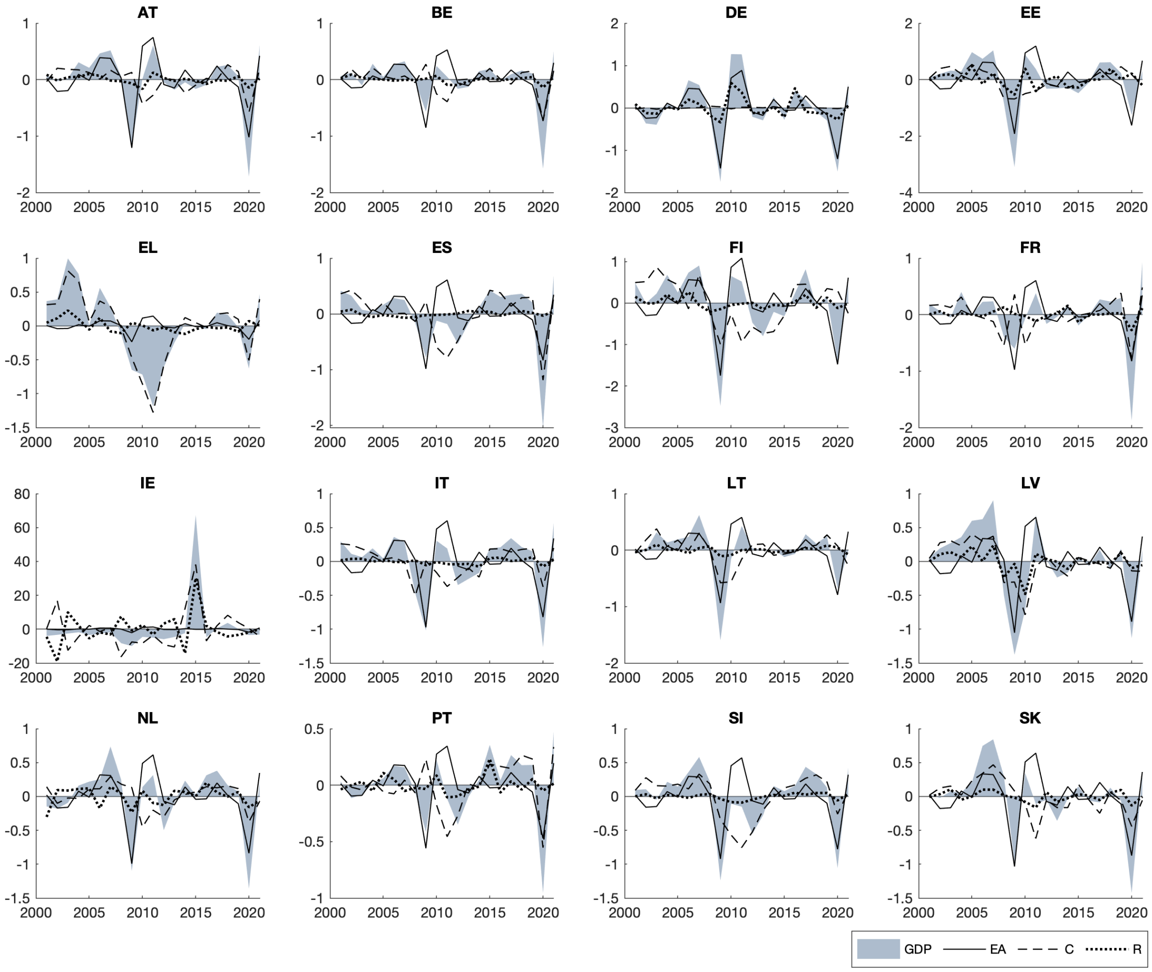

Figure 18: Regional growth decomposed into eurozone, country, and idiosyncratic components, averaged over regions per country.