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Dancing Alone or Together: The Dynamic Effects of Independent and Common Monetary Policies [*]

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ABSTRACT

What would have been the hypothetical effect of monetary policy shocks had a country never joined the euro area, in cases where we know that the country in question actually did join the euro area? It is one thing to investigate the impact of joining a monetary union, but quite another to examine two things at once: joining the union and experiencing actual monetary policy shocks. We propose a methodology that combines synthetic control ideas with the impulse response functions to uncover dynamic response paths for treated and untreated units, controlling for common unobserved factors. Focusing on the largest euro area countries, Germany, France, and Italy, we find that an unexpected rise in interest rates depresses inflation and significantly appreciates exchange rate, whereas GDP fluctuations are less successfully controlled when a country belongs to the monetary union than would have been the case under the independent monetary policy. Importantly, Italy turns out to be the overall beneficiary, since all three channels – price, GDP, and exchange rate – deliver the desired results. We also find that stabilizing an economy within a union requires somewhat smaller policy changes than attempting to stabilize it individually, and therefore provides more policy space.

Keywords: Dynamic causal effects, Monetary union, Price puzzle, Common factors.

JEL Classification: C14, C32, C33, E52.

1 Introduction

What would have been the macroeconomic effects of changes to the interest rate of a certain economy if monetary policy was exercised by a national authority, in cases where we know that the economy in question actually belongs to a monetary union? How would the trajectory of its macroeconomy have changed outside the union? More importantly, how would this different trajectory react to monetary policy interventions? These are important questions not only from a theoretical perspective, but also in terms of policy. For instance, in the aftermath of the global financial crisis and during the European sovereign debt crisis, they arose not only in the case of Greece but also Italy, the third largest euro area economy. Despite their relevance, the challenge in answering these questions lies in the fact that it is one thing, though already complicated, to investigate the effect of joining a monetary union on the macroeconomy, but quite another to examine two things at once: joining the union and experiencing actual monetary policy shocks. In other words, when dealing with a known structural change due to an "intervention" or "treatment," the dynamics of interest may not only reflect a one-time change, but also *reactions* to subsequent, possibly substantially smaller, shocks than the treatment (e.g. policy shocks under single and joint monetary policy).

The need to evaluate the effect of treatment just after it has been implemented – though still dominant in the policy evaluation literature – may be too narrow for any dynamic phenomenon where responses to the sequence of subsequent shocks after a treatment or a structural break, are of interest. We focus on membership in a monetary union, which may yield considerably different outcomes depending on whether one evaluates a country that joined the union and relinquished its independent monetary policy or an economy that exercises independent monetary policy. In the latter case, policymakers can better target individual policy, taking into account whether a national economy faces stable versus expansionary or recessionary periods, or periods when the zero lower bound is hit. However, this view is challenged by such arguments as business cycle synchronization (a vast literature initiated by Frankel and Rose, 1998) or global financial cycles, as put forward by Rey (2013) and recently elaborated in Miranda-Agrippino and Rey (2020). The latter idea posits that smaller economies have largely constrained monetary policies, independent of exchange rate regimes, whenever capital is freely mobile. This is because core countries' monetary policies affect global banks and credit growth in the regional or even global financial system. That is particularly true for US monetary policy, which affects the variation of risky asset prices around the world, the provision of domestic credit, international credit flows, and foreign financial conditions (see, among many others, Bräuning and Ivashina, 2020, Lastauskas and Nguyen, 2021, Obstfeld, 2020). Despite these academic and policy debates, the importance of global financial spillovers and the limits of national monetary policy lack quantitative evaluation for those economies currently operating within the monetary union.

Given that one of the core pillars of the European Union (applicable to all members, not only those in the euro area) is free capital mobility, this raises questions as to whether leaving the union would indeed make national monetary policy more effective. For instance, some policymakers, politicians, and economists have claimed that Southern European economies would have fared better exiting the euro area during the whirl of the European sovereign debt crisis than they did staying inside it, giving rise to such terms as Grexit and Graccident (referring to Greece leaving the monetary union intentionally or unintentionally). The idea largely rested on the possibility for a nation to depreciate its own currency and boost export and tourism. Interestingly, ordinary people's sentiment towards the EU has soured substantially, but support for the euro has strengthened (Clements et al., 2014). This raises a question as to whether national monetary policy could indeed deliver the intended results.

To answer how monetary policy would have affected the macroeconomy, we focus on the three largest euro area member-states, Germany, France, and Italy. We propose a methodology that combines synthetic control ideas with the standard structural VAR methodology to uncover dynamic response paths for treated and untreated units, allowing for common unobserved factors. We ask how an economy undergoing intervention (or one that has experienced a structural break at known time T_0) would have reacted to a shock of interest and how the reaction would have differed without intervention. We therefore construct both an impulse response function in a standard structural VAR and the counterfactual impulse response function. Similarly to the method of synthetic control proposed by Abadie and Gardeazabal (2003); Abadie et al. (2010, 2015), we construct the counterfactual data by weighting the donor set data with optimal weights found in the pre-treatment period. However, unlike the synthetic control literature, which aims to recover the counterfactual variable of interest, our focus is on the multivariate system's reactions to shocks in the "alternative reality", thus relying on the impulse response functions. We propose an ℓ^2-norm-based loss function which tries to mimic an entire economy's, not a single variable's, reaction to monetary policy shocks had the economy run an autonomous central bank, knowing that the economy in question was actually part of a monetary union.

We find that the so-called inflation (price) puzzle when prices increase after an unexpected tightening of monetary policy is documented before the monetary union but disappears afterwards. Though monetary policy is more effective at driving prices, it targets GDP more successfully before the monetary union. This could be because of ECB's narrow mandate and the main focus on price stability, thus demonstrating structural differences vis-à-vis national monetary policy. We document that France would have been more effective at managing GDP fluctuations, but its currency would not have appreciated as much as it did under joint monetary policy, leading to higher prices of imported varieties. Importantly, among the three largest euro area members, Italy turns out to be the overall beneficiary, since all three channels – price, GDP, and exchange rate – deliver the desired results under the union rather than under the individual monetary policy. Lastly, stabilizing an economy within a union requires somewhat smaller policy changes than attempting to stabilize it individually, and therefore provides more policy space.

The paper is organized as follows. Section 2 places our contribution in the context of the existing literature. In Section 3, we describe our main object of interest and lay down our methodology for its recovery. We cover synthetic control, impulse response functions, and the procedure by which we merge the two. We collect results, including matching weights and impulse response functions, in Section 4. To expand our findings, we cover generalized rather than identified shocks in Section 5. Finally, Section 6 concludes and specifies policy implications as well as directions for further research. The Appendices collect additional results and robustness checks.

2 Literature Review

In hindsight, and in contrast to the many proponents of exiting the monetary union in the whirl of the sovereign debt crisis, our counterfactual analysis provides a basis for the claim that leaving the union and conducting independent monetary policy may not have delivered the intended results. This is particularly true for the Italian economy. There is already a significant body of literature on the counterfactuals of monetary union; however, our approach differs in both the focus and the method. This literature tends to be interested in the effects of monetary policy on macroeconomic aggregates, such as income, inflation, and unemployment. For instance, Puzzello and Gomis-Porqueras (2018) analyze effects on the income per capita of six early adopters of the euro. Using the synthetic control method, they find that the income per capita of France, Germany, and Italy would have been higher without the euro. These findings are in contrast to those of Gasparotti and Kullas (2019), who claim that Germany has gained by far the most from the introduction of the euro, whereas France and Italy have experienced a drop in prosperity. Our take is different – we are interested in the efficacy of monetary policy under different regimes, that is, autonomous and joint monetary policy. From a policy perspective, the discussion on leaving the monetary union has revolved around exchange rate channels to boost exports and the transmission mechanism, rather than the long-term effects of monetary policy (which are also more obscure from a theoretical perspective, which posits the relationship between monetary policy and the business cycle).

Other applications similar to ours which have explored impulse responses include Pesaran et al. (2005, 2007), who take a fully specified model, conduct shocks on them, and compare conditional (with imposed restrictions, in the case of the euro) and unconditional forecasts. That approach is distinct from the impulse response analysis, the object of this paper, as it places restrictions on the observable variables. Our approach is to construct synthetic data rather than parameterize the model and explore different scenarios; like us, however, the quoted authors account for international interdependence via common factors. Our question is reversed, too – we ask not what would have happened if non-euro area members had adopted the euro, but rather if the member-states had conducted independent monetary policy. A similar question is raised by Dubois et al. (2007), who build on Pesaran et al. (2005, 2007), and modify the GVAR to test different scenarios describing a counterfactual of no euro by imposing restrictions on the interest and exchange rate equations. The authors find that prior to monetary union, France and Germany gain output under the euro in two scenarios, while Italy gains in three scenarios. After 1999, however, the evidence disperses, depending on the adopted scenarios. In fact, the authors find that Germany may have suffered from over-restrictive monetary policy in terms of output. Though interest rates are found to be smaller under the euro area Taylor-rule regime, exchange rate adjustment is substantially larger than what is predicted by the actual data. Even if our methodology and time frame differ from the conditional predictions (we cover an additional decade of quarterly data), based on the GVAR, results are comparable. We find that Germany (and France) may pay the price of a limited ability to stir GDP, but both enjoy more effective price channels. Moreover, interest rates may provide more space for policy action under the union than outside it.

Moving beyond our focus on the largest euro area economies, there is also a more structural literature which exploits a New Keynesian small open economy model to construct counterfactuals. For instance, Gomez-Gonzalez and Rees (2018) construct a counterfactual based on Spain's historical data (1998-2016) and responses to previous shocks, in which Spain retains monetary autonomy and introduces inflation targeting in the mid-1990s but does not adopt the euro. They find that membership in the union has negatively affected economic performance after the global financial crisis. A different conclusion than that of Gomez-Gonzalez and Rees (2018), though this time focusing on the UK, was reached by Mazumder and Pahl (2013), who studied counterfactual unemployment and output had the UK actually adopted the euro in 1999, using different variants of the Phillips curve. They found that the monetary union could have shielded the UK during the financial crisis but would have slowed down economic growth during non-crisis times.

On the methodology side, we combine the synthetic control idea with the impulse response analysis. One strand of the literature tries to parametrize interventions in terms of the policy equation.[1] The approach closer to ours uses synthetic weights and the factor error structure (Wan et al., 2018; Hsiao and Zhou, 2019). For instance, Hsiao et al. (2012) propose a two-step procedure that relies on first selecting an optimal number of peers (donors) to predict a counterfactual of a treated unit and then picking a low-dimensional set of observed covariates. The model is estimated on the basis of the pre-treatment data and then used to predict what would have happened to the treated unit had it not been subject to treatment. Hsiao and Zhou (2019) recover past periods of the self that resemble the treatment period(s), computed over all non-treated units. Our method combines non-parametric – to uncover matching weights – and semi-parametric methods (we use a vector autoregressive model with common factors to uncover impulse responses). We do not assume that factor dynamics and relationships remain the same before and after the monetary union formation, but rather assume that a donor set remains valid before and after the union formation. The construction of the synthetic data is guarded against parametric assumptions, which we only use to construct the impulse response functions. We thus also differ from a panel data method where, instead of trying to mimic untreated units, one focuses on the accuracy of predicting the outcomes of the treatment unit.[2]

3 Methodology

We turn to describing the proposed method. The standard approach of causal inference using observational data concerns itself with the short-term or one-time effect. The most obvious example in the latter case is the before-and-after estimator, which takes a simple average before and after a treatment (say, entry into the monetary union at time T_0), such that the effect is estimated by $\bar{\mathbf{x}}_N^{After} - \bar{\mathbf{x}}_N^{Before}$. Unfortunately, such an averaged vector cannot be used

[1] Pesaran and Smith (2016, 2018) propose using the policy response equation, which explains the target variable by means of its own lags and by current and lagged values of the policy variable and policy-invariant exogenous variables. The idea is to construct a model-based counterfactual for the outcome variable without the treatment (policy intervention) and compare it to the realized outcome. Both reduced-form versions (Pesaran and Smith, 2016) and complete systems of dynamic stochastic general equilibrium (DSGE) models (Pesaran and Smith, 2018) have been put forward.

[2] Though, as demonstrated by Wan et al. (2018), one can think of the synthetic approach as a constrained regression, whereas panel data approach is unconstrained. The former is more efficient than the latter but may be biased if constraints are not valid.

to identify the effect of a subsequent shock (say, tightening monetary policy). Moreover, it is subject to spurious dynamics resulting from common or global shocks that are independent of the N's entry into the monetary union, and also ignores potentially valuable information in the donor set. Even if dynamics were uncovered using the pre-treatment data $t < T$, and predictions conditional on the pre-euro area parameters and the euro average output per capita were made, as in, for instance, Giannone et al. (2010), the problems of structural stability, functional form, and potential feedback effects from the treated unit before treatment to the control group during the treatment periods would potentially remain (Hsiao et al., 2012). That is why, instead of modeling dynamic correlations directly, i.e. running a VAR on the pre-treatment data and using obtained parameters to make conditional predictions, we instead first uncover the synthetic data $\mathbf{x}^0_{Nt}$. We will make the parametric assumptions necessary to uncover impulse response functions, but instead of averaging them, we will find the vector of weighted variables that resembles the "counterfactual reality" for the treated economies.

3.1 Synthetic Control

To be more precise, in the usual parlance used by the policy evaluation literature, we can express the observed dynamics of $\mathbf{x}_{Nt}$ as a sum of counterfactual $\mathbf{x}^0_{Nt}$ and the effect of intervention, i.e.,

$$\mathbf{x}_{Nt} = \mathbf{x}^0_{Nt} + D_{it}\tau_{it},$$

where $\tau_{it} \equiv \mathbf{x}_{Nt} - \mathbf{x}^0_{Nt}$ captures time-varying causal effects for each variable in $\mathbf{x}_{it}$ whereas D_{it} is an indicator function, turning to 1 when a structural break or intervention occurs and 0 otherwise. In our example, the structural change in question is joining a monetary union, which makes the function $D_{it} = 1$ at $t = T_0$. The synthetic control idea is to replicate the treated variable according to what is going on in the donor set during the treatment period(s):

$$\mathbf{x}^0_{NT} = \sum_{j=1}^{N-1} w_j \mathbf{x}_{jT},$$

and the treatment effect is then given by $\mathbf{x}_{NT} - \mathbf{x}^0_{NT}$. The synthetic control method assumes that there exists a synthetic control such that the pre-intervention fit between the synthetic control and the treated unit is perfect. To explore the quality of the fit, we will apply two different sets of donors.[3]

3.2 Impulse Response Functions

Traditionally, applied macroeconomists and policymakers attempt to discover the path of a variable of interest (in the conditional expectation function sense) under a shock, and without

[3]Ferman and Pinto (2016) show that, when the number of control units is fixed, the estimated SC weights will generally not converge to the weights that reconstruct the factor loadings of the treated unit, even when the number of pre-intervention periods goes to infinity if treatment assignment is correlated with the unobserved heterogeneity. The relevance of such bias depends on the variance of the idiosyncratic error and only vanishes when this variance goes to zero. The authors recommend to demean the data using the pre-intervention period, controlling for selection into treatment driven by a time-invariant common factor.

it:

$$\mathcal{IRF}\left(h, \text{shock}_t, \mathcal{I}_{t-1}\right) = \mathbb{E}\left(\mathbf{x}_{N,t+h} \mid \text{shock}_t, \mathcal{I}_{t-1}\right) - \mathbb{E}\left(\mathbf{x}_{N,t+h} \mid \mathcal{I}_{t-1}\right),$$

where variable of interest $\mathbf{x}_N$ is predicted up to horizon h, making use of information set $\mathcal{I}_{t-1}$. Yet this calculation does not account for any structural breaks (or interventions) that may have occurred during T_0. For instance, it is of interest to learn the effect exerted by monetary policy shocks on macroeconomic variables. However, that ignores the fact that different economies may have experienced structural changes, such as joining the monetary union at different time periods. Our method is capable of employing different $T_{N,0}$ for different countries (although we will focus on the three largest euro area economies, all of whom joined the monetary union at the same time, and one treated country for the purposes of notation and brevity).

If we only consider periods before or after such intervention, then the counterfactual analysis of impulse responses is capable of shedding light on the macroeconomic developments both after a policy shock and without it. However, if our sample is richer and includes a pre-intervention period $1, \ldots, T_0$, such that $T > T_0 > 1$, then one may want to ask instead:

$$\begin{aligned}
&\mathbb{E}\left(\mathbf{x}_{N,t+h} - \mathbf{x}^0_{N,t+h} \mid \text{shock}_t, \mathcal{I}_{t-1}\right) - \mathbb{E}\left(\mathbf{x}_{N,t+h} - \mathbf{x}^0_{N,t+h} \mid \mathcal{I}_{t-1}\right) \\
&= \mathbb{E}\left(\mathbf{x}_{N,t+h} \mid \text{shock}_t, \mathcal{I}_{t-1}\right) - \mathbb{E}\left(\mathbf{x}_{N,t+h} \mid \mathcal{I}_{t-1}\right) - \left[\mathbb{E}\left(\mathbf{x}^0_{N,t+h} \mid \text{shock}, \mathcal{I}_{t-1}\right) - \mathbb{E}\left(\mathbf{x}^0_{N,t+h} \mid \mathcal{I}_{t-1}\right)\right] \\
&= \mathcal{IRF}\left(h, \text{shock}_t, \mathcal{I}_{t-1}\right) - \mathcal{IRF}^0\left(h, \text{shock}_t, \mathcal{I}_{t-1}\right).
\end{aligned} \tag{1}$$

This expression investigates potential reactions to a shock of interest in an economy undergoing intervention (or one that has experienced a structural break at known time T_0), and without it, knowing that in reality, the intervention has actually occurred. In other words, we uncover the difference between impulse response functions with regard to factual ($\mathcal{IRF}\left(h, \text{shock}_t, \mathcal{I}_{t-1}\right)$) and counterfactual ($\mathcal{IRF}^0\left(h, \text{shock}_t, \mathcal{I}_{t-1}\right)$) data.

Suppose we observe a number of countries, including some countries that have joined the monetary union and others that have not, as well as some that have been subject to tightening monetary policy and some that have not. This creates four counterfactuals: the predicted reality under the treatment and the shock ($\mathbb{E}\left(\mathbf{x}_{N,t+h} \mid \text{shock}_t, \mathcal{I}_{t-1}\right)$), the counterfactual of no intervention under the shock ($\mathbb{E}\left(\mathbf{x}^0_{N,t+h} \mid \text{shock}, \mathcal{I}_{t-1}\right)$), the counterfactual of the observed reality with no shock ($\mathbb{E}\left(\mathbf{x}_{N,t+h} \mid \mathcal{I}_{t-1}\right)$), and the counterfactual of no intervention under a counterfactual of no shock ($\mathbb{E}\left(\mathbf{x}^0_{N,t+h} \mid \mathcal{I}_{t-1}\right)$). Then the main question revolves around the evaluation of $\mathbf{x}_{Nt} - \mathbf{x}^0_{Nt}$, which is interpreted as a (potentially casual) dynamic path of variables $\mathbf{x}$ after intervention in country N at time T_0, and its expected reaction to the monetary policy shock. The "alternative reality" of no intervention $\mathbf{x}^0_{Nt}$ is, of course, not observed, and needs to be proxied or approximated by observables. Though the literature has explored parametric, semi-parametric, and non-parametric methodologies, all of which come with particular data requirements and assumptions, we suggest combining the idea of the synthetic control matching with the factor-augmented identified VAR methodology to deliver a rich, yet simple and parsimonious, framework that reveals the dynamic paths of policy-relevant interventions in two states of the world, in our case, monetary union and independent monetary policy.

3.3 Procedure

Our procedure involves the following steps. First, we need to uncover impulse responses for the real data. Second, we have to construct synthetic data and then conduct impulse response analysis on that data. In order to limit our attention to the main contribution of counterfactual impulse responses, we do not innovate on the identification schemes.[4] We follow the structural VAR (SVAR) literature (Sims, 1980) to identify monetary policy shocks. We employ the Cholesky decomposition with the following variable ordering: GDP, inflation, short interest rate, and real exchange rate. The latter variable is used to accommodate a number of trading economies within a monetary union (see Gali and Monacelli (2005) and Dees et al. (2014) for the modeling choices when it comes to open economies within the New Keynesian framework).

Unlike emphasis on the macroeconomic dynamics itself, we are after responses to monetary policy shocks. We suggest the following objective function,[5] which is to be minimized, $\min_{\{w_j\}_{j=1}^{N-1}} \mathcal{F}$:

$$\mathcal{F} = \sum_{i,h} \left[\left(\mathcal{IRF}_i \left(h, \text{shock}_t, \mathcal{I}_{T_0-1} \right) - \mathcal{IRF}_i^0 \left(h, \text{shock}_t, \mathcal{I}_{T_0-1} \right) \right) / \left| \mathcal{CI} \left(\mathcal{IRF}_i \left(h, \text{shock}_t, \mathcal{I}_{T_0-1} \right) \right) \right| \right]^2, \tag{2}$$

where $\left| \mathcal{CI} \left(\mathcal{IRF}_i \left(h, \text{shock}_t, \mathcal{I}_{T_0-1} \right) \right) \right|$ refers to the 68% confidence interval (CI) length,[6] i refers to one of the variables (inflation, real GDP, real exchange rate, and interest rate), $h = 0, 1, \ldots, 12$, as before, stands for the horizon, and $\mathcal{IRF}_i, \mathcal{IRF}_i^0$ depict i variable response to the monetary policy (interest rate) shock. The $\mathcal{IRF}_i^0$ is computed as a response to the monetary policy shock in synthetic variables, constructed as weighted averages from the donor series.

The algorithm can be described as follows: 1) We construct VAR models for the "treated" economies; 2) Using a standard Choleski-decomposition with the variables ordered as follows,

$$\mathbf{x}_t = \left[\text{ Real GDP}_t, \quad \text{Inflation}_t, \quad \text{Interest rate}_t, \quad \text{Real exchange rate}_t \right]',$$

[4]There are alternatives to uncover impulse responses, such as local projections, as pioneered by Jordà (2005), rather than fully-fledged VARMA processes. Plagborg-Moeller and Wolf (2020) show that Jordà (2005) local projections estimate the same impulse responses in population as vector autoregressions, provided that the lag structures are left unrestricted. Kilian and Kim (2011) provide a more critical approach. Instead of structural shocks, one can employ generalized impulse responses, as advanced by Koop et al. (1996); Pesaran and Shin (1998).

[5]Though it seems similar, our approach is distinct from the impulse response matching estimators (see Rotemberg and Woodford (1997) for the early contribution) used in the DSGE literature. In fact, monetary policy shock has been employed to estimate DSGE model parameters using empirical and theoretical responses (e.g. Christiano et al., 2005). These limited-information estimators find parameter values that match two sets of IRFs. In our case, we do not observe counterfactual variables, and we optimize over synthetic data weights so that ultimate IRFs are as close as possible (rather than first imposing structure on the data, obtaining IRFs, and then weighting them). For econometric issues on the use of weighting matrix in the objective function, see Guerron-Quintana et al. (2017).

[6]An alternative interpretation of the CI length being used to scale the difference between impulse response functions is adjustment by the standard deviation $\text{s.d.} \left(\mathcal{IRF}_i \left(h, \text{shock}_t, \mathcal{I}_{T_0-1} \right) \right)$ of the impulse response function on factual data. For the Normally distributed random variables, 68% of data lie in the interval of one standard deviation, i.e. $\pm \text{s.d.} \left(\mathcal{IRF}_i \left(h, \text{shock}_t, \mathcal{I}_{T_0-1} \right) \right)$.

we identify monetary policy shocks in accordance with Sims (1980), Christiano et al. (1999), and Peersman and Smets (2001), among many others; 3) We find impulse response functions (call them "factual"); 4) We construct $\mathbf{x}^0_{NT}$ as $\sum_{j=1}^{N-1} w_j \mathbf{x}_{jT}$, where the set of weights (such that $\|w\| = 1$ and $w_j \geq 0$ for all j) are uncovered as the solution to minimand (2), which is optimized using pre-treatment data. In other words, 1)-3) are conducted on the pre-treatment data for the treated units, then VAR is run on the synthetic data, $\sum_{j=1}^{N-1} w_j \mathbf{x}_{jt}$, $t < T_0$, picking such $\{w_j\}_{j=1}^{N-1}$ that minimize the deviation between two impulse response functions, on actual and synthetic data. We initialize the process using weights from the matching on variables.[7] Importantly, however, we do not match impulse response functions directly, but rather find the weights for vectors of macroeconomic variables from the donor set, so that the synthetic data are constructed on the basis of as few assumptions as possible. Our method relies on the assumption that matching under equation (2) remains valid over time when intervention is not yet observed.[8]

In the pre-intervention period, we identified the treated country's factual monetary policy shocks using a SVAR model augmented with exogenous factors. In the post-intervention period, however, we can no longer identify the factual monetary policy shock using only the data from the treated country itself, as the interest rate reaction rule has changed and now involves euro-area wide variables. To accommodate this change for the monetary policy shock identification within the monetary union, we applied the following two-block VAR model:

$$\begin{pmatrix} \mathbf{x}_t^{EA} \\ \tilde{\mathbf{x}}_t \end{pmatrix} = \begin{bmatrix} \boldsymbol{A}_1 & \mathbf{0} \\ \boldsymbol{A}_2 & \boldsymbol{A}_3 \end{bmatrix} \begin{pmatrix} \mathbf{x}_{t-1}^{EA} \\ \tilde{\mathbf{x}}_{t-1} \end{pmatrix} + \mathbf{\Gamma}'_{Nf}\mathbf{f}_t + \begin{pmatrix} \xi_t^{EA} \\ \tilde{\boldsymbol{\xi}}_{Nt} \end{pmatrix}, \tag{3}$$

where variables with tilde exclude interest rates but remain the same as defined earlier, and matrix $\boldsymbol{A}_2$ has non-zero elements only corresponding to the interest rate variable.

Such structure in (3) means that the monetary policy shock is identified in the euro-area-wide variables, and is featured in the country-specific variables, but the latter are excluded from the ECB interest rate rule (among similar modeling choices, see Peersman and Smets, 2001, and Stakėnas and Stasiukynaitė, 2017). To make the counterfactual (which is based on the one-block VAR model) and factual impulse responses comparable, we put overidentifying restrictions on the covariance matrix, not allowing contemporaneous reactions of country-specific GDP and inflation variables to the euro-area interest rate shock.

In the pre-intervention period, when constructing impulse responses, we assume the following structure:

$$\begin{aligned} \mathbf{x}_{Nt} &= \mathbf{\Gamma}'_{Nz}\mathbf{z}_{Nt} + \mathbf{u}_{Nt} \\ &= \mathbf{\Gamma}'_{Nz}\mathbf{z}_{Nt} + \mathbf{\Gamma}'_{Nf}\mathbf{f}_t + \xi_{Nt},\ t < T_0. \end{aligned} \tag{4}$$

To ease notation, we omit the usual notation of the treated unit, $\mathbf{x}^0_{Nt}$, since here we consider non-treatment periods (thus there is no counterfactual for $t < T_0$). Covariates $\mathbf{z}_{Nt}$ could include exogenous and pre-determined variables, whereas $\mathbf{\Gamma}'_{Nf}\mathbf{f}_t$, factor loadings and factors themselves will be treated as fixed constants (though an extension to a random setting would not change much except for a need to specify stochastic properties and the conditions to be

[7]We explore robustness by randomly generating initial values and reporting results for the three lowest loss values in the Online Appendix, Section C.

[8]In the most straightforward cases, the method works when the country-specific IRFs do not change, or when they change by a constant only.

met). The data generating process in (4) assumes away dominant units; panel extensions with richer interactions among cross-sectional units, though feasible, are nevertheless outside the scope of this paper.[9] It is important to note that the factor structure helps controlling for common forces and spillovers that may be shared with other economies, outside the treated group.

We first obtain $\mathbf{\Gamma}_f^{\star\prime}\mathbf{f}_T$ using cross-sectional averages of a donor group (dependent and independent variables and their lags). This strategy is built on Pesaran (2006) and its many extensions (Chudik et al. 2011; Chudik and Pesaran 2015; Harding et al. 2020). Notice that the structure is well-suited for our empirical application, as workhorse dynamic stochastic general equilibrium models end up being expressed as vector autoregressive moving average processes, which, allowing for the distributed lag structure, are nested in the multi-factor structure (Fernandez-Villaverde et al., 2007). Since there is more than one period of treatment (being of the monetary union), for $t \geq T_0$,

$$\mathbf{y}_{jt} = \begin{pmatrix} \mathbf{x}_{jt} \\ \mathbf{z}_{jt} \end{pmatrix} = \mathbf{C}_j'\mathbf{f}_t + \mathbf{u}_{jt}, \tag{5}$$

where we assumed that $\mathbf{z}_{jt} = \boldsymbol{\gamma}_j'\mathbf{f}_t + \varepsilon_{jt}$ (let there be k variables in $\mathbf{z}_{jt}$), it follows that $\mathbf{C}_j = \begin{pmatrix} \mathbf{\Gamma}_{jf} & \boldsymbol{\gamma}_j \end{pmatrix} \begin{pmatrix} 1 & \mathbf{0} \\ \mathbf{\Gamma}_{jz} & \mathbf{I}_k \end{pmatrix}$, $\mathbf{u}_{jt} = \begin{pmatrix} \xi_{jt} + \mathbf{\Gamma}_{jz}'\varepsilon_{jt} & \varepsilon_{jt} \end{pmatrix}'$. Weighting on both sides leads to

$$\begin{aligned} \textstyle\sum_{j=1}^{N-1} w_j^f \mathbf{y}_{jt} = \bar{\mathbf{y}}_{wt} = \textstyle\sum_{j=1}^{N-1} w_j^f \mathbf{C}_j'\mathbf{f}_t \\ + \textstyle\sum_{j=1}^{N-1} w_j^f \mathbf{u}_{jt} = \bar{\mathbf{C}}_w'\mathbf{f}_t + \bar{\mathbf{u}}_{wt} \end{aligned}$$

or

$$\bar{\mathbf{C}}_w'\mathbf{f}_t = \bar{\mathbf{y}}_{wt} + O_p\left(N^{-1/2}\right).$$

This result is given in Pesaran (2006), but further extensions with the lag structure, as derived in Chudik and Pesaran (2015), follow the same reasoning. As demonstrated in Pesaran (2006), even though the weights can be individual-specific, consistent estimation requires granularity conditions ($w_j^f = O_p\left(1/N\right)$, $\sum_j \left(w_j^f\right)^2 = O\left(1/N\right)$, and $w_j / \left(\sum_j \left(w_j^f\right)^2\right)^{\frac{1}{2}} = O_p\left(1/\sqrt{N}\right)$); see also Chudik and Pesaran (2011)). It follows that $\bar{\mathbf{u}}_{wt}$ is ignorable (in the quadratic mean sense) for large N. We make simple averages to construct $\bar{\mathbf{y}}_{wt}$, and arrive at

$$\mathbf{x}_{NT}^0 = \mu_N^0 + \sum_{j=1}^{N-1} w_j \mathbf{\Gamma}_{jz}'\mathbf{z}_{jT} + \tilde{\mathbf{\Gamma}}_f^{\star\prime}\bar{\mathbf{y}}_{wT} + \xi_{NT}^\star. \tag{6}$$

The effect of interest is then given differences in impulse response functions, obtained by subjecting $\mathbf{x}_{Nt}$ and its counterfactual value $\mathbf{x}_{Nt}^0$ to the monetary policy shock (1 percentage point increase in the interest rate).

[9] A natural extension is to consider a set of treated units jointly, provided there are many of them, and develop a global VAR (Pesaran et al., 2004; Garratt et al., 2006; Dees et al., 2007) or, if interlinkages are of less interest, infinite-dimensional VARs, which can be consistently estimated separately, as in our case, provided that observed and unobserved common factors are accounted for (Chudik and Pesaran, 2011, 2013). The latter can be uncovered using the cross-sectional averages as proposed in the seminal work of Pesaran (2006).

Having laid down the empirical strategy, it is worthwhile to compare it to the literature. Hsiao and Zhou (2019) cover parametric, semi-parametric, and non-parametric versions. The parametric method requires us to assume that parameters of explanatory variables and factor loadings extend to the treatment group from the donor groups and the pre-treatment time. The semi-parametric approach requires us to assume that parameters of explanatory variables extend to the treatment group from the donor groups and the pre-treatment time, whereas the factor loadings are not as restrictive. Using cross-sectional averages constructed from the donor group, one can derive an intercept and weights on those averages merely conditional on the parameters of explanatory variables. Finally, non-parametric approaches include the synthetic control method (Abadie et al., 2010), which minimizes the distance between treated and weighted donor group variables, and panel data approach (Hsiao et al., 2012), which uses donor units to predict the treated unit (similarity between treated and control units matters inasmuch it helps in prediction). Our approach is a combination of non-parametric methods – used to discover matching weights – and semi-parametric methods (we use VAR with unobserved factors to compute impulse responses). Importantly, the factors are constructed as in Hsiao and Zhou (2019), employing averages, composed of donor group countries only. We do not assume that factor dynamics and the relationships remain the same before and after the monetary union formation, but rather assume that a donor set remains valid before and after the union formation.[10]

4 Empirical Results

As our interest lies in the post-monetary union period, we identify VAR over the period Q1 1999 to Q4 2016, using a quarterly change in short-term interest rates. We combine datasets from Mohaddes and Raissi (2018) and Krippner (2015), along with IMF (IFS) and OECD datasets, to include Danish data into the set of donor countries. Table 1 collects summary statistics. We cover 3 euro area countries, 26 donor countries, and four variables: GDP growth, inflation, real exchange rate (versus US dollar, divided by CPI), and a short interest rate.

Though our multivariate framework can be extended to the non-stationary case, provided cointegration relationships exist, we restrict our attention the stationary environment (we deal with the first differences, which are approximately growth rates on the log scale). Table 2 reports p values for two unit root tests. We find several cases of potential non-stationarity for the inflation[11] variable under the augmented Dickey-Fuller test, but no such evidence under the Phillips-Perron test. Other variables, under reasonable significance levels, are found to be stationary across countries and both tests. As demonstrated in Masini and Medeiros (2020), processes, integrated of order one, yield standard spurious results and inconsistency, whereas cointegration delivers consistency in the intervention estimates, albeit with a nonstandard distribution.[12] We leave these more complicated setups for future extensions of our research.

[10] In other words, we do not rely on prediction using inferred relationships from the pre-treatment period, but rather estimate new parameters on cross-sectional averages, composed of the donor group, over the post-treatment period.

[11] As documented in Juselius (2004), periods of high and particularly persistent inflation may render prices

Table 1: Summary statistics

	GDP growth		**Inflation**		**Interest rate**		**RER**	
	mean	sd	mean	sd	mean	sd	mean	sd
France	0.40	0.49	0.77	0.87	-0.05	0.78	-0.48	4.77
Germany	0.40	0.88	0.53	0.47	-0.04	0.50	-0.49	4.87
Italy	0.30	0.71	1.20	1.25	-0.08	0.84	-0.63	4.87
Argentina	0.58	2.10	14.21	25.88	-0.63	7813.36	-0.23	13.57
Australia	0.78	0.74	1.02	0.88	-0.04	0.97	-0.75	5.09
Brazil	0.57	1.80	18.39	27.45	-0.13	6338.23	-0.64	8.01
Canada	0.60	0.74	0.79	0.75	-0.07	0.95	-0.69	3.14
China	2.37	1.18	1.16	1.59	-0.03	0.52	-0.19	4.26
Chile	1.09	1.94	2.42	2.34	-0.27	8.09	-0.48	4.99
Denmark	0.42	1.08	0.80	0.79	-0.06	1.40	-0.64	4.67
India	1.61	1.80	1.91	1.13	-0.01	0.87	-0.51	3.38
Indonesia	1.25	2.02	2.28	2.64	-0.06	4.69	-0.24	9.40
Japan	0.44	0.99	0.25	0.56	-0.03	0.52	-0.70	5.16
Korea	1.33	1.70	1.19	1.36	-0.12	1.52	-0.61	4.82
Malaysia	1.39	1.50	0.74	0.70	-0.001	0.52	-0.30	3.37
Mexico	0.65	1.47	5.09	6.16	-0.06	8.83	-0.59	6.59
Norway	0.66	1.28	0.94	0.91	-0.05	1.26	-0.60	4.80
New Zealand	0.54	0.90	1.15	1.37	-0.07	1.84	-0.89	5.37
Peru	0.81	2.88	12.56	26.70	-0.16	613.17	-1.59	8.78
Philippines	0.90	1.47	1.94	2.28	-0.07	2.47	-0.70	4.00
South Africa	0.58	0.82	2.20	1.25	0.01	1.16	-0.32	6.64
Saudi Arabia	0.73	2.06	0.39	0.96	-0.05	1.19	-0.32	1.07
Singapore	1.50	1.83	0.52	0.78	-0.04	0.80	-0.82	2.48
Sweden	0.54	1.25	0.87	1.00	-0.04	1.10	-0.37	5.24
Switzerland	0.41	0.79	0.42	0.56	-0.01	0.66	-0.77	4.95
Thailand	1.21	2.07	0.96	1.15	-0.08	1.81	-0.60	4.00
Turkey	1.00	2.63	8.27	6.10	0.04	8.78	-0.51	6.80
UK	0.47	0.71	1.00	0.97	-0.08	0.77	-0.64	4.94
USA	0.62	0.71	0.81	0.72	-0.06	0.76	-0.81	0.72

Table 2: Unit root tests (p values)

	GDP growth		**Inflation**		**Interest rate**		**RER**	
	ADF	PP	ADF	PP	ADF	PP	ADF	PP
France	0.01	0.01	0.31	0.02	0.01	0.01	0.01	0.01
Germany	0.01	0.01	0.30	0.01	0.01	0.01	0.01	0.01
Italy	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01
Argentina	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.01
Australia	0.01	0.01	0.09	0.01	0.01	0.01	0.01	0.01
Brazil	0.01	0.01	0.33	0.06	0.01	0.01	0.01	0.01
Canada	0.01	0.01	0.15	0.01	0.01	0.01	0.01	0.01
China	0.09	0.01	0.10	0.01	0.01	0.01	0.01	0.01
Chile	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Denmark	0.01	0.01	0.20	0.01	0.01	0.01	0.01	0.01
India	0.01	0.01	0.07	0.01	0.01	0.01	0.01	0.01
Indonesia	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Japan	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Korea	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Malaysia	0.01	0.01	0.04	0.01	0.01	0.01	0.01	0.01
Mexico	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
Norway	0.01	0.01	0.27	0.01	0.01	0.01	0.01	0.01
New Zealand	0.01	0.01	0.12	0.01	0.01	0.01	0.01	0.01
Peru	0.01	0.01	0.36	0.01	0.01	0.01	0.01	0.01
Philippines	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
South Africa	0.02	0.01	0.06	0.01	0.01	0.01	0.01	0.01
Saudi Arabia	0.01	0.01	0.04	0.01	0.01	0.01	0.02	0.01
Singapore	0.01	0.01	0.06	0.01	0.01	0.01	0.04	0.01
Sweden	0.01	0.01	0.05	0.01	0.01	0.01	0.01	0.01
Switzerland	0.01	0.01	0.10	0.01	0.01	0.01	0.01	0.01
Thailand	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Turkey	0.01	0.01	0.65	0.01	0.01	0.01	0.01	0.01
UK	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
USA	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Note: ADF and PP stand for Augmented Dickey Fuller and Phillips-Perron tests, respectively. Both tests assume unit root under the null.

4.1 Matching Weights

Using the procedure described in Section 3.3 and minimizing function (2), we obtain a set of weights for France, Germany, and Italy, as depicted in Figure 1. There is no dominant economy from the donor group that consistently appears as the primary donor economy in uncovering counterfactual realities across the largest euro area members. Sweden, Switzerland, and Denmark are the three top donors for France; Malaysia, UK, and South Africa for Germany; and Canada, Norway, and Sweden for Italy. Non-European countries receive less data-driven weight, which is intuitive, given deep economic integration within the old continent.

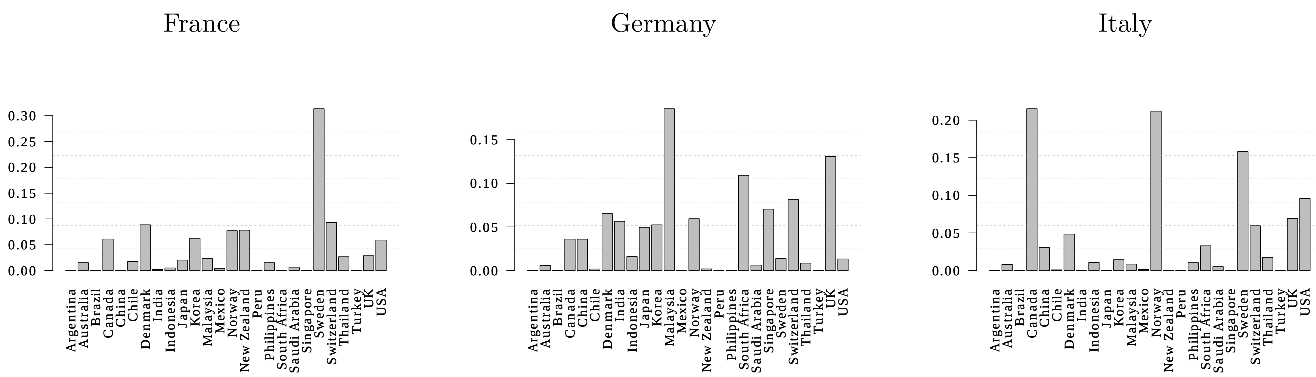

Figure 1: Matching Weights

However, one may worry that the inclusion of EU members that are not part of the euro area could violate the assumption of random assignment if euro opt-out decisions were driven by economic considerations (see Puzzello and Gomis-Porqueras, 2018, for the arguments), which is one of the key identifying assumptions of the synthetic methodology. Similarly, turbulent financial markets and sovereign defaults in Latin America introduce copious noise, high volatility, and extreme values in interest rates and inflation. Though our method has not placed much weight on Latin America, we nevertheless exclude Peru, Argentina, and Brazil.[13] Lastly, one could argue that Australia's exchange rate is driven by terms of trade, and barely follows relative consumer prices, and as such is a poor guide for the European economies. After excluding all of them, we draw updated weights in Figure 2. Switzerland, Norway, and Japan emerge as the key countries in the case of France; South Africa, Switzerland, and Saudi Arabia for Germany; and Norway, Japan, and Philippines for Italy.

as integrated of order two processes.

[12]A recent method on testing the validity of the treatment effect estimated by the synthetic control estimator, valid under non-stationarity, is discussed in Chernozhukov et al. (2020).

[13]We thank anonymous referees for this helpful suggestion for modeling common factors, which may be vastly different for each of these economies.

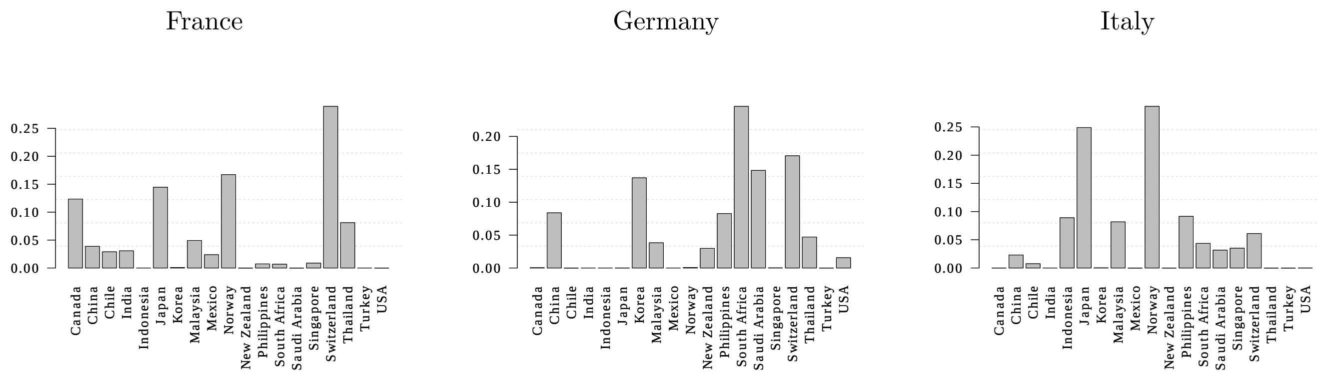

Figure 2: Matching Weights (EU and AUS, PERU, ARG, BRA Excluded)

We will stick to the smaller donor set as our baseline. Though the literature has not converged on the relative importance of the trade-off between the convex hull assumption and the quality of donors, our simulations hint that a smaller set is more robust. On the one hand, the larger set of economies makes it easier for the treated unit to belong to the convex hull of the control units. As demonstrated by Gobillon and Magnac (2016), the synthetic control method performs poorly in the simulation study compared to other estimators when the convex hull assumption is violated.[14] On the other hand, donor similarity and independence of treatment are also important considerations for the estimator's reliability.[15] Though, unlike standard applications, we seek similarity in terms of economies' reactions, rather than variables, there remains a fair amount of discretion over the appropriate donor set. We leave it for future research to fully explore the trade-off between the convex hull assumption and the quality of donors. To ensure that our results are robust, we generate random initial values of weights, and collect evidence of their stability, the similarity of impulse response functions, and the robustness of the findings. A smaller set turns out to be robust, whereas a larger set may sometimes get stuck in local minima (refer to Online Appendix).

4.2 Discussion

According to New Keynesian theory, as summarized for open economies, among others, in Gali 2015, Gali and Monacelli (2005), and Dees et al. (2014), traditional macroeconomic variables are complemented by international prices (terms of trade or real exchange rate). An unexpected increase in the interest result (an exogenous tightening of monetary policy) results in persistent decline in output and inflation, though the impact differs from the closed-economy setup. Notice that both nominal and real interest rates rise. A new terms of trade effect arises, since consumer prices depend not only on domestic but also on imported varieties. According to the theory, terms of trade appreciate in the short run due to an unexpected rise in home interest rates, i.e. the relative price of foreign goods goes down. Under a simplified setting, where the law of one price holds and the openness share is fixed,

[14]The assumption may not hold, not only because the donor set is too limited, but simply because of level differences across units. The latter can be rectified by adding additive fixed effects or interactive effects, thereby nesting additive time and fixed effects.

[15]A smaller group may also help to avoid overfitting (Abadie et al., 2015).

the real exchange rate can be expressed as the scaled terms of trade. It is then predicted that the real exchange rate appreciates; while it subsequently depreciates, it stays at a different value than before the shock. In addition to changes in the price level, there are impacts on aggregate demand through substitution effects between traded and non-traded home goods, and traded home and foreign goods, on aggregate supply due to the prices of imported varieties, and on asset prices, provided that there are no capital controls.

We start out by analyzing impulse responses computed using the pre-treatment data, where the counterfactual refers to the impulse response of the monetary policy shock on synthetic data. In all cases, we cover a 68% confidence interval. Impulse responses before the monetary union fail to predict the effectiveness of the monetary policy to curb inflation (Figure 3).[16] The pre-intervention period has been heavily analyzed in the literature, which has documented the so-called price and exchange rate puzzles. The puzzle is covered in Sims (1992), and further elaborated for European economies in Mojon and Peersman (2003). In essence, the puzzle is an empirical finding that an unexpected tightening of monetary policy leads to an increase in prices. Demiralp et al. (2014) has concluded that the puzzle has not been decisively resolved, despite the significant body of literature on the topic. The authors look at the US experience and document significant changes in the structure of monetary policy over time, emphasizing varying dynamics of the puzzle. Rather than focusing on the US, we shed a new light on the European experience.

As demonstrated in Figure 4, among all three major euro area economies, the inflation puzzle has been alleviated for contemporaneous and short-run effects, even if statistical precision is limited. Inflation slightly declines for all economies upon impact and, except for Germany, in the longer run. Within the monetary union, inflation is depressed, but the counterfactual predicts the return of the price puzzle over the medium to the long run. The counterfactual of independent monetary policy predicts that we are back to growing inflation in the medium and the longer run across the board (this effect is also significantly different from the reaction inside the monetary union for the three largest euro area economies).[17]

With regards to GDP, it declines on impact for Germany and Italy on actual data, but shows persistently negative impact on the synthetic data for France and Germany. In effect, French and German IRFs on counterfactual data lie below factual ones, hinting that it would have been easier for them to suppress a booming economy or revive an economy with a drop in interest rates. This evidence hints of some risk-sharing costs among monetary union members. Interestingly, in contrast to a popular view during the European sovereign crisis, Southern European countries, like Italy, would not have gained much by leaving the monetary union, at least in terms of the variables we cover. If anything, the policy effects would have had less of the desired impact; even if policies were better targeted, it is highly unlikely that they would have done a better job.

In the real exchange rate, we find fewer differences. The actual data predict real ex-

[16]The same conclusion also holds for a larger donor set (Figure A3), though the matching quality for Italian inflation differs across two sets of donors. It thus seems that the treated unit may not belong to the "convex hull" of the control units in a smaller set (that is, a weighted average of the pre-intervention outcomes of the control units are not equal to the pre-intervention outcomes of the treated unit). As a result, when it comes to the Italian inflation, we will treat the results from the smaller donor set with more caution.

[17]See Figure A4 for a full donor set. The counterfactual derived from the full donor set predicts a significantly different reaction to the tightening monetary policy shock for France.

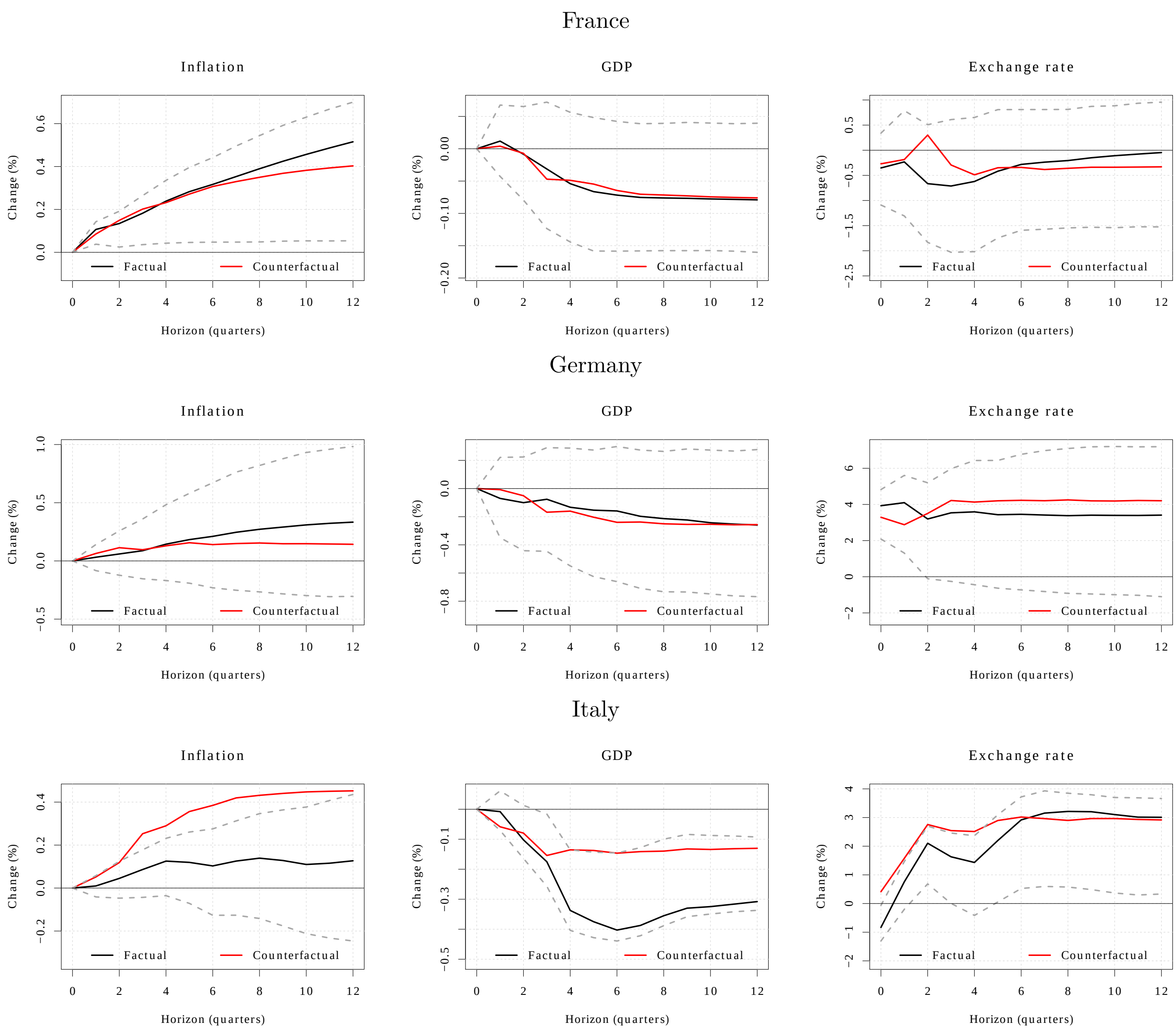

Figure 3: Impulse response functions to identified monetary policy shocks, smaller donor set (pre-intervention data)

change rate appreciation, solving the exchange rate puzzle. French and Italian, though not German, counterfactual realities predict a stronger appreciation effect inside the monetary union. Hence, monetary policy is not as effective under independent rule than it is under the monetary policy union. This is because a more limited increase in the exchange rate weakens the restrictive impact of monetary policy on economic activity by helping exports and domestic demand. If anything, remaining in the monetary union makes the largest euro area economies subject to more effective monetary policy, at least with regards to price and exchange rate channel. One of the explanations is that the union internalises some of the spillovers.

Judging from the point estimates, French independent monetary policy would have potentially affected GDP more strongly but enhanced the prize puzzle and exerted a more limited impact on the real exchange rate, whereas Germany could have lowered GDP over a longer horizon had it exercised its own monetary policy, and Italy would have been worse off across the board. We can therefore conclude that the joint monetary policy is more effective at solving the price puzzle for all three of the largest euro area economies, though its effect on the real economy is weaker in case of France and Germany. Lastly, the real exchange rate channel may only be more effective under the nation's own monetary policy in Germany. When it comes to Italy, joint monetary policy has been more effective across the board: price, output, and exchange rate channels.

Finally, we look at the monetary policy shocks. Figure 5 documents that stabilizing the economy within a union requires somewhat smaller policy changes than stabilizing it separately, thereby providing more policy space than it otherwise would. We also document a more stable interest rate reaction within a monetary union. This could be rooted in the fact that the data for the euro area are itself more stable, because it is aggregated from across countries; therefore, the Taylor rule is more stable. It could also reflect the fact that ECB is more conservative than an independent national central bank. It should also be noted that a textbook reaction would be for the interest rate to go back to zero in the long run. However, we model changes rather than levels, and thus we do not model long-run relationships and the interest rate does not return to a pre-shock state. Here, the essential difference between factual and counterfactual is that the interest rate path in the factual case is defined by the euro area variables (the Taylor equation), whereas the counterfactual is driven by the country-specific variables.

5 Generalized IRFs

The global financial crisis and the COVID pandemic have made it clear that orthogonality of shocks is hardly a realistic assumption. One way to circumvent orthogonalization of shocks and avoid ordering of the variables in the VAR is to apply generalized impulse response functions (GIRF), as developed by Koop et al. (1996); Pesaran and Shin (1998). Since GIRF accounts for all shocks and their inter-correlations, the estimator of variance-covariance matrix plays a crucial role in the analysis. In principle, to properly capture the counterfactual's initial period, we should have included GIRF in the loss function. To save on space and make our methodology as transparent and concise as possible, we will report GIRFs using the same objective function as above.

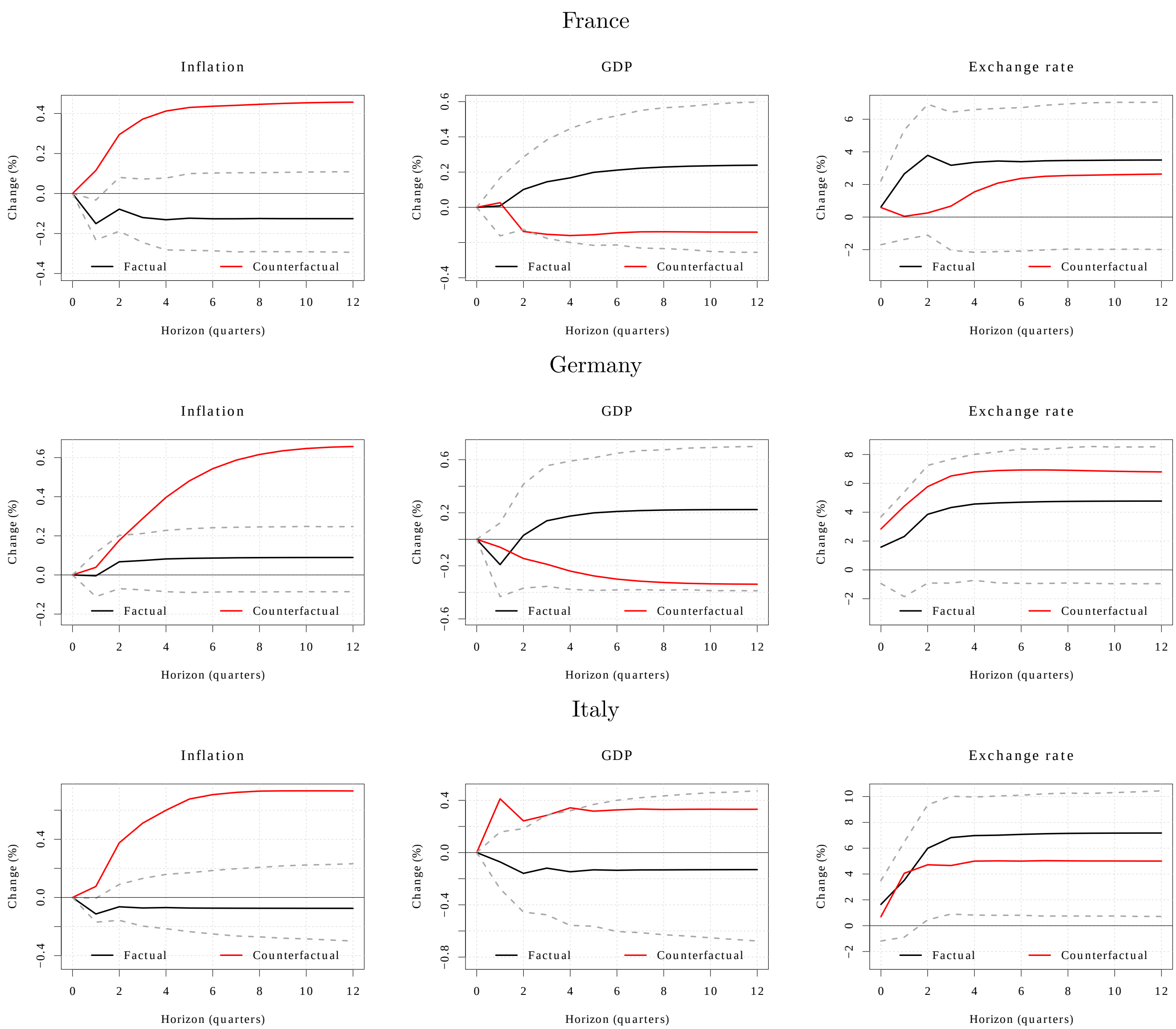

Figure 4: Impulse response functions to identified monetary policy shocks, smaller donor set (post-intervention data)

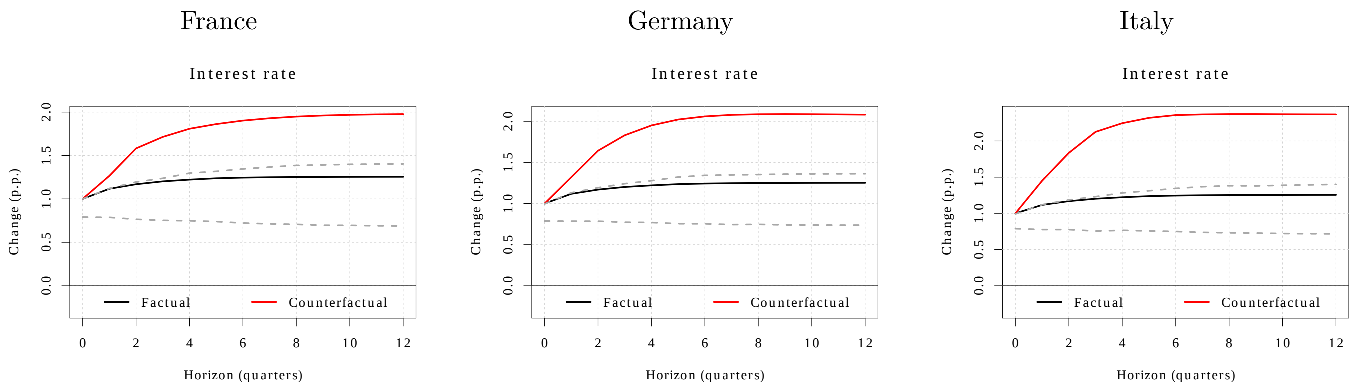

Figure 5: Impulse response functions of interest rates, smaller donor set (post-intervention data)

Figure 6 covers post-intervention GIRFs to the interest rate shock.[18] Just as in the identified shock case, French prices experience no puzzling behavior inside the union. France's exchange rate appreciates, just as predicted by the economic theory, but its GDP is not managed as well as it would have been under an independent monetary policy. Qualitatively, Germany's responses and differences are very much like those of France. By improving prices and exchange rate channels, the monetary union negatively impacts the management of GDP fluctuations, possibly because output and employment management has not been a primary mandate of ECB, and seems to be a higher priority for domestic policymakers. Italian evidence seems to be slightly more sensitive to the shock identification. Despite this, inflation, especially over the longer run, is better managed under the union, and effects on GDP fluctuations are indistinguishable, whereas exchange rate displays a much more powerful channel when monetary policy is conducted jointly. Hence, GIRF preserves the conclusion that Italy is the main beneficiary of the monetary union among the three largest euro area members, as the other two may be paying a higher price in GDP risk-sharing but also benefiting in terms of the monetary policy's price and exchange rate channels.

6 Conclusion

We proposed a framework that may be useful to tackle a number of real-world questions. Our method combines the synthetic control idea with impulse response analysis, allowing for common factors which capture cross-country interdependence. We build two counterfactual realities using identified monetary policy shocks and generalized impulse response functions. This makes our approach different from many synthetic control applications, which focus either on one-off effects or reactions in macroeconomic variables, but not on the effectiveness of the monetary policy. We document that French and German independent monetary policies may have been more effective at addressing GDP fluctuations, but that this effectiveness would have come at the price of an enhanced price puzzle. We find that Italy, despite

[18]The evidence is quite comparable across two donor sets (qualitatively, the responses are very similar, though quantitatively, it seems, the full donor set predicts responses that are smaller in absolute value). Refer to Figure A6 for a full donor set.

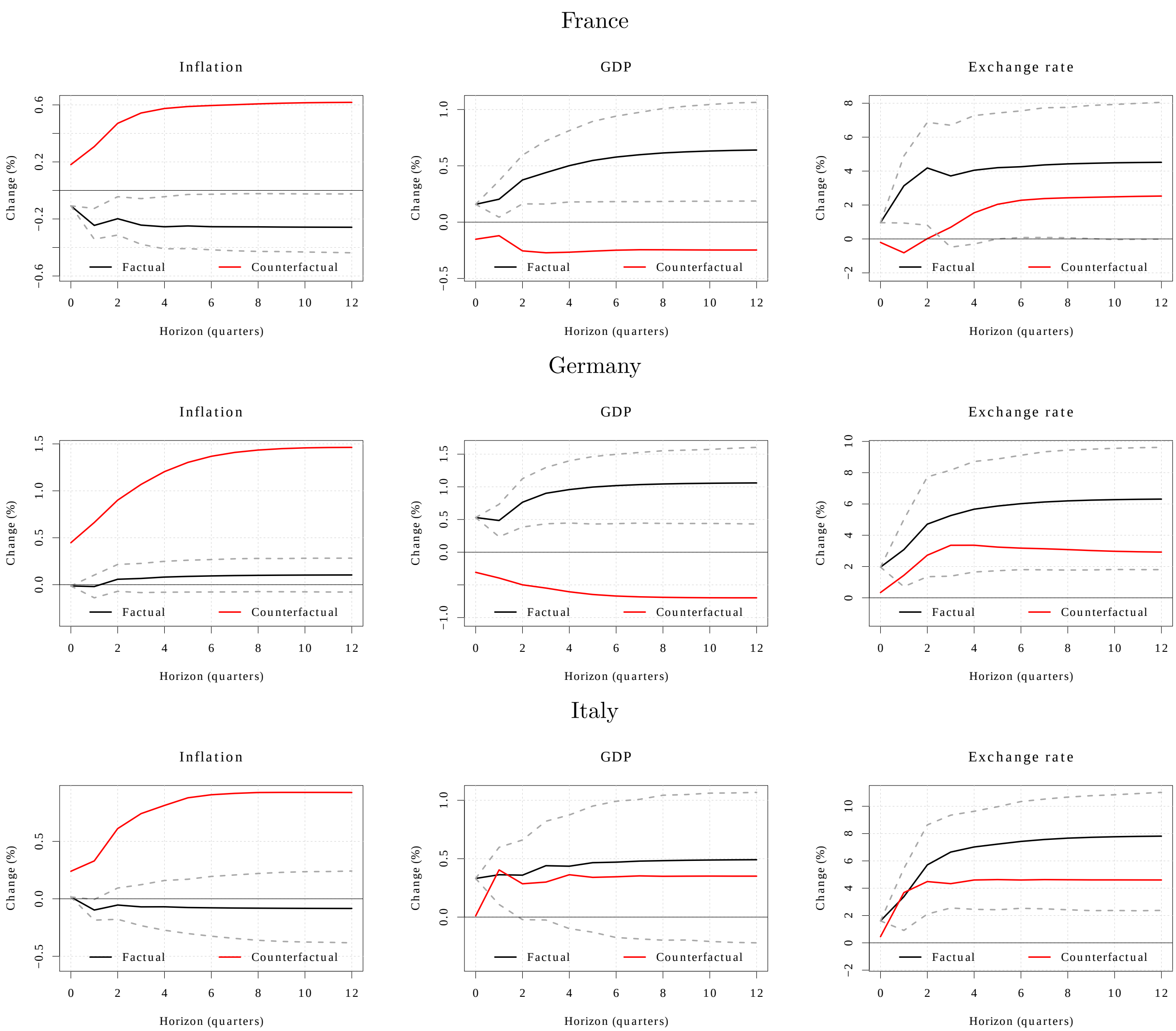

Figure 6: Generalized impulse response functions to identified monetary policy shocks, small donor set (post-intervention data)

the many voices advocating for departure from the union during the sovereign debt turmoil, would not have gained by leaving the monetary union, at least in terms of the variables we cover. On the contrary, we find no tradeoffs for Italy, since joint monetary policy is found to have been more effective with regards to all three channels considered: prices, GDP, and exchange rate.

These findings are important from a policy perspective. Contrary to the suggestions that Southern European economies exit the monetary union, particularly in the whirl of the European sovereign debt crisis, our counterfactual analysis hints that leaving the union and conducting an independent monetary policy would not necessarily have delivered the intended results. Importantly, short-term reactions, especially in exchange rates, feature prominently in proposals of this kind, and more work on the effectiveness and transmission of monetary policy under different regimes is warranted. We find that adjustments must be implemented in area other than the monetary policy conduct. In addition to our focus, we foresee other applications of our framework, which will prove useful whenever one seeks to compare dynamic reactions to exogenous shocks between two states of the world (member/non-member, as in our case).[19] From a technical perspective, many improvements to our method remain to be made. We have not addressed nonstationarity and cointegration,[20] the evolving nature of shocks after a structural break/treatment, regional shocks, and integration of the treated and donor units into connected trade networks, among other important directions for future research.

We also foresee an extension of our approach to the seminal contribution by Pesaran et al. (2004) (also see extensive treatments in Garratt et al. 2006; di Mauro and Pesaran 2013; Chudik and Pesaran 2016) to model global economy in a coherent and consistent manner. If one has access to a large donor set, observed over a long time, instead of merely conditioning on common factors, one can model their dynamics as is done in the GVAR literature. By making use of cross-sectionally weighted averages (Pesaran, 2006), the treated economy's model would already have 'a counterfactual reality' embedded, and thus a shock in any policy variable would yield an interpretation closer to real-world policy evaluation exercises. In addition, as GVAR models all economies for a set of important variables, this gives us a substantially richer environment than single-regression-based approaches, including the novel synthetic differences-in-differences of Arkhangelsky et al. (2019), which cannot disentangle the effects of joint policy action (or double counterfactuals as in our case, i.e., belonging to the monetary union *and* responding to monetary policy shocks). All these exciting directions, including those already mentioned, are left for future investigation.

[19] A non-exhaustive list includes the following: What are the effects of economic sanctions, given subsequent terms-of-trade shocks? What are the effects of unemployment benefits, and active labor market policies, given labor market liberalization reform like the Hartz structural change in Germany? Many other possible avenues of investigation include inflation versus price-level targeters, choices of exchange rate regimes, etc. In all these cases, we need to construct a counterfactual path for the alternative world, then subject the observed and counterfactual world to the exogenous shocks of interest.

[20] Hsiao and Zhou (2019) demonstrated that there is no single method that dominates others for different data-generating processes, sample sizes, and pre-treatment periods. Since macroeconomists are often interested in nonstationary phenomena, non- or semi-parametric approaches seem to dominate the alternatives, making our proposal all the more useful.

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Online Appendix

A Actual and Counterfactual Data

A.1 Pre-intervention Fit

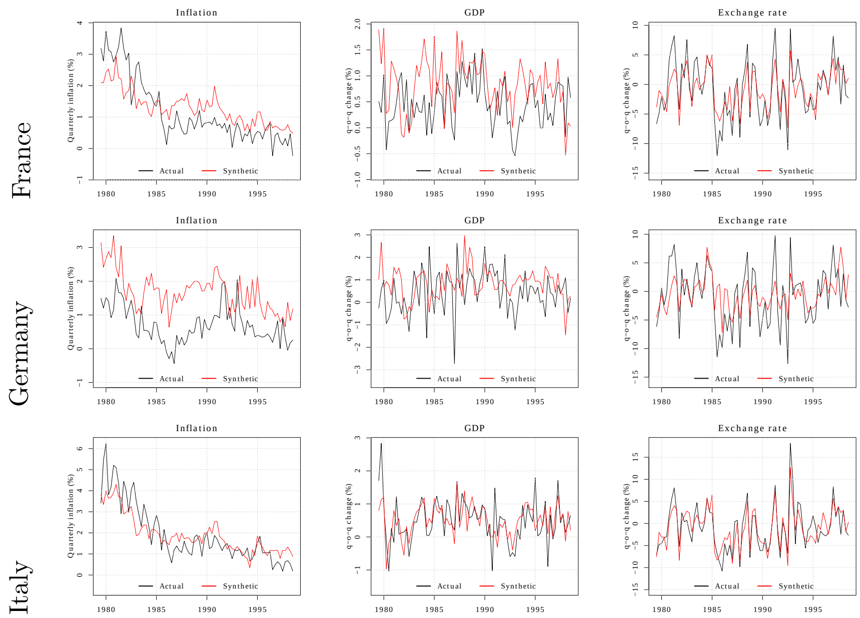


Figure A1: Pre-intervention fit of main variables

A.2 Post-intervention Fit

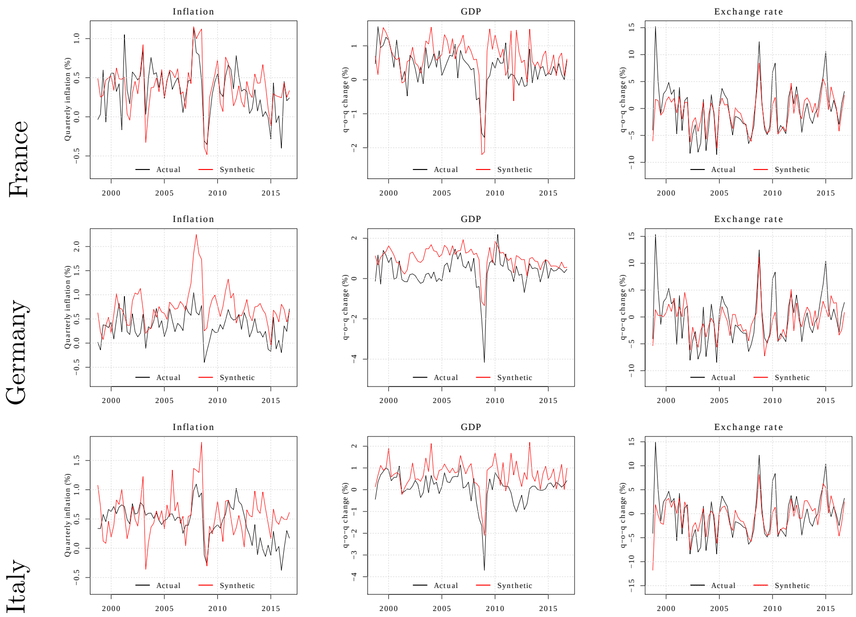


Figure A2: Post-intervention fit of main variables

B Full Donor Set

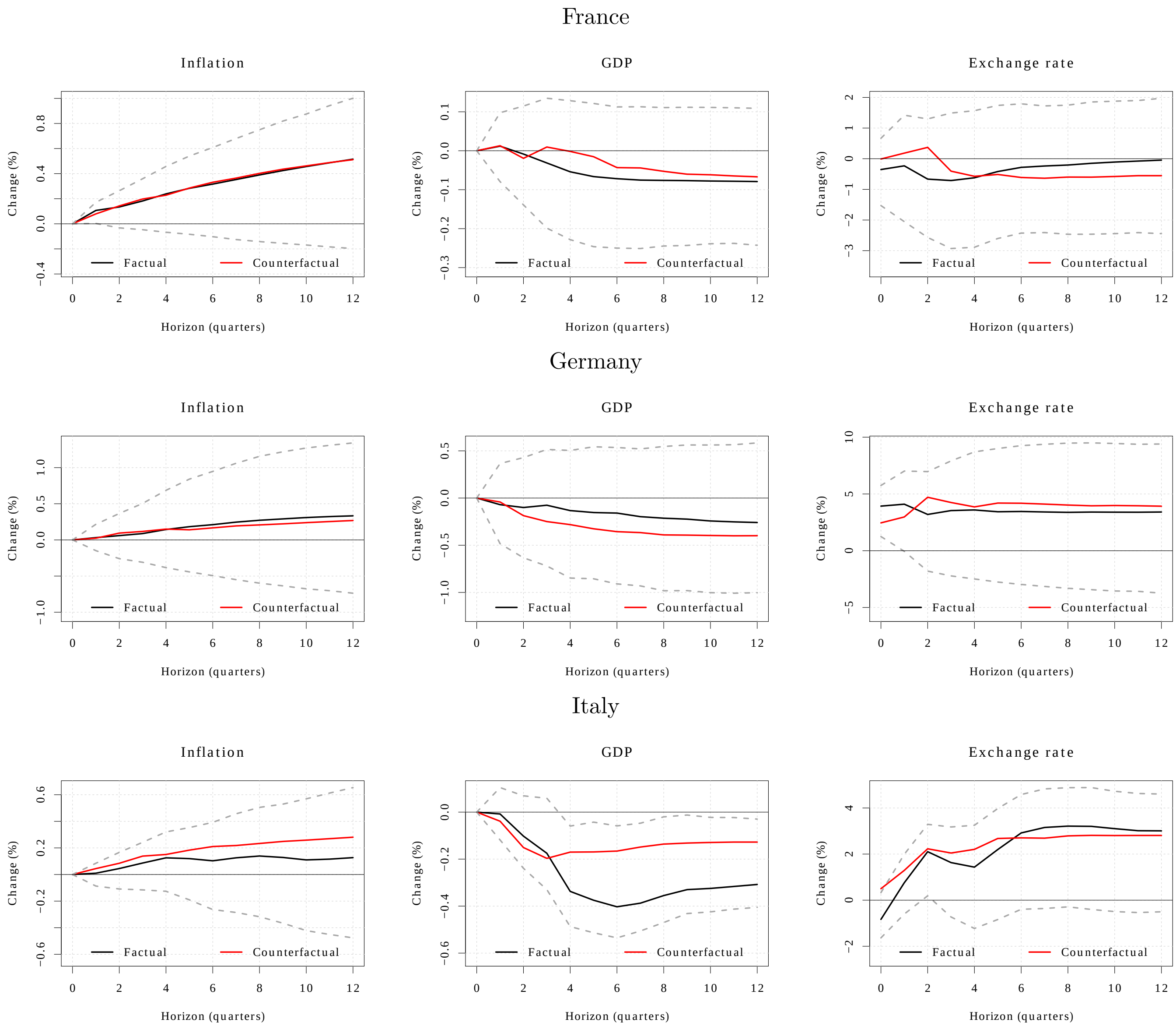


Figure A3: Impulse response functions to identified monetary policy shocks, full donor set (pre-intervention data)

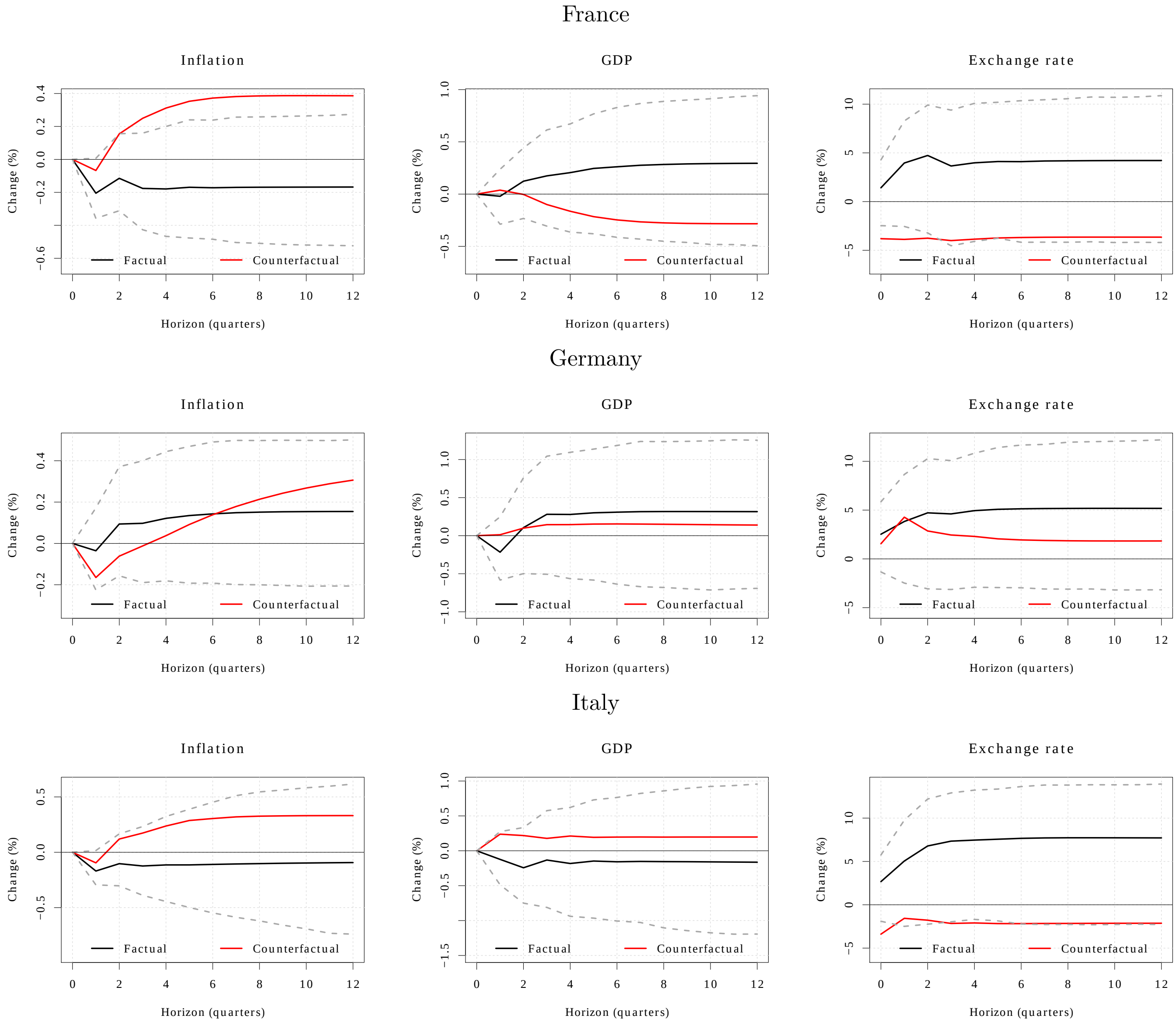
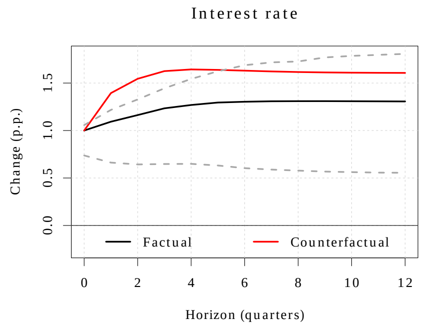


Figure A4: Impulse response functions to identified monetary policy shocks, full donor set (post-intervention data)

France



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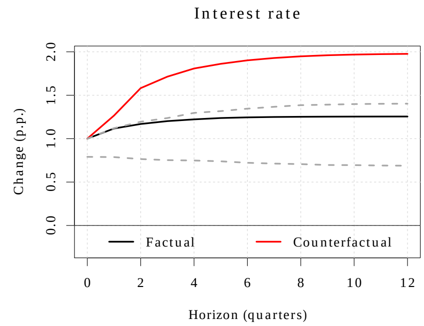
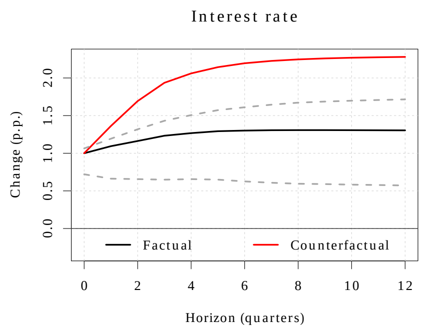
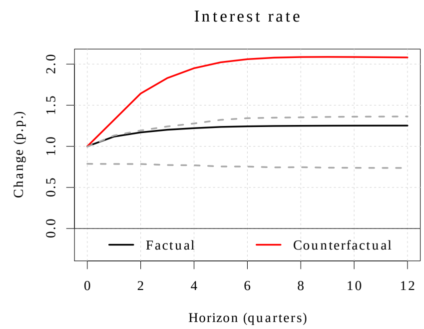


b)

Germany

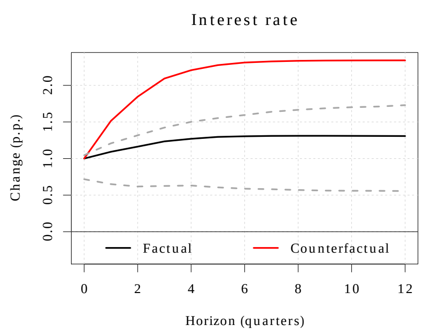


a)



b)

Italy



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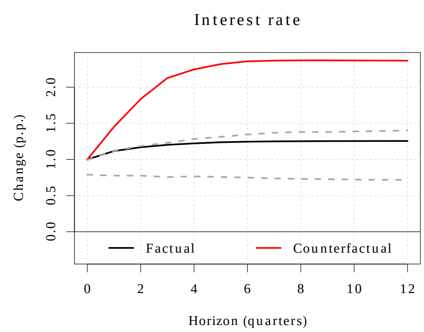

b)

Figure A5: Comparison of impulse response functions of interest rates using a) full and b) smaller donor set (post-intervention data)

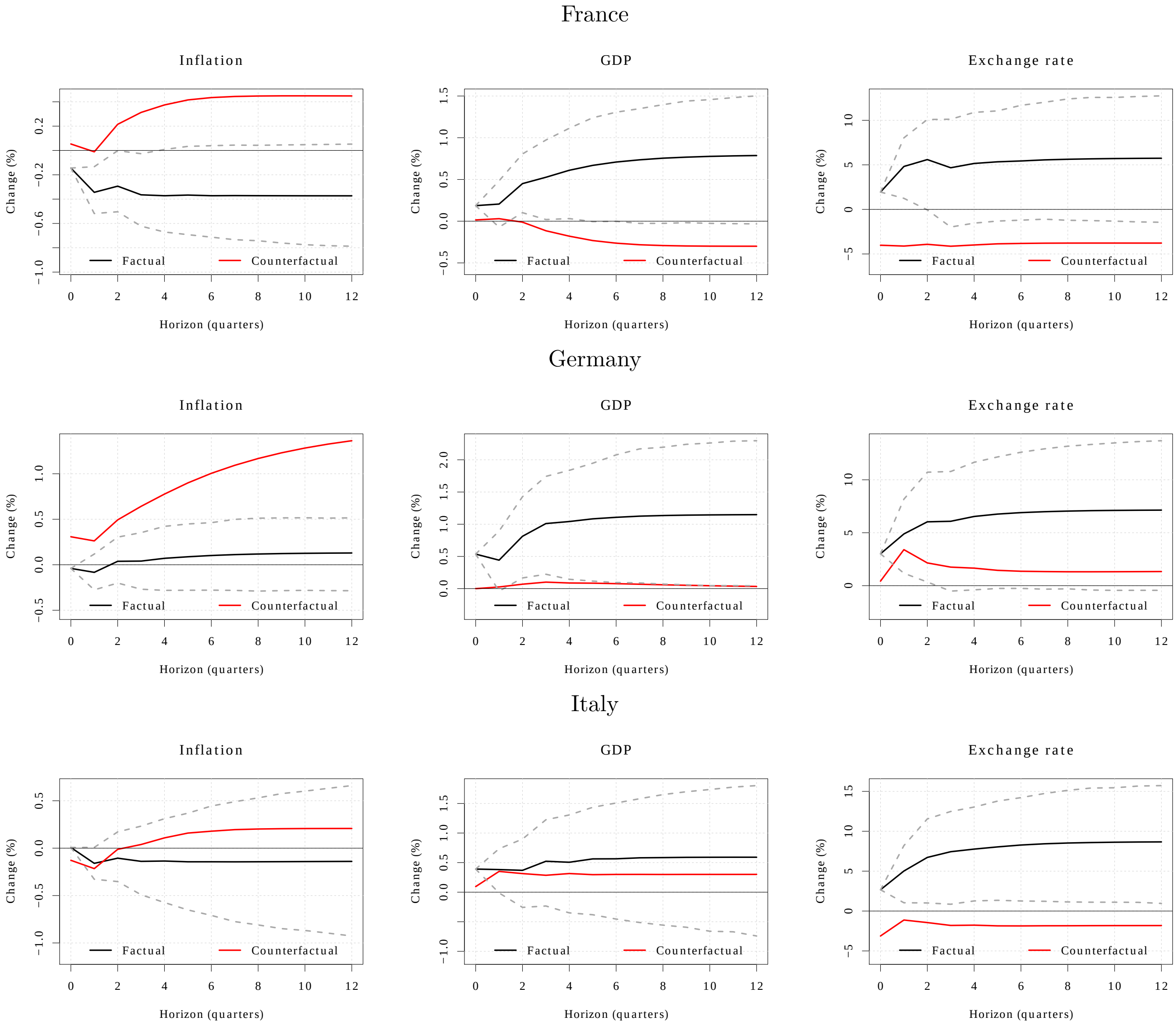

Figure A6: Generalized impulse response functions to identified monetary policy shocks, full donor set (post-intervention data)

C Robustness

C.1 Random Weights

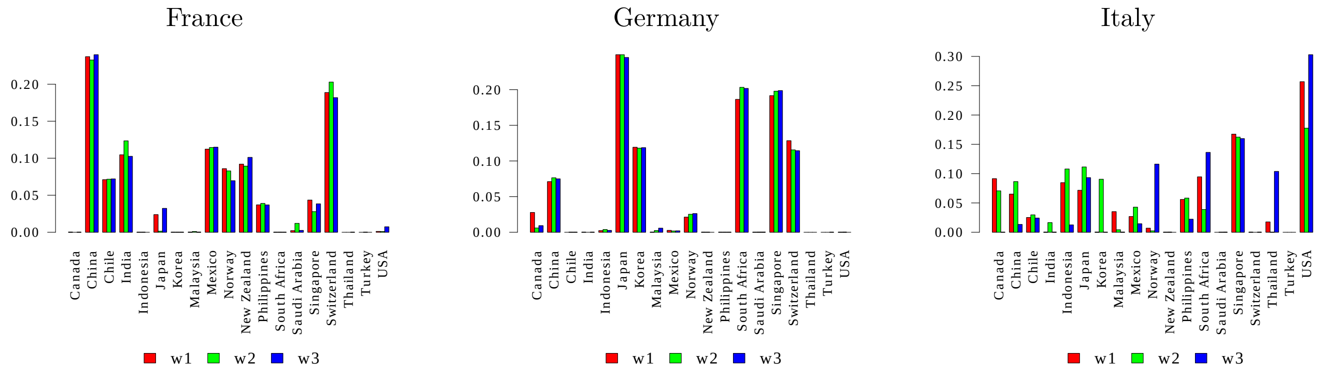

Figure A7: Three sets of weights with the lowest loss function value, smaller donor set (random initial weights)

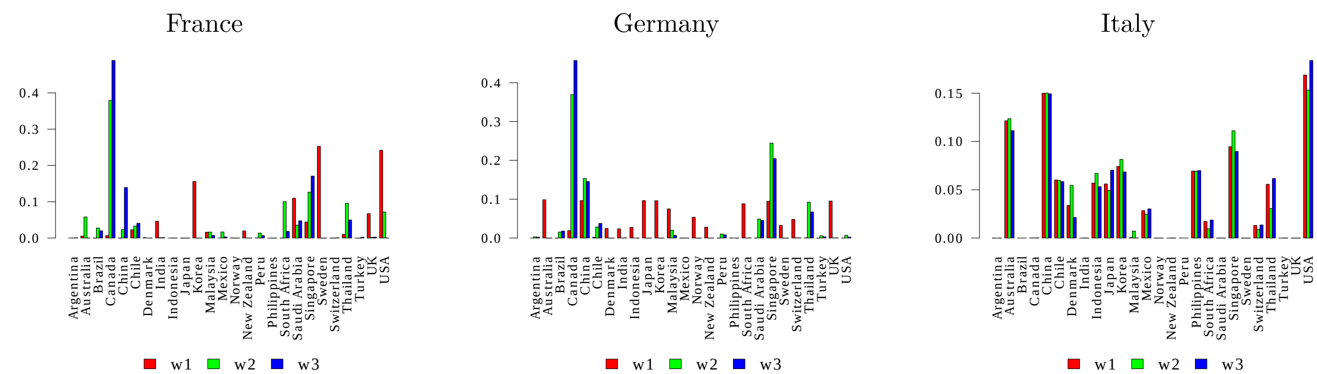

Figure A8: Three sets of weights with the lowest loss function value, full donor set (random initial weights)

C.2 Pre-intervention Period

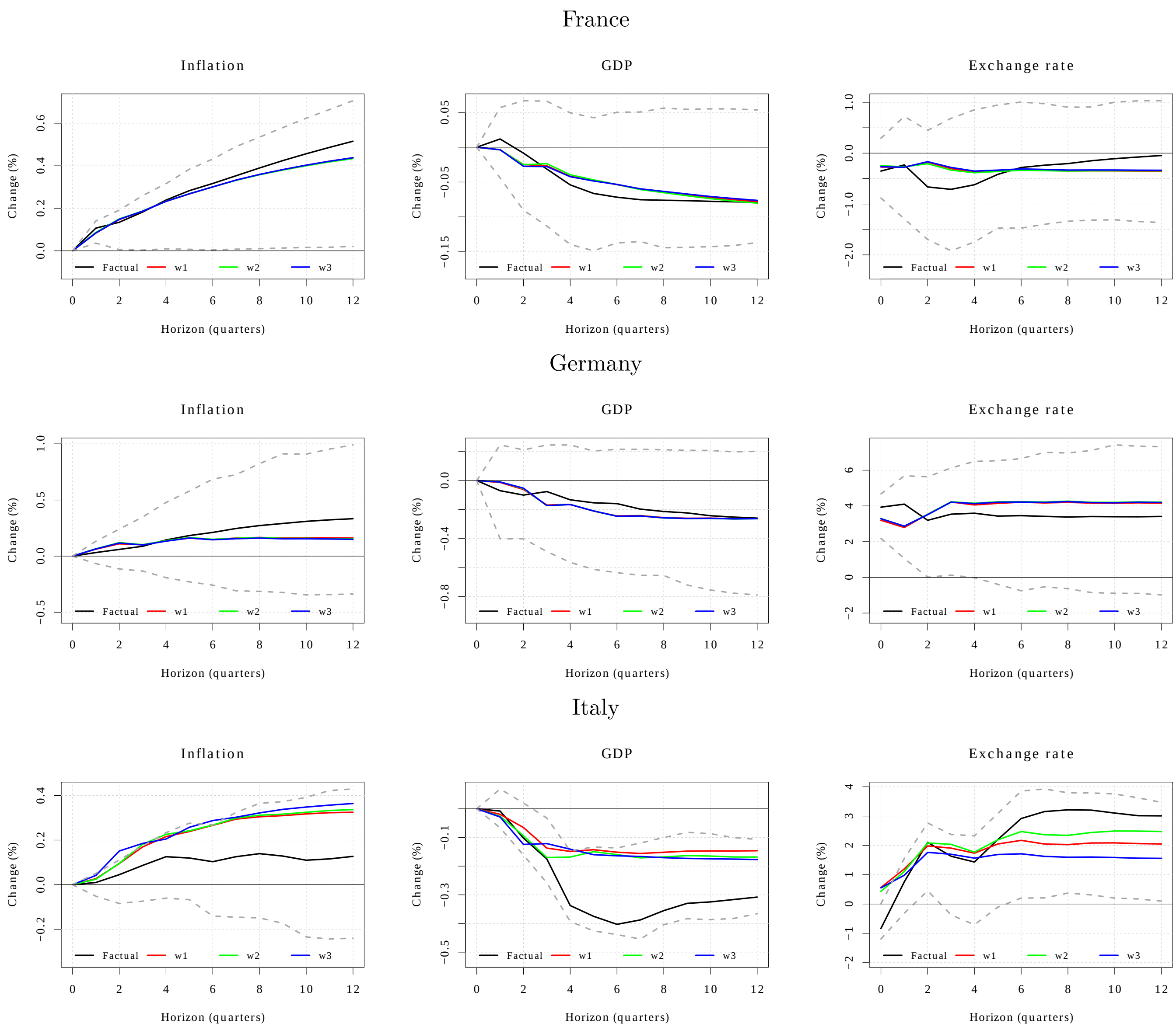

Figure A9: Impulse response functions to identified monetary policy shocks for the three sets of weights, smaller donor set (pre-intervention data)

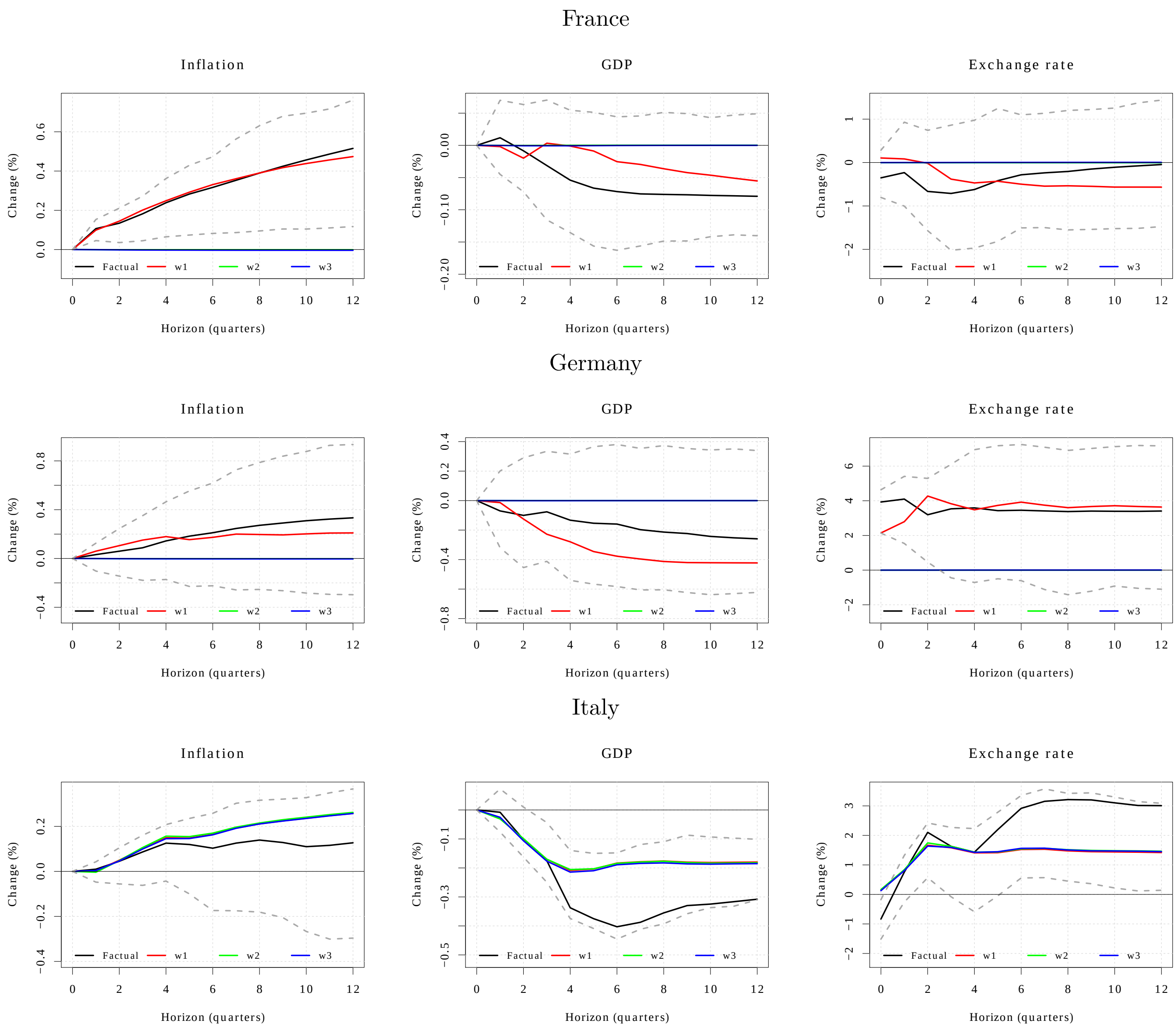

Figure A10: Impulse response functions to identified monetary policy shocks for the three sets of weights, full donor set (pre-intervention data)

C.3 Post-intervention Period

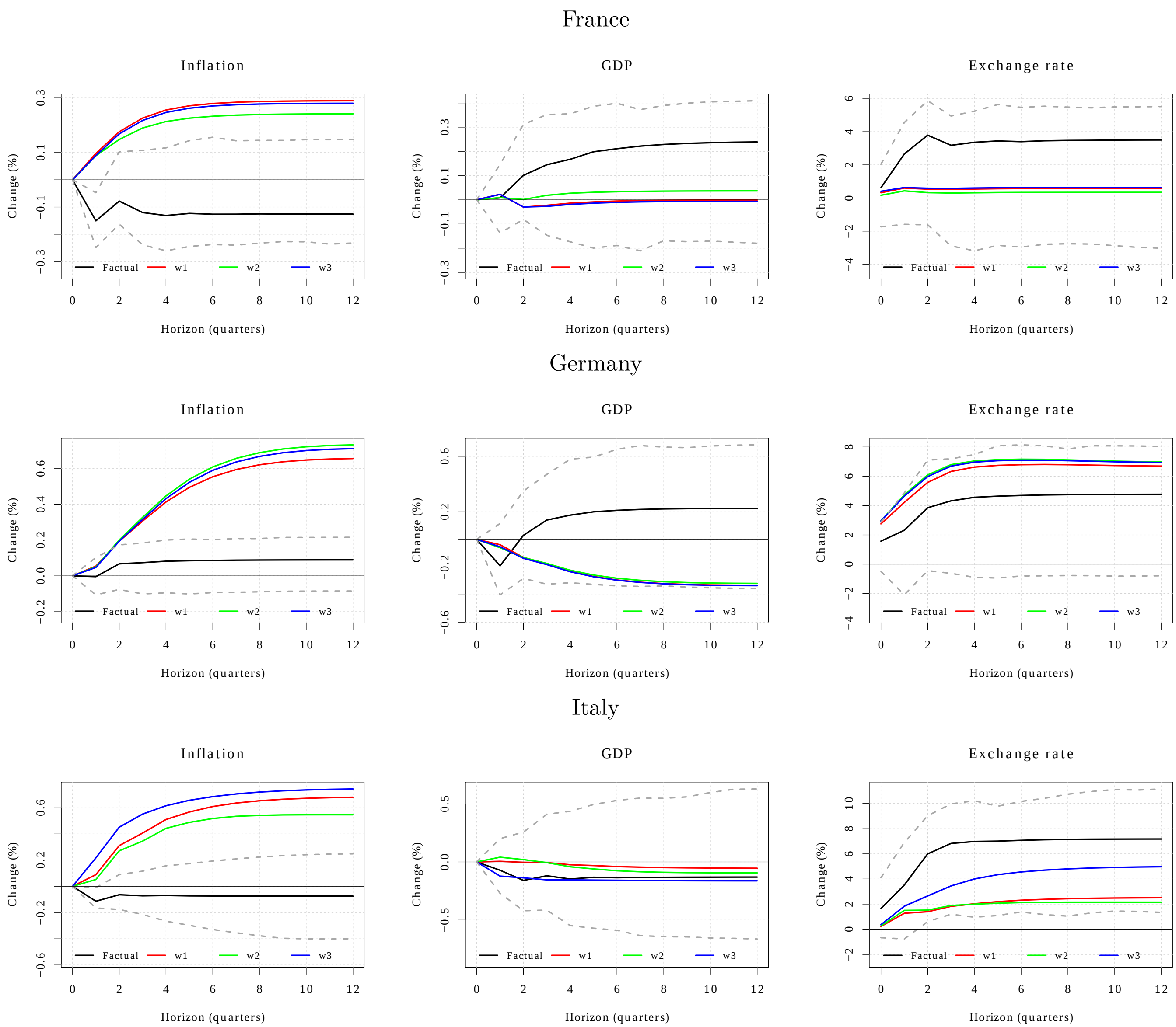

Figure A11: Impulse response functions to identified monetary policy shocks for the three sets of weights, smaller donor set (post-intervention data)

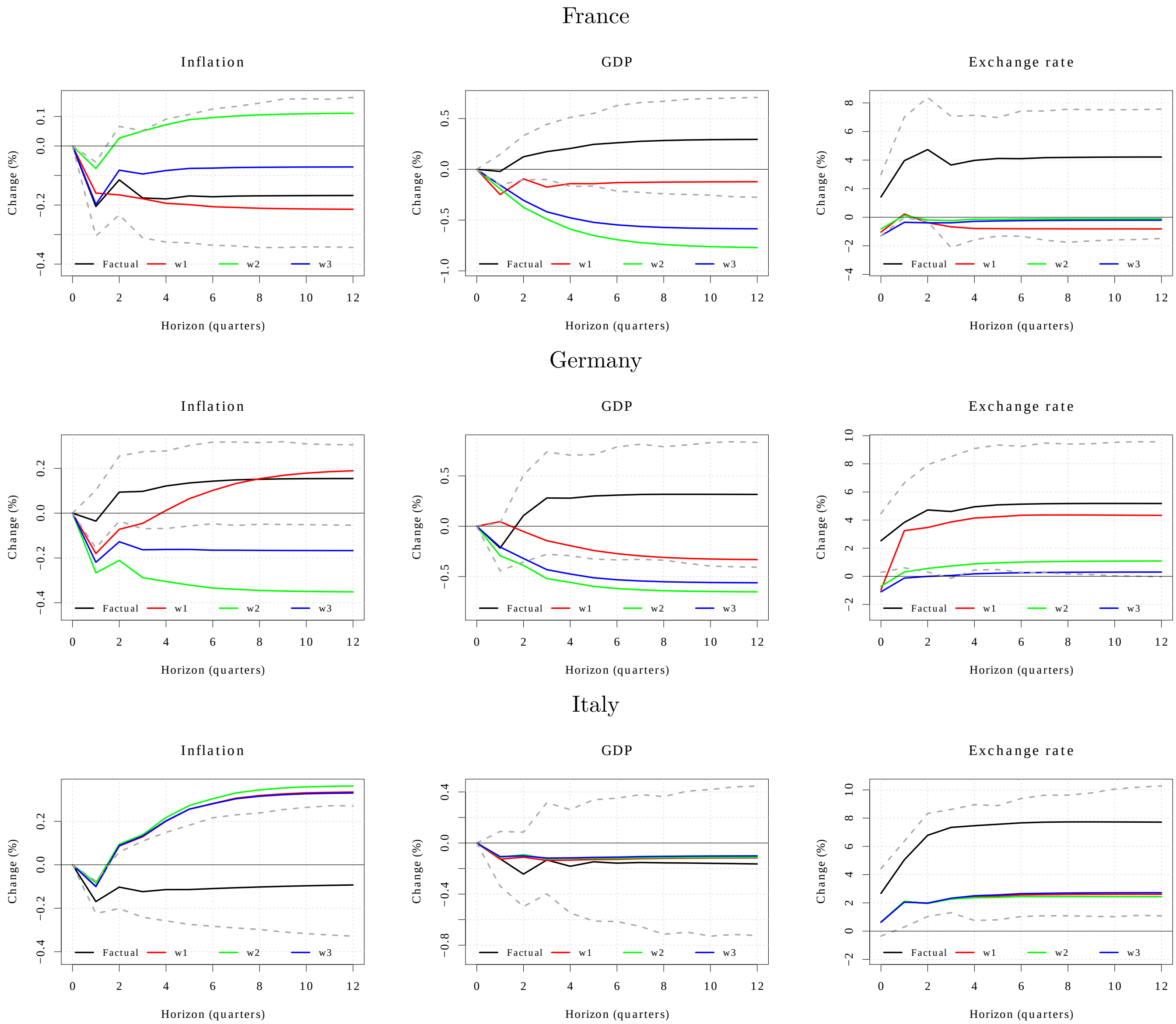

Figure A12: Impulse response functions to identified monetary policy shocks for the three sets of weights, full donor set (post-intervention data)