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LEQS Paper No. 175/2022

March 2022

LSE Europe in Question
Discussion Paper Series

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## Abstract

This paper studies the unemployment-output relationship from 1979 to 2019 in advanced countries. The paper offers three main contributions: it reports (i) structural and (ii) dynamic estimates that (iii) account for idiosyncratic and common shocks in a Structural Panel-VAR framework. The main results show that unemployment responses to output (Okun's Law estimates) are stable and have not changed significantly since the Global Financial Crisis. We also find they are driven by common shocks in both core and peripheral countries. Yet the post-crisis stability results for the periphery require extra-model explanations chiefly via strictness of product market regulations.

**Keywords:** Economic growth, unemployment, Okun's Law, Panel VAR

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**Acknowledgments**

We would like to thank Paul De Grauwe, Jarko Fidrmuc, Frédérique Bec, Chris Papageorgiou, Prakash Loungani, Davide Furceri, Vassilis Monastiriotis and seminar participants at the London School of Economics, 6ième "Journee D'Econometrie Appliquee a la Macroeconomie" in Paris, and at the Democritus University of Thrace. The usual disclaimer applies.

# Unemployment and Growth Before and After the Global Financial Crisis: New Evidence from Structural Okun Estimates

## 1. Introduction

The global financial crisis that started in 2007 led to massive output disruptions and acute increases in unemployment in almost all advanced economies, particularly in those countries that are members of the euro area. However, significant differences in the volume and duration of these fluctuations persist and many economists fear that these have been further amplified recently, first by the European sovereign debt crisis (Blanchard 2018) and then by the COVID-19 pandemic. Currently, the dispersion in unemployment rates across EU countries remains considerable, ranging from just above 2 percent in the Czech Republic to double digits in southern Europe, remaining particularly high in Greece and Spain.

A large literature has been devoted to understanding the relationship between unemployment and growth (e.g., Ball et al. 2015, 2019) mostly departing from the canonical Okun's law framework (Okun 1962). Yet regarding the strength and robustness of such linear relationship during crisis episodes the literature remains inconclusive. Some conclude that unemployment becomes significantly more sensitive to output shocks following severe crisis (that is, if these shocks are large), while others find that the relationship is surprisingly stable. In fact, much of the findings depend on factors such as sample periods and the econometric methodologies adopted (for a survey, see Gordon, 1984; Kaufman, 1988; Prachowny, 1993). Kaufman (1988) estimated the cyclical responses of unemployment rate to output shocks among six industrial countries by testing the Okun's law before and after the 1970s oil shocks. He concluded that the output elasticity of employment significantly increased after the outbreak of the oil crisis. Many studies have thus focused on the stability of this relationship. Lee (2000), for instance, evaluated the robustness of Okun's law for 16 OECD countries on post-war data, concluding that there are marked differences depending on whether unemployment and output were considered in deviations from their trend (hence, the output/unemployment gap) or in first differences, with a substantial disparity between what is observed in the US compared to continental Europe. Other important comparative work, such as Moosa (1997), Freeman (2001) and Furceri et al (2020), further support the conclusion that unemployment tends to be much more reactive to output shocks in the US than in Europe.

With the outbreak of the financial crisis, analysis using Okun's law gained momentum, particularly from a policy-making perspective. This is because had the responsiveness of unemployment to output altered fundamentally, policies beyond active labour market strategies and short-term demand stimulus would seem more appropriate, including structural reforms (Campos et al., 2016; Macchiarelli et al. 2018). Knotek (2007) estimated a negative relationship in the unemployment rate and real output growth for USA in a rolling regression framework. He documents that the estimates underlying Okun's law varied over time and over the business cycle. A similar conclusion is reached by Aguiar-Conraria et al. (2020) using wavelet methods. Perman and Tavera (2007) tested the convergence of Okun's law coefficient using data from 17 European countries over the period 1970Q1-2002Q2 (see also Evans, 1996), and shows that convergence of the Okun's law coefficient is rejected for most country groupings. Similarly, Owyang and Sekhposyan (2012) support the view that the stability of Okun's law hugely depends on the business cycle and that deviations from this law (that is, instability in the relationship) were observed in the US during the three most recent recessions, including in 2007 (see also Ball et al. 2019).

It must be added that much research has focused on the stability of employment-growth Okun's relationship focusing on the role of different labour market institutions. Cazes et al. (2013), for instance, investigated whether unemployment tented to respond differently to the global financial crisis across OECD countries. They point out that Okun's law coefficient increased rapidly in economies such as US, Canada and Spain after the crisis. On the other hand, in countries where unemployment remained low, the Okun estimates decreased thus indicating that the reaction of unemployment to GDP weakened. These findings were found to be related to changes in the strictness of employment protection legislation (i.e., labor market reforms). Similar results were found by Oberst and Oelgemoller (2013). Guisinger et al. (2015) and Prieto et al. (2018) examine individual US states and find that the heterogeneity in the Okun estimates seems to be better explained by labour market and demographic differences, as well as industrial and labour regulation.

Other studies have generally argued that – despite the heterogeneity observed across countries – there is not yet sufficient evidence to conclude that there have been dramatic changes in Okun's coefficient during the Great Recession; notably, Ball et al. (2015, 2019) and Daly et al. (2014). These find that Okun's law was surprisingly stable during the last financial crisis.

This paper makes three main contributions to the literature. Firstly, it provides *structural* estimates of Okun's law. Most of the literature estimates univariate reduced-form equations while here we embed the Okun relationship within a simple structural closed-economy model with theory-driven restrictions where unemployment rate is considered in the context of output growth, (wage) inflation and nominal money growth (see Blanchard, 1989). We carry out a detailed comparison between structural and reduced-form estimates. Secondly, we study whether our structural Okun estimates change dynamically over time and/or across countries in a Structural Panel VAR (SP-VAR) framework (Pedroni 2013). We assess the validity of the Okun's law for a set of euro area countries between 1979 and 2019 using annual data, by looking at the marginal contribution to Impulse Response Functions of the Great Financial Crisis (GFC) over the full sample. Third and finally, we study the roles of common and idiosyncratic shocks in the P-VAR in driving the behaviour of our Okun's law estimates and investigate the extent to which labour market regulation, product market regulations and union density play a role in this context.

Our main findings are as follows. Our structural estimates are substantially lower than most of the reduced-form figures found in the literature: our Okun structural estimate is -0.12 while we estimate that the same figure from a reduced-form single-equation setting is -0.32. The responsiveness of output to unemployment is mainly driven by *common* factors in both core and periphery country groups and this has *not* significantly changed before and after the Great Financial Crisis. We also show that this structuiral estimate is remarkable stable, before and after the Global Financial crisis (and, as a further test, also before and after the introduction of the euro single currency). These results are robust to conditioning the sample on institutional factors, such as employment protection legislation (EPL), trade union density and wage bargaining institutional set-ups, both in the overall sample and in core and periphery countries. Interestingly, the results for the periphery are however mainly explained by the strictness of product market regulation when the sample includes the crisis years post-2009.

The paper is organised as follows. The next section describes our theoretical framework, a simple macroeconomic model that embedds an equation for Okun's Law. Section 3 discusses how it is econometrically implemented. Section 4 discusses our results, by providing evidence excluding or not the years of the GFC, as well as by core and periphery as different country groupings. Section 5 concludes.

## 2. Theory

Okun's Law has been at the center of macroeconomic research for many decades because it elegantly brings in supply-side considerations to the standard Keynesian perspective. There are basically two versions of Okun's law, the one measuring output and unemployment as gaps, or in trend-deviation; the second considering their first difference. The first version is defined as

(1) $$(U - U^{*}) = \beta(y - y^{*}) + \varepsilon_t$$

where the term on the left-hand side, is the difference between the actual rate of unemployment ($U$) and natural rate of unemployment ($U^*$) , i.e., cyclical unemployment. The coefficient $\beta$ is the Okun's coefficient to be estimated, y is real GDP, $y^*$ is potential GDP, and $\varepsilon_t$ is the standard disturbance.

The second version of the Okun's law calculates the relationship in the changes of the unemployment rate ($\Delta u$) and growth rate of output ($\Delta y$), as:

(2) $$\Delta u_t = \ a + \beta \Delta y_t + \ e_t$$

To estimate (2), we contribute to this literature by using a simple structural 5-equation model which allows a traditional interpretation of macroeconomic fluctuations in the aggregate demand and aggregate supply dynamics. The variables of interest are a) the log of output$y$, b) the unemployment rate $u$, c) the logarithms of the price level $p$, d) the logarithm of wage level $w$, and e) the logarithm of nominal money $m$.

Following a modification of Blanchard and Quah (1989) which allows embedding the Okun's law, the structural identification of the model is built on a system of equations as follows: an aggregate demand equation (AD), Okun's law (OL), a price setting equation (PS), a wage settings equation (WS), and a simple money rule (MR). These are specified in this way:

(AD) $$y \ = \ + c e_u \ + \ e_d,$$

(OL) $$u = a_{21} y \ + \ e_u,$$

(PS) $$p = a_{34} w + \ a_{31} y \ + \ c_{32} e_u \ + \ e_p$$

(WS) $$w \ = \ a_{43} p \ + \ a_{42} u \ + \ c_{42} e_u \ + e_w$$

(MR) $$m = a_{51} y \ + \ a_{52} u \ + \ a_{53} p \ + \ a_{54} w \ + \ e_m$$

where $e_d$ , $e_u$, $e_p$, $e_w$ and $e_m$ are considered autonomous shocks to aggregate demand, shocks to labour supply and technology, or supply shocks, shocks to price and wage setting, and shocks to nominal money, respectively. The shocks have no cross correlation. We transform the variables depending on their statistical properties, hence, we estimate a 5-variables $I(0)$ VAR including output growth, unemployment rate growth, $CPI$-inflation, wage inflation, and nominal money growth.

Defining as $X$ the vector of variables $X = [\Delta y, \Delta u, \pi, \Delta w, \Delta m]$, the structural VAR model is written as:

(3) $$A\,X_t = A(L)X_{t-1} + BZ_t + Ce_t$$

where $e$ is the vector of innovations to the structural disturbances, $V(e) = D$ is the covariance matrix of the structural innovations, $Z$ is a vector of deterministic variables, $A(L)$ is a matrix in the lag-operator. Multiplying both sides of equation (3) by $A^{-1}$ gives the reduced form VMA representation associated with the structural model:

$$X_t = A^{-1}\,A(L)X_{t-1} + A^{-1}BZ_t + A^{-1}Ce_t$$

or, redefining the matrices as

$$X_t = F(L)X_{t-1} + GZ_t + x_t$$

where x is the vector of reduced form innovations. This means, reduced form innovations are related to structural innovation with this equation as:

$$Ax_t = Ce_t$$

The reduced form (3) summarizes the sample information about the joint process of the $X$ variables. To go from the reduced form to the structural model, one needs a set of identifying restrictions on $A$ and $C$. Given the restrictions derived from AD, OL, PS, WS and MR one can recover the structural equations, as well as the structural innovations.

# 3. A Structural Panel VAR (SP-VAR) for the Euro Area

To empirically estimate the dynamic impact on unemployment of changes in output over the short and medium term, we follow Pedroni (2013). This method consists of estimating impulse response functions (IRFs) from a Panel SVAR model to test the dynamics between different responses to idiosyncratic and common shocks, using a recursive identification method. This allows using the structural identification of Blanchard (1989) and Blanchard and Quah (1989) in a multicounty framework, controlling at the same time for country fixed- effects and allowing for full heterogeneous dynamics across countries.

Formally, we recognize an unbalanced panel composed of $i = 1,\dots,N$ individual member states for $N = 11$ euro area country, each of which consists of an $M \times 1$ vector of observed endogenous variables, $X_{1,it} \dots X_{m,it}$, with $m = 1,\dots,M$.

The data are assumed to be observed over specific time $t = [1,\dots,T_i]$. To control for fixed effects and to simplify the notation, we demean the data, where $X_{i,t}^{*} = X_{i,t} - X_i$, with $\bar{X}_i = T_i^{-1} \sum_{t=1}^{Ti} X_{it}, \forall_i$

To allow for heterogeneous dynamics, we first estimate and identify reduced-form VARs for each country $i$, consistent with our previous notation

(6)
$$\begin{aligned} A_1 X_{1,t}^{*} &= A_i(L) X_{1,t-1}^{*} + BZ_{1,t} + Ce_{1,t} \\ &\vdots \\ A_M X_{M,t}^{*} &= \mathrm{A_i}(L) X_{M,t-1}^{*} + BZ_{M,t} + Ce_{M,t} \end{aligned}$$

where $\mathrm{A_i}(L)$ is a polynomial of lagged coefficients $A_i(L) \equiv \sum_{j=0}^{Ji} A_j^i \, L^j$ with country - specific lag-lengths $J_i$, The matrix $A_j^i$ is a matrix of coefficients, $e_{i,t}$ is a vector of stacked residuals, and $A_i$ is a matrix of contemporaneous coefficients. We also estimate another auxiliary VAR to recover *common* dynamics, which are captured by averages, across countries, for each period ($\bar{X}^{*} \equiv M^{-1} \sum_{i=1}^{M} X_{i,t}^{*}$). Disregarding the predetermined factors to simplify the notation, we obtain

$$\bar{A}\bar{X}_t^{*} = \bar{A}(L)\bar{X}_{t-1}^{*} + \bar{C}\bar{e}_t$$

Following usual practice, after transforming the reduced form residuals in their structural equivalent ($x_{i,t} = A^{-1}Ce_{i,t}$ and $\bar{x}_{i,t} = \bar{A}^{-1}\bar{C}\bar{e}_{i,t}$), and run $nM$ linear regressions to decompose the shocks into two terms:

(7)
$$\begin{aligned} x_{1,t} &= \Lambda_1 \bar{x}_t + \tilde{x}_{1,t} \\ &\vdots \\ x_{M,t} &= \Lambda_N \bar{x}_t + \tilde{x}_{M,t} \end{aligned}$$

where $x_{i,t}$ are the so-called *composite* shocks, $\bar{x}_{i,t}$ are *common* shocks, $\tilde{x}_{i,t}$ are *idiosyncratic* shocks and $\Lambda_i$ are $n$-by-$n$ diagonal matrices with country specific loadings OLS regressions coefficients. The $\tilde{x}_{i,t}$vectors are truly idiosyncratic, since they are by construction orthogonal to the shocks derived from the average dynamics shared by all members in the panel.

We finally use the method described in Lütkepohl (2007) to recover the matrices of composite responses to structural shocks [$R_i(L)$] for each country, which are shown below in the vector moving average representations of $M$ structural VARs (see Goes, 2016):

$$\begin{aligned} X^*_{1,t} &= R_1(L)x_{1,t} \\ &\vdots \\ X^*_{M,t} &= R_1(L)x_{M,t} \end{aligned}$$

and then use the loading matrices estimated in (7) to decompose the composite responses into country-specific responses to common shocks and responses to idiosyncratic shocks:

$$\begin{aligned} R_1(L) &= \Lambda_1 R_1(L) + (I - \Lambda_1\Lambda_1')R_1(L) \\ &\vdots \\ R_M(L) &= \Lambda_M R_M(L) + (I - \Lambda_M\Lambda_M')R_M(L) \end{aligned}$$

Equivalently, $R_i(L) = \bar{R}_i(L) + \tilde{R}_i(L)$ , where $\bar{R}_i(L) \equiv \Lambda_i R_i(L)$ and $\tilde{R}_i(L) \equiv (I - \Lambda_i\Lambda_i')R_i(L)$. We finally use the cross-sectional distribution of $R_i(L)$, $\bar{R}_i(L)$ and $\tilde{R}_i(L)$ to describe some properties of the collection of impulse response functions calculated, such as their medians, averages and interquartile ranges.

# 4. Results

In this section we present our econometric results from the implementation of the model described above. We first focus on the structural estimation of the model and in the second part discuss in more detail the stability of our results in general and, more specifically, carefully contrast their behavior before and after the Global Financial Crisis.

## 4.1. Full sample

Figure 1 provides a first descriptive account of the Okun's law relationship. There is a statistically negative correlation between unemployment growth and output growth. This hinges on the classical idea that a higher economic growth leads to lower unemployment and vice versa.

Figure 1 – Correlation between output and
unemployment growth across 11-euro area countries

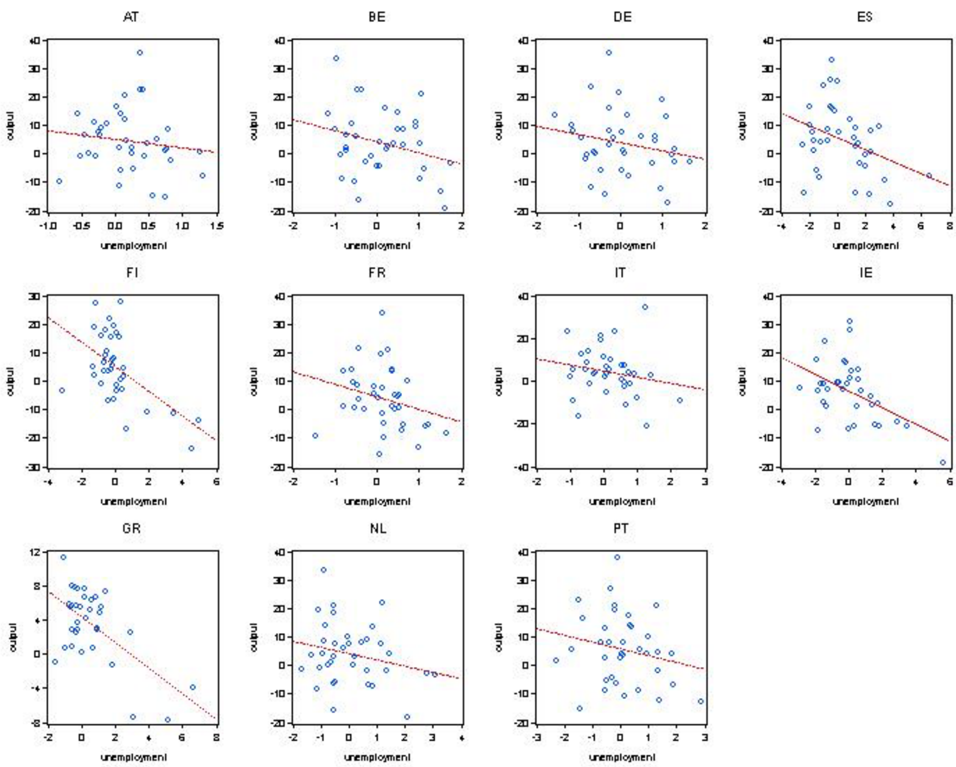


Table 1 presents the results for a group of 11-euro are countries, over the period 1979-2019. For sake of exposition, we first present the results from a reduced-form regression in first differences and contrast it to our 5-equation SVAR estimated individually for each country.[1] The average value of the coefficient is -0.313 with the univariate method and -0.125 with the 5-equation SVAR. Notice that the SVAR results display sometimes higher standard errors but a much higher goodness of fit overall, with the R2 being on average substantially higher than that reported with the univariate approach. These univariate results are broadly in line with those from other recent contributions, such as, e.g., Ball *et al.* (2019), who estimate the Okun's relationship over about the same time period. Results by country should be taken with care, however, due to the relatively small sample post-crisis, which is evident also from a visual inspection of the data in Figure 1.

An important question pertaining to the estimates above has to do with the stability of Okun's law over time (see, e.g., Lee 2000, Knotek *et al.* 2007). Previous findings suggest that there has not been substantial change in Okun's coefficient after the Great Recession (Daly 2014; Ball et al., 2017) such as that the post-2008 the shock does not seem to challenge the validity of Okun's law.

[1] In the estimation, we use GNP as in Blanchard (1989) opposed to GDP.

Table 1 – Okun law estimates (univariate vs multivariate)
for 11 Euro Area countries, 1979 – 2019

| 1979-2019 | | | | | | |
|---|---|---|---|---|---|---|
| | OLS | | | SVAR | | |
| | Coeff. | St.error | R2 | Coeff. | St.error | R2 |
| AT | -0.169 | 0.049 | 0.235 | -0.071 | 0.079 | 0.195 |
| BE | -0.262 | 0.085 | 0.199 | -0.244 | 0.096 | 0.384 |
| FI | -0.349 | 0.055 | 0.511 | -0.224 | 0.088 | 0.537 |
| FR | -0.233 | 0.062 | 0.271 | -0.219 | 0.079 | 0.329 |
| DE | -0.221 | 0.059 | 0.270 | -0.064 | 0.063 | 0.538 |
| IE | -0.229 | 0.046 | 0.402 | -0.084 | 0.062 | 0.379 |
| IT | -0.135 | 0.065 | 0.101 | -0.084 | 0.072 | 0.334 |
| NL | -0.309 | 0.061 | 0.400 | -0.179 | 0.069 | 0.658 |
| PT | -0.338 | 0.060 | 0.455 | 0.033 | 0.274 | 0.528 |
| ES | -0.840 | 0.105 | 0.625 | -0.176 | 0.300 | 0.470 |
| GR | -0.367 | 0.061 | 0.491 | -0.067 | 0.091 | 0.635 |
| **AVER** | **-0.314** | **0.065** | **0.360** | **-0.125** | **0.116** | **0.453** |

Table 2 – Half-lives of the median heterogeneous composite impulse responses
across sample of unemployment to output growth
(SP-VAR for 11-euro area countries)

| 1979-2019 | Core | Core (PMR) | Core (EPL) | Core (TU) | Core (CBC) |
|---|---|---|---|---|---|
| Common | 6.000 | 3.000 | 3.000 | 3.000 | 3.000 |
| Idiosync. | 5.000 | 3.000 | 6.000 | 3.000 | 3.000 |
| | Periphery | Periphery (PMR) | Periphery (EPL) | Periphery (TU) | Periphery (CBC) |
| Common | 5.000 | 4.000 | 5.000 | 4.000 | 3.000 |
| Idiosync. | 7.000 | 4.000 | 4.000 | 4.000 | 4.000 |

Table 3 – Median heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for 11-euro area countries)

| | *Common* | *Idiosyncratic* |
|---|---|---|
| Conditioning set = NA | | |
| All | -0.11 | -0.3 |
| Core | -0.16 | -0.16 |
| Periphery | -0.19 | -0.4 |
| Conditioning set = PMR | | |
| All | -0.10 | -0.30 |
| Core | -0.12 | -0.16 |
| Periphery | -0.30 | -0.30 |
| Conditioning set = EPL | | |
| All | -0.13 | -0.3 |
| Core | -0.14 | -0.18 |
| Periphery | -0.38 | -0.4 |
| Conditioning set = TU | | |
| All | -0.09 | -0.27 |
| Core | -0.12 | -0.15 |
| Periphery | -0.30 | -0.3 |
| Conditioning set = CBC | | |
| All | -0.09 | -0.28 |
| Core | -0.13 | -0.15 |
| Periphery | -0.29 | -0.38 |

In what follows, we consider the structural identification jointly in the form of a SP-VAR, accounting for heterogenous effects, as explained in Section II. This is a much more informative way of reading the results than in traditional panel VAR analyses. In fact, knowing exactly how many countries in the sample present certain dynamics provides for much more robust inference than simply relying on average estimates. In addition, as shown by Pesaran & Smith (1995), if individual dynamics are heterogeneous, aggregating or pooling coefficient estimates can bias the results, making individual regressions for each group member mostly preferable.

Despite country-specific heterogeneity, the estimated SP-VAR is stable, and the variables are – by definition – stationary. This means shocks should be interpreted as temporary and, following any shock, variables are expected to converge back to their means or deterministic trends over the long run.

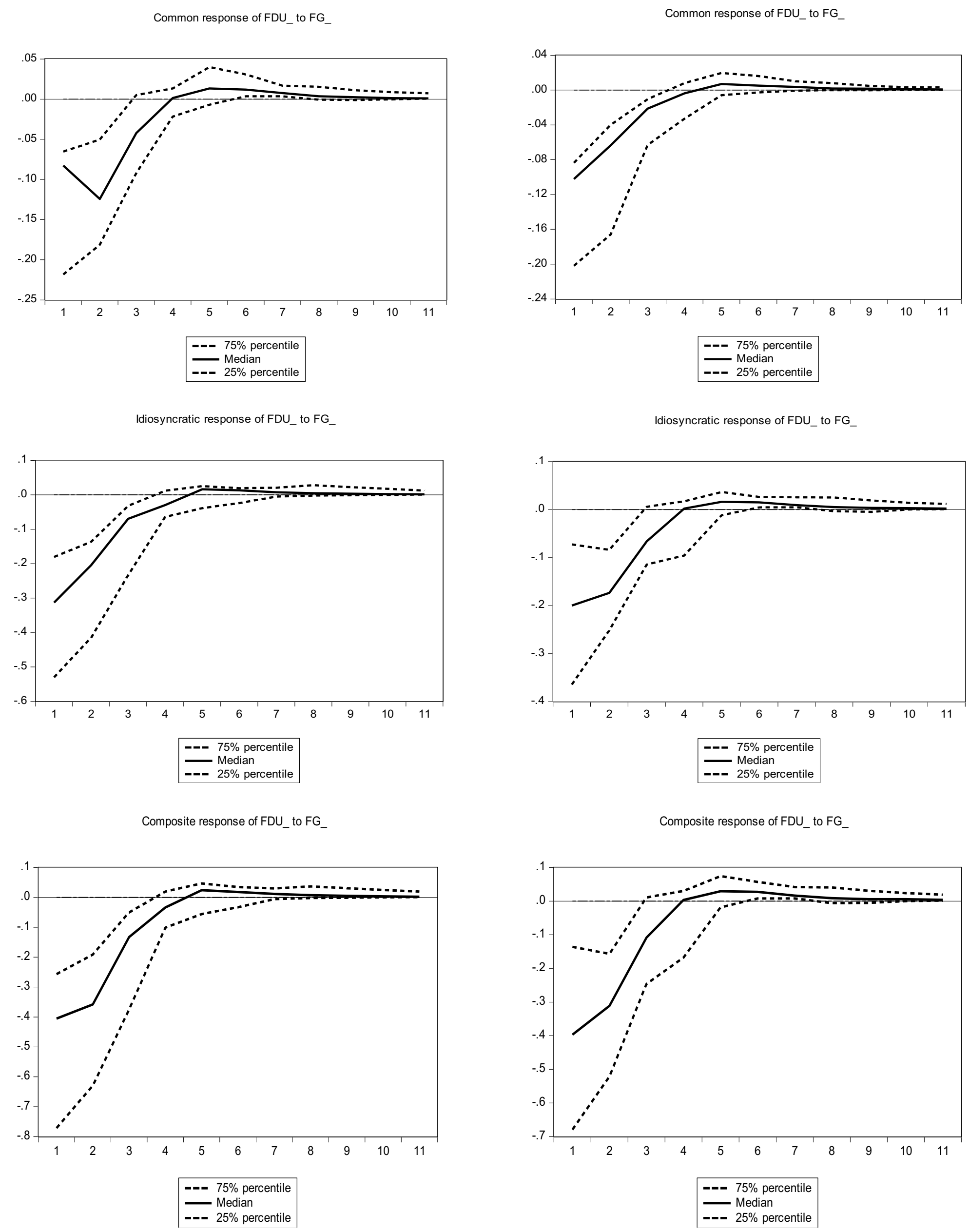
In Figure 2, we observe that our main hypothesis can be considered as strongly supported since the average heterogeneous composite impulse responses across sample of unemployment to output growth – displaying the dynamic impact of output growth on unemployment – is negative and averaging around -0.4. This is in line with the standard Okun's law predictions discussed previously.

This approach confirms that Okun's law is still valid in euro area countries, as there is the usual negative relationship between unemployment and output (Figure 2). The responses are then decomposed into country-specific responses to common shocks and responses to idiosyncratic shocks. Based on the impulse response functions, we calculate the median and the top/bottom quartiles (5%). The composite chart in Figure 2 for the pool of 11-euro area countries shows the negative relationship between output and unemployment. This result, while confirming previous findings, it also suggests the response is mostly driven by the impact of common responses in the sample, which tend to be much stronger. The findings are moreover not susceptible to whether we exclude the years since the Great Financial Crisis.

We then present the results by country groupings. We divide the sample in *core countries*: Austria, Belgium, Finland, France, Germany, Netherland; and *periphery countries*: Greece, Ireland, Italy, Portugal, Spain. As pointed out by Belke et al. (2016), there exists no broadly accepted and exact definition as to which countries belong to the core or to the periphery. For instance, some studies place Italy in the periphery group (e.g., Hughes-Hallet and Richter, 2008; Caporale et al., 2015), but recent evidence suggests otherwise, showing it has strong business cycle synchronization with the core (Belke et al., 2016; Campos and Macchiarelli, 2016). As far as the unemployment rate is concerned, we here place Italy in the periphery, in line with the idea that the labour market dynamics may be affected by its welfare systems (see also Macchiarelli et al., 2018).

Figure 2 – Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **11-euro countries**)

**FULL SAMPLE** **PRE-FINANCIAL CRISIS**




*Note:* The median and interquartile ranges were calculated from the distribution of IRFs of the 11 cross-sections.

When we look at different groups of countries, we find that, for the whole sample, the unemployment response to output tends to be varied. In particular, idiosyncratic shocks tend not to be much stronger on average in the periphery. This effect of common and idiosyncratic shocks is significant both in the cross-section of core (Figure 3 (a)), and peripheral countries (Figure 3 (b)).

Figure 3 – (a) Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **core countries**)

**FULL SAMPLE** **PRE-FINANCIAL CRISIS**

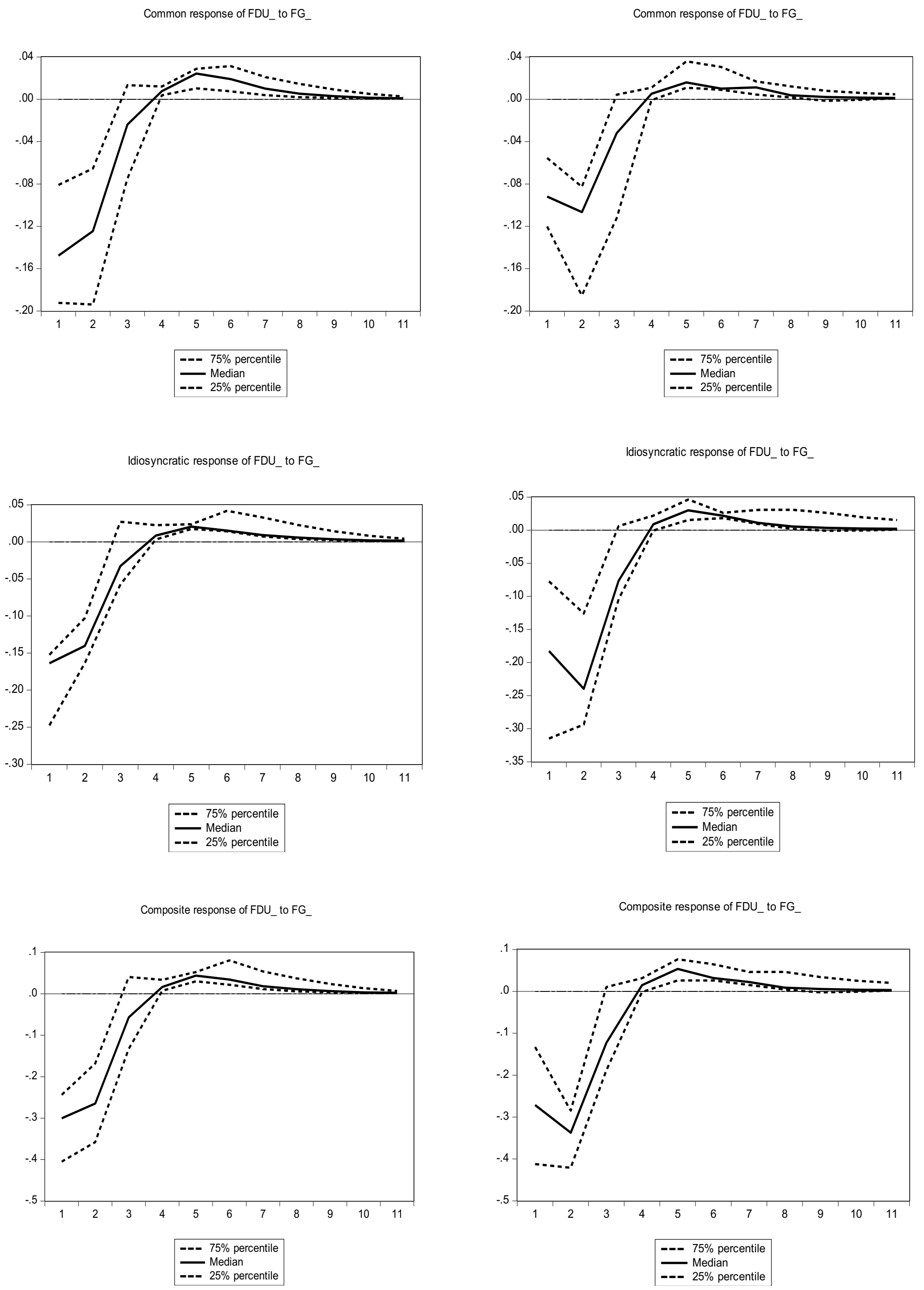
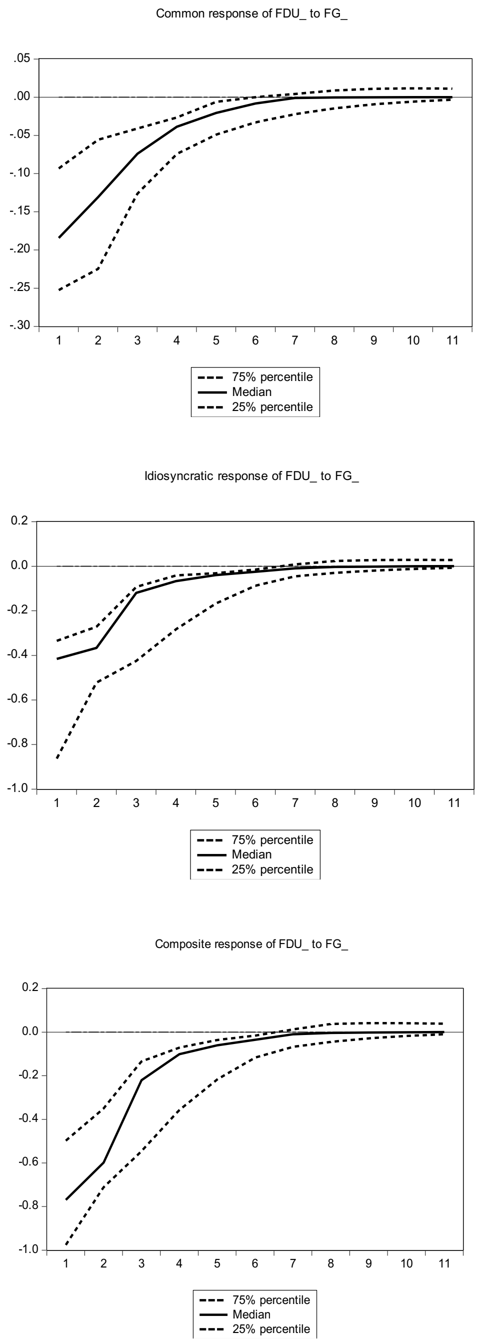
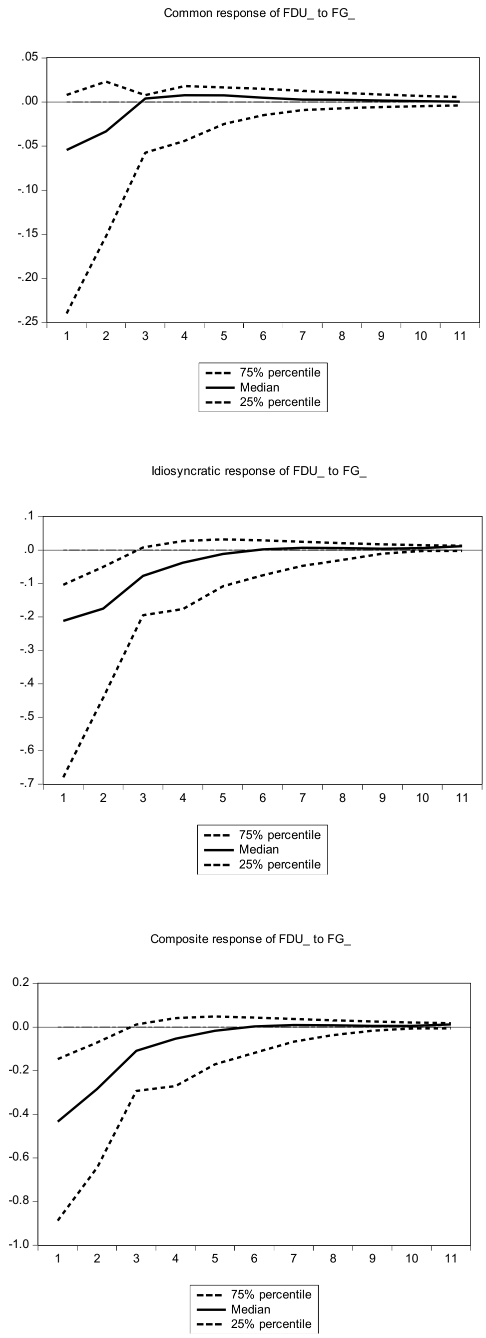


Figure 3 - (b) Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **peripheral countries**)

**FULL SAMPLE**




**PRE-FINANCIAL CRISIS**




*Note:* The median and interquartile ranges were calculated from the distribution of IRFs of the 11 cross-sections.

While country fixed effects are taken into account in the SP-VAR, there might be still country specific (or labor market 'type') time-varying effects that could lead to an important endogeneity bias. One could argue the heterogeneous composite impulse responses across sample of unemployment to output growth are simply capturing different labor market types instead of changes deep-rooted in the Okun's law structural relationship. For instance, does the unemployment response have a stronger (negative) impact in countries that have more flexible labor markets? As idiosyncratic (and common) factors may have been affected by structural reforms, the latter can be useful tool to explain the decomposition of shocks. To address this concern, we calculate the effects of several exogenous variables in our model, by conditioning the SP-VAR on the following set of covariates, one at a time: product market regulation (PMR), employment product legislation (EPL), trade of union intensity (TU), collective bargaining coverage (CBC).

In Table 2 we look at the median IRFs half-lives (the first number is the number of years it takes to go to 0.0) as follows. Let $f$ denote the sampling frequency of the data ($f = 1$ for years). Let $\varphi(f)$ denote the median response of unemployment to a unit demand shock $i$ periods ago. First, we find the largest $i$ in the range $(1, \ldots, 11)$ for which $\varphi(f) = 0.0$; we denote that $i$ by $h$. Secondly, we verify $\varphi(j) < 0.1$ for all $j > h$ for at least another 5 years. This condition effectively rules out unstable or explosive oscillatory patterns. If $h$ satisfies this second condition, we say that $h$ is the half-life. The findings show that the main effect of exogenous parameters is visible primarily on idiosyncratic shocks in the periphery and common shocks in the core.

When conditioning the SP-VAR on PMR, for instance, the typical Okun's response of unemployment to output growth tend to fade more quickly, as regulation seem to hinder the labor market adjustment in the medium run. When conditioning on institutional factors in particular, the half-life of idiosyncratic response (median) is almost halved in most cases. Importantly, this effect appears to be slightly larger in peripheral countries where idiosyncratic shocks are stronger. On the contrary moderate levels of PMR, trade union density and central bargaining, as observed in the core countries, seem to affect common responses of unemployment to output in core countries by a similar degree. This suggests not only that the group of countries considered as 'core' is more homogenous, but also that countries that have flexible labor market on average are more sensitive to frictions and limits to lay-offs and/or hiring in the light of business cycle fluctuations.

The heterogeneous composite impulse responses across sample of unemployment to output growth, conditional on PMR, EPL, TU and CBC are reported in Figure 4-11, both for the all 11-euro area countries, and for the core-periphery split, looking both at our full sample and for the period just before GFC. In the periphery, and in some countries in particular, the share of contracts covered by some form of collective bargaining is among the highest among Western countries: around 85%. This happens even though union membership is on the low side. The potential reason is that collective contracts typically apply to non-unionized workers as well as unionized ones, and they are also enforced outside the sector where they are negotiated. Among core countries, in Germany, for instance, the institutional framework is very different. Collective bargaining takes place at regional/lander level; this helps keeping wages well in line with firms' productivity in a situation where there is a lot of heterogeneity among regions.

### *4.2. Sample excluding the GFC*

Here we explored the heterogeneous composite impulse responses of unemployment to output growth by excluding the crisis years, i.e. considering the sample 1979-2008 (consistent with the idea that unemployment rate often presents a structural break around 2008; see Macchiarelli *et al.*, 2018), as well as since the introduction of the euro, i.e. 2000-2019 (the latter shown in the on-line Appendix), as an obvious potential criticism of our finding of the stability of the Okun's coefficient could be around the existence of structural changes. The results are reported in the Figures 2 – 11, both for the whole cross-section of 11-euro area countries, and for the core-periphery split for the sample excluding the Global Financial Crisis (for the results over the 2000-2019 period see Appendix, Figures 12 - 21). This allows assessing the stability of the Okun's law and the marginal contribution to the SP-VAR Impulse Response Functions of the crisis years post-2009.

The results are robust to these different sample specifications, i.e., the years of the euro and the GFC, and do not vary by conditioning the P-VAR on institutional indicators over the 11 countries considered. The results for the periphery are however mainly explained by the strictness of product market regulation during the crisis years 2009-2019. On the other side, the findings tend to be more homogenous for the group of core countries. That is, when we exclude the crisis years and condition our framework on PMR, the Okun's law relationship is no longer valid for peripheral countries.

## 5. Conclusions

By relaxing the usual limitations of estimating Okun's law in a univariate setting, we find that the responsiveness of output to unemployment has not particularly weakened in the euro area countries post-crisis. The validity of the Okun's law is driven by common shocks across core and periphery country groups. Looking at heterogeneous effects across countries, the results are however mainly explained by product market regulation for the periphery during the years of the Global Financial Crisis. In other words, the recession in the euro area periphery, which brought about strong labor market adjustments in those countries, substantially helps to explain the significance of Okun's law. Yet, when the years of the crisis are excluded, high levels of product market regulation would normally hinder the regular labor market adjustment in peripheral countries. In the list of priorities for labor market reforms, we think that tackling high levels of product market regulation rigidities should come first. Otherwise, reviving growth in a labor market with high nominal frictions could risk having little effect on employment, and labor productivity more generally.

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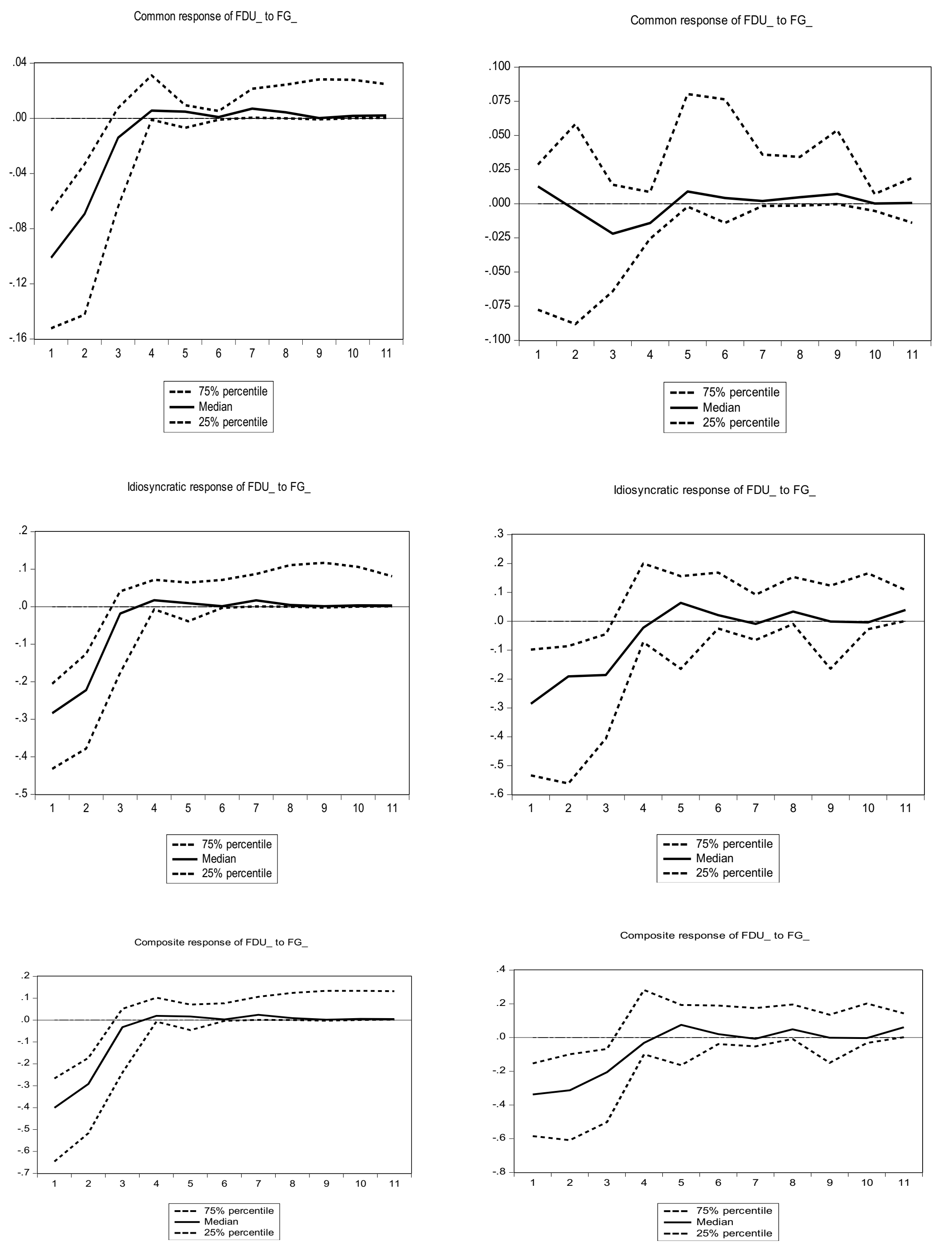
# Appendix

Figure 4 – Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **11-euro countries**), conditional on **PMR**

**FULL SAMPLE** | **PRE-FINANCIAL CRISIS**




*Note:* The median, and interquartile ranges were calculated from the distribution of IRFs of the 11 cross-sections.

Figure 5 – (a) Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **core countries**), conditional on **PMR**

**FULL SAMPLE** | **PRE-FINANCIAL CRISIS**

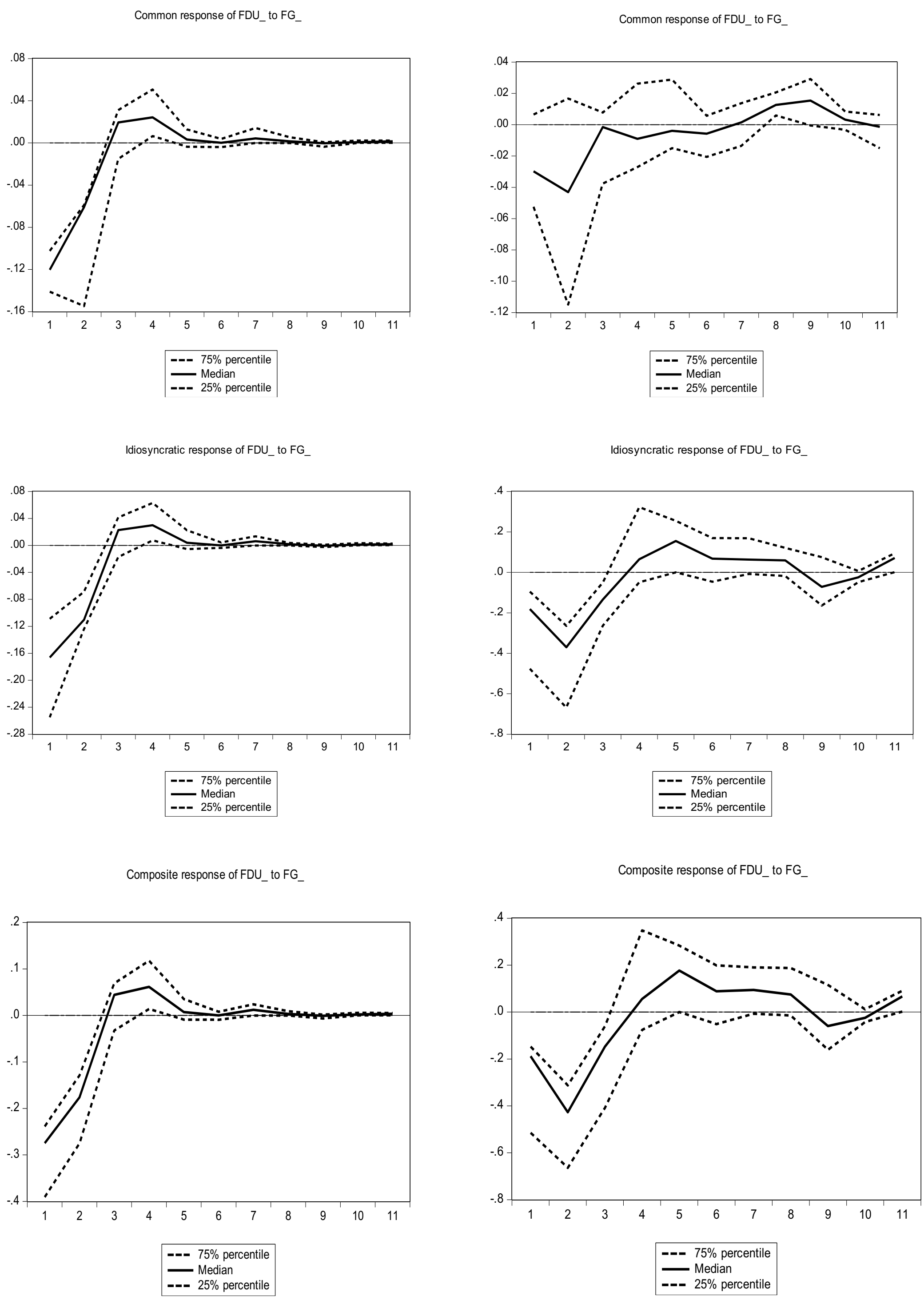
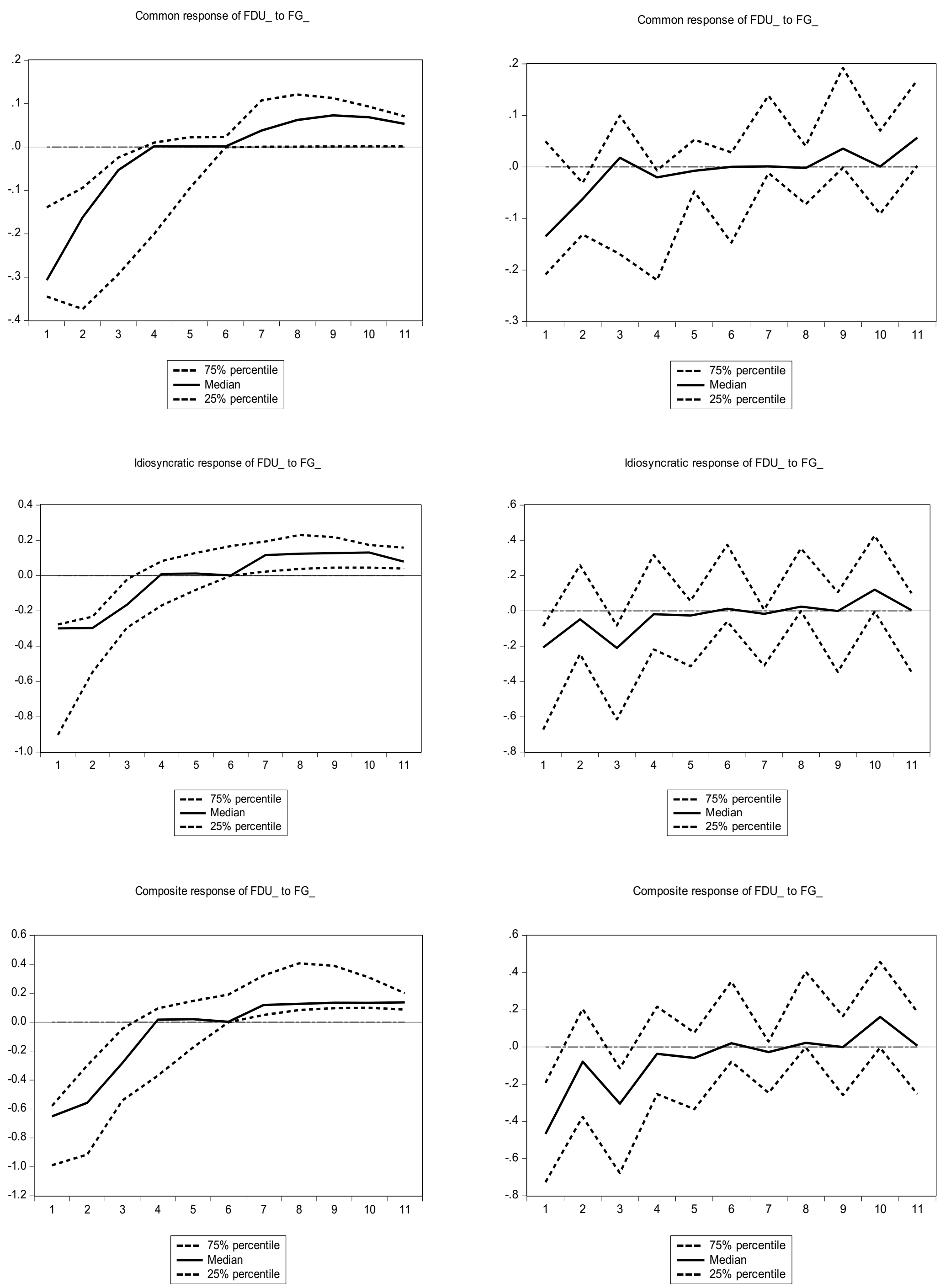


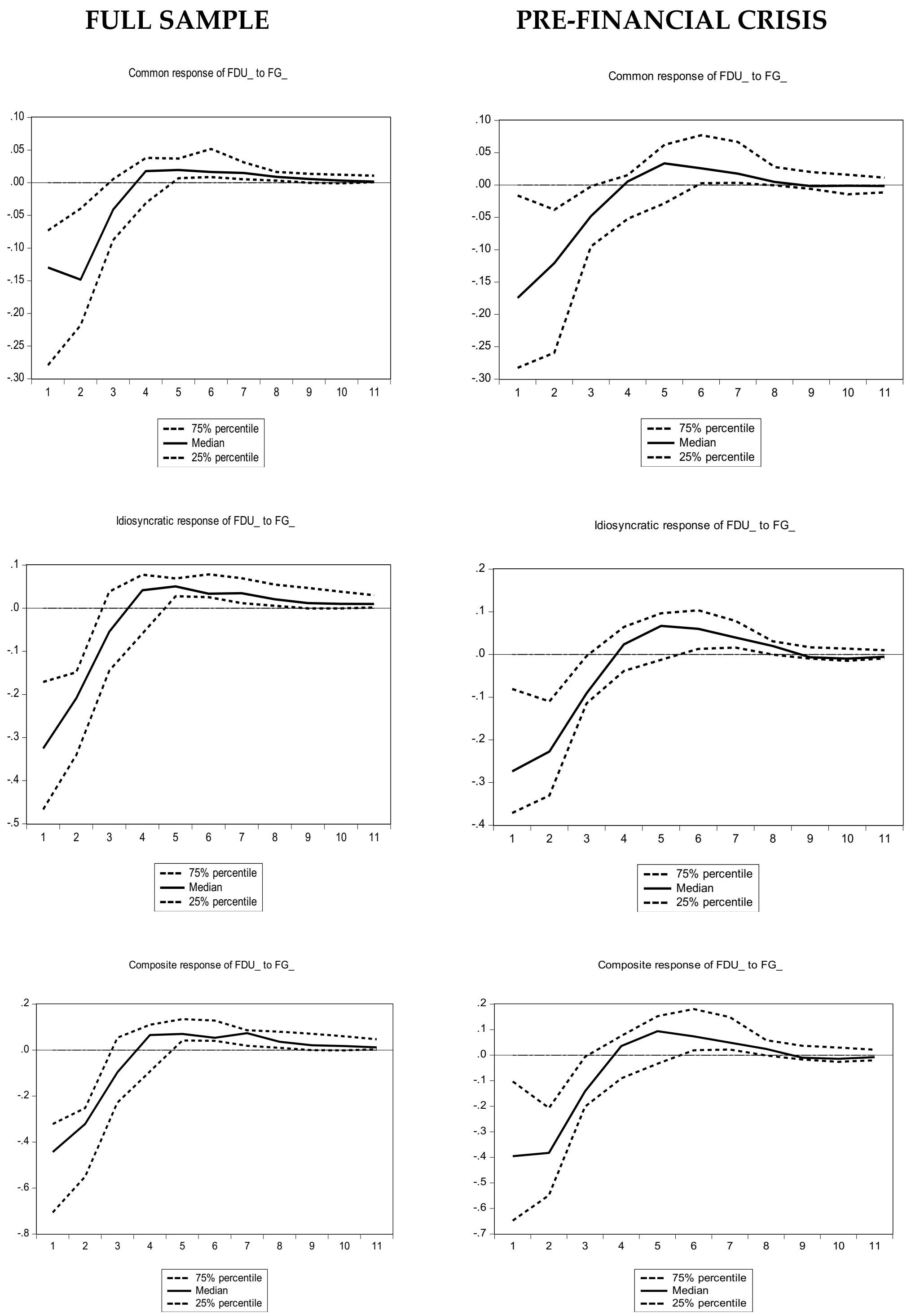
Figure 5 - (b) Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **peripheral countries**), conditional on **PMR**

**FULL SAMPLE** **PRE-FINANCIAL CRISIS**




*Note:* The median and interquartile ranges were calculated from the distribution of IRFs of the 11 cross-sections.

Figure 6 – Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **11-euro countries**), conditional on **EPL**




*Note:* The median and interquartile ranges were calculated from the distribution of IRFs of the 11 cross-sections.

Figure 7 – (a) Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **core countries**), conditional on **EPL**

**FULL SAMPLE** **PRE-FINANCIAL CRISIS**

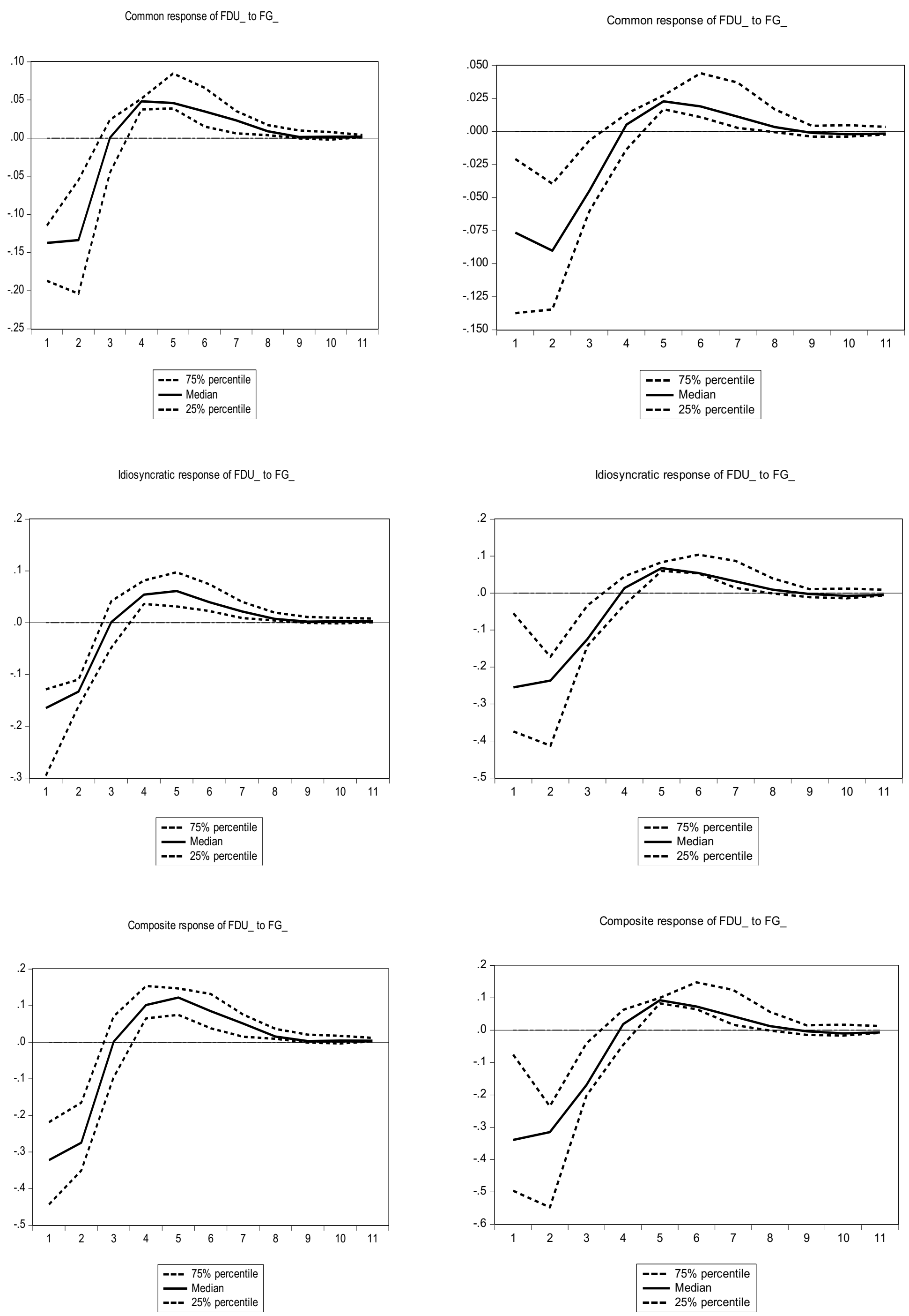
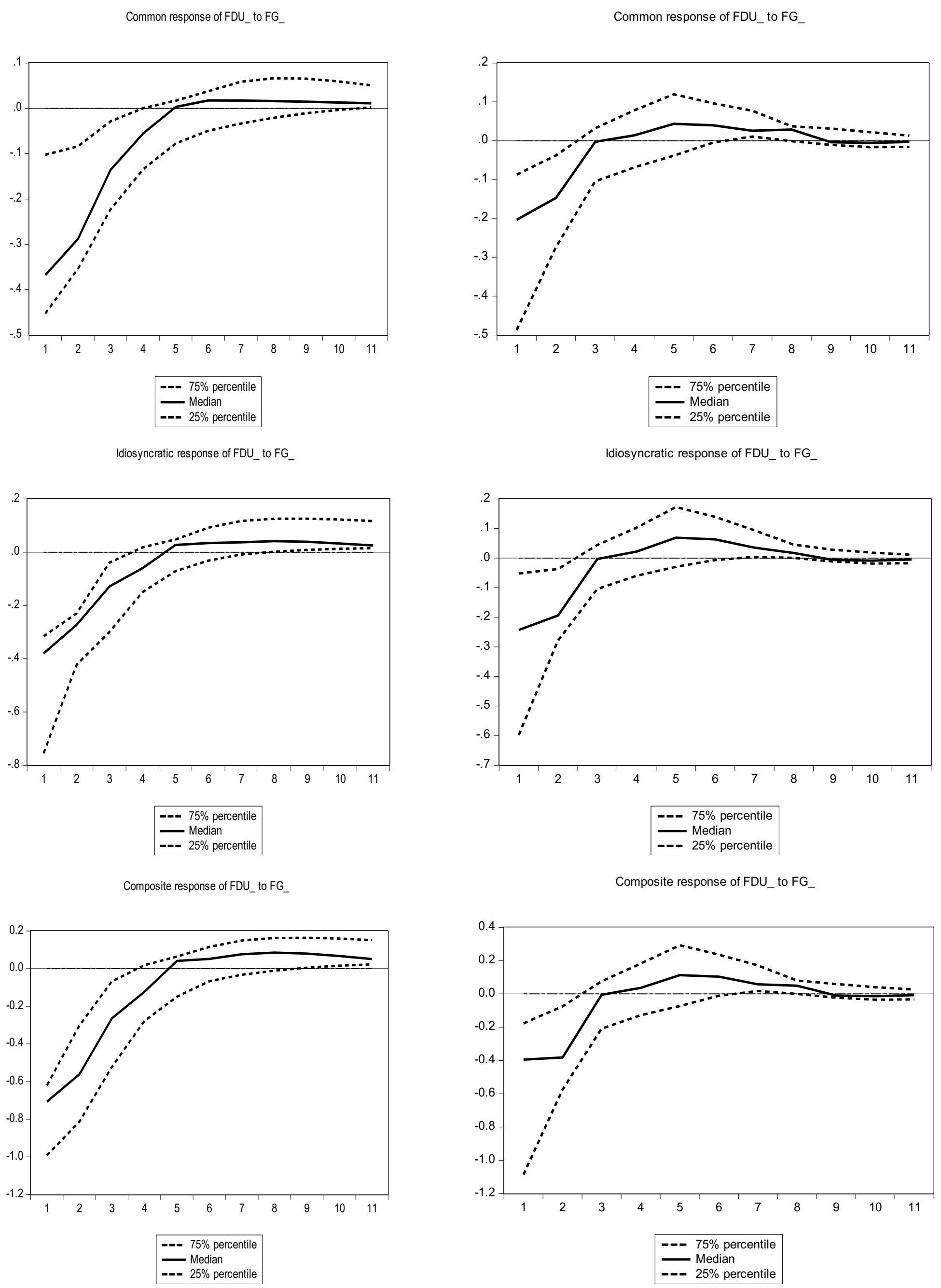


Figure 7 - (b) Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **peripheral countries**), conditional on **EPL**

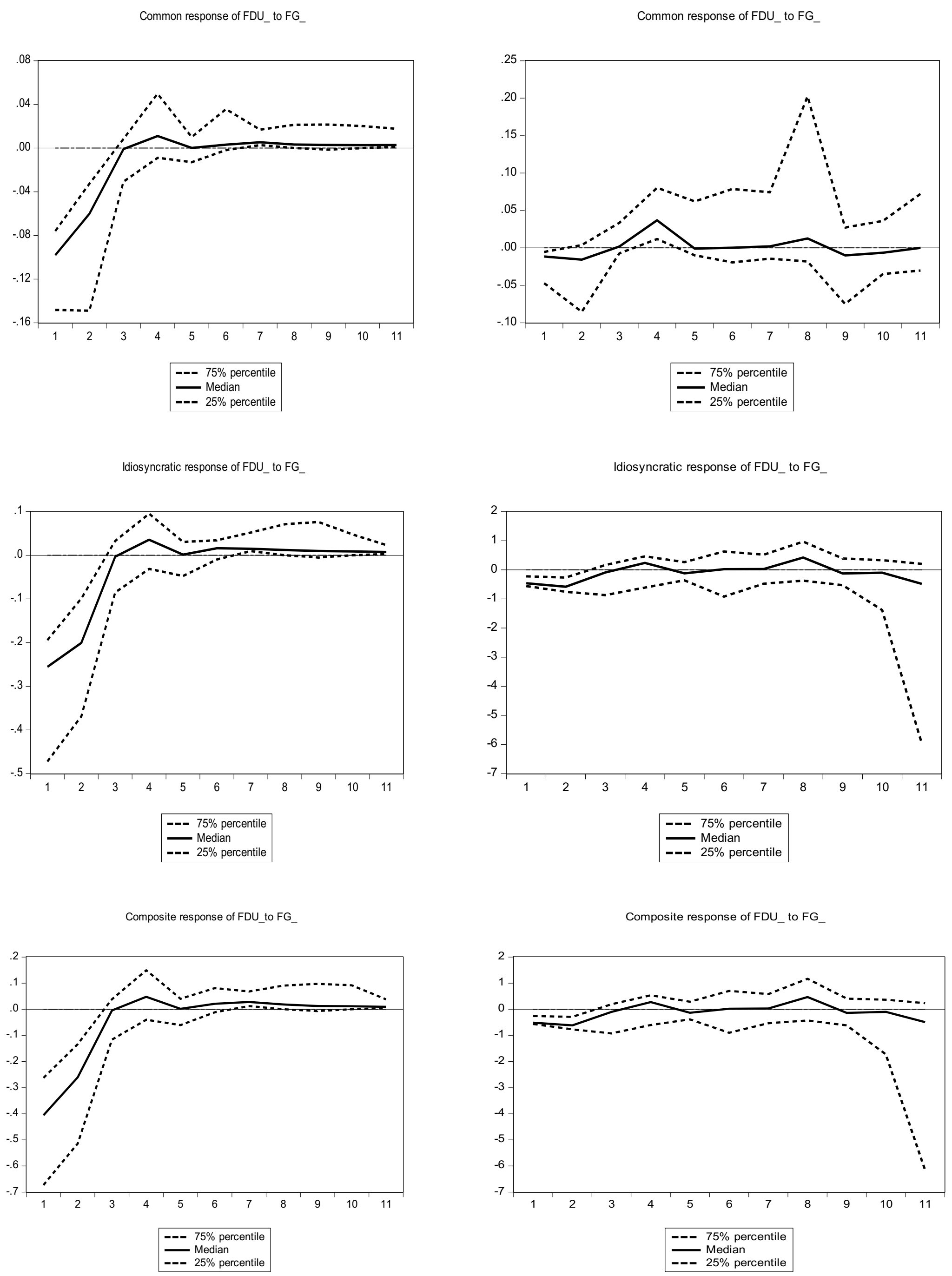
**FULL SAMPLE** | **PRE-FINANCIAL CRISIS**




*Note:* The median, averages, and interquartile ranges were calculated from the distribution of IRFs of the 11 cross-sections.

Figure 8 – Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **11-euro countries**), conditional on **TU**

**FULL SAMPLE** **PRE-FINANCIAL CRISIS**




*Note:* The median and interquartile ranges were calculated from the distribution of IRFs of the 11 cross-sections.

Figure 9 – (a) Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **core countries**), conditional on **TU**

**FULL SAMPLE** **PRE-FINANCIAL CRISIS**

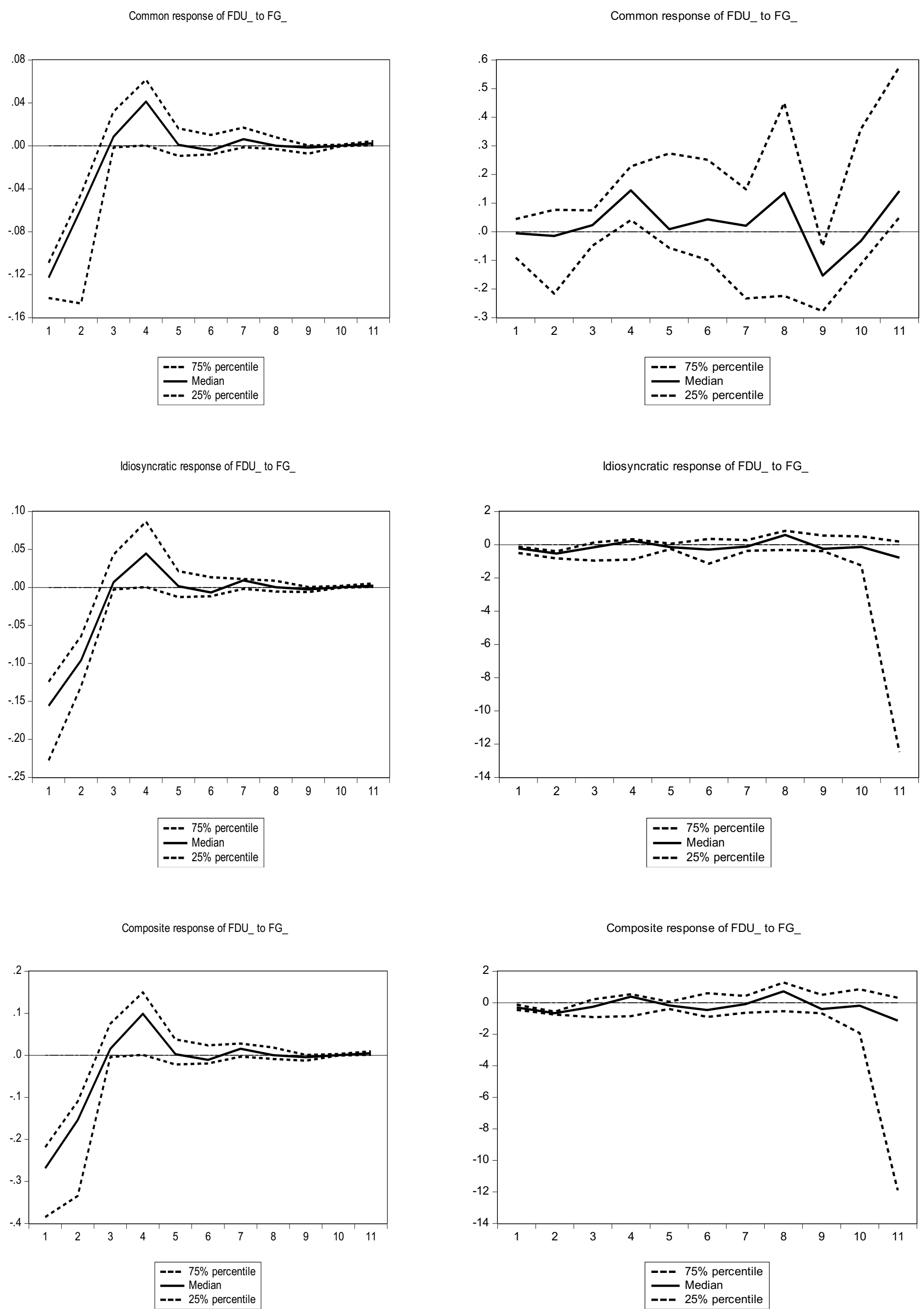
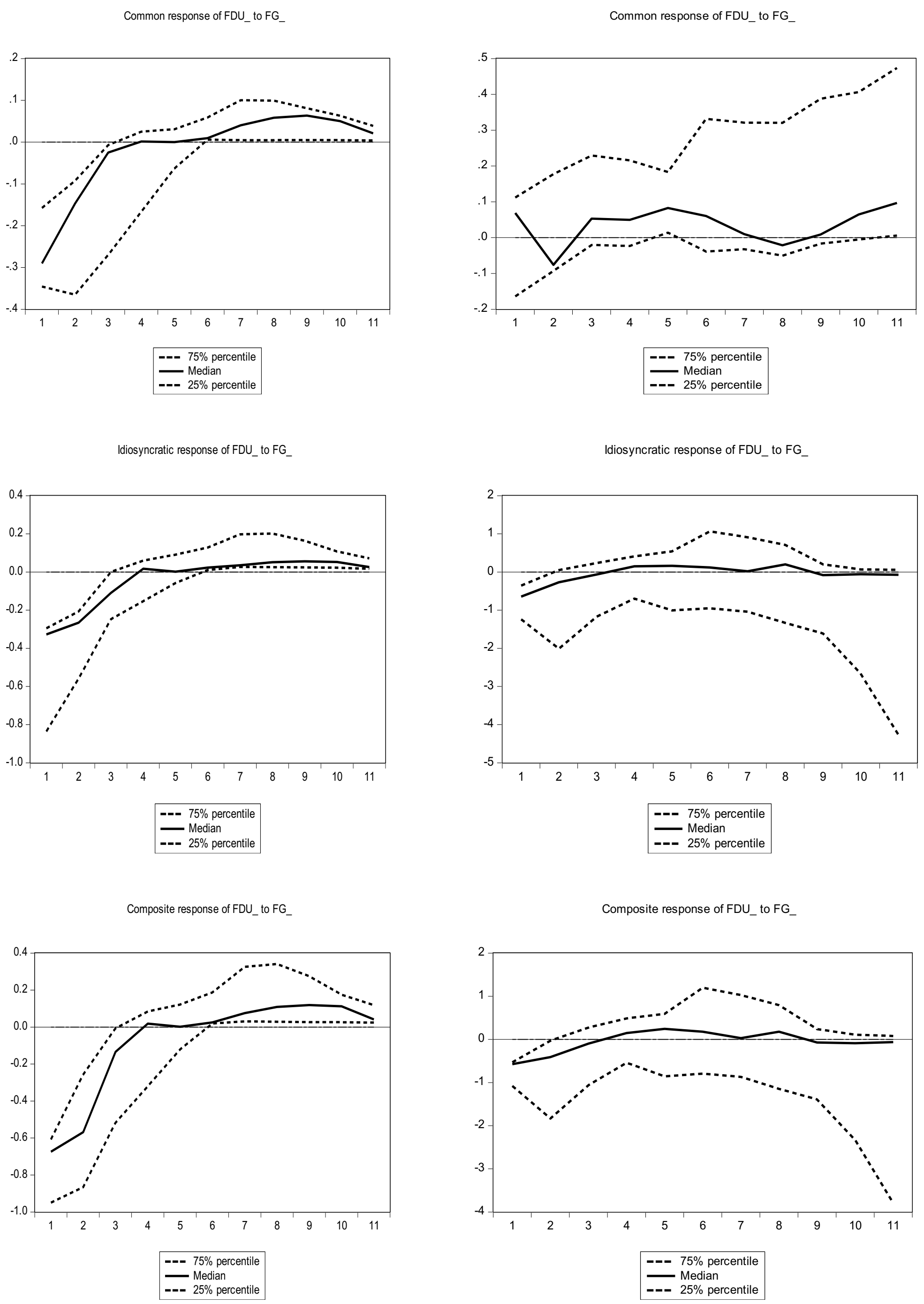


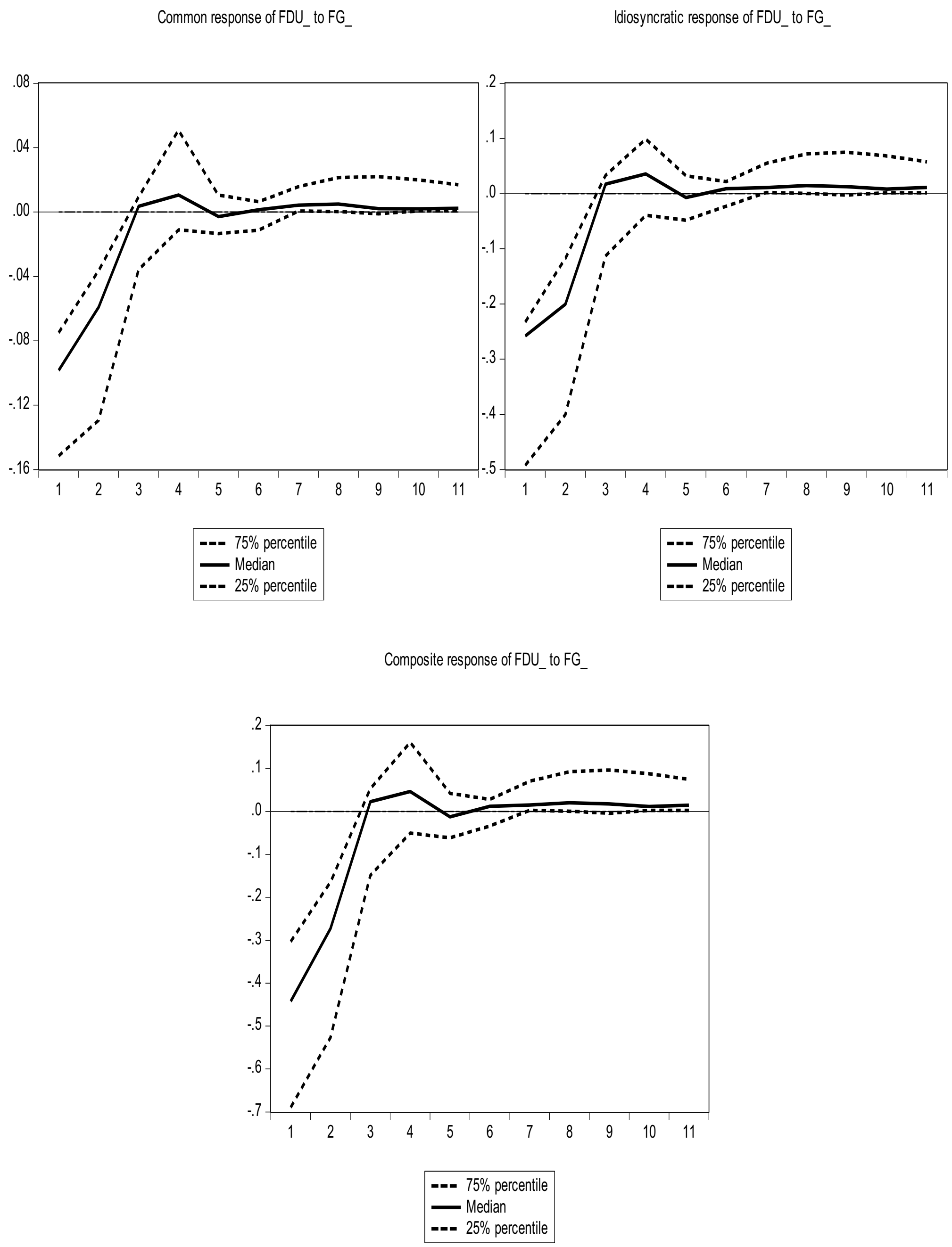
Figure 9 – (b) Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **peripheral countries**), conditional on **TU**

**FULL SAMPLE** | **PRE-FINANCIAL CRISIS**




*Note:* The median, averages, and interquartile ranges were calculated from the distribution of IRFs of the 11 cross-sections.

Figure 10 – Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **11-euro countries**), conditional on Collective Bargaining (**CBC)**




*Note:* The median and interquartile ranges were calculated from the distribution of IRFs of the 11 cross-sections

Figure 11 – (a) Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **core countries**), conditional on **CBC**

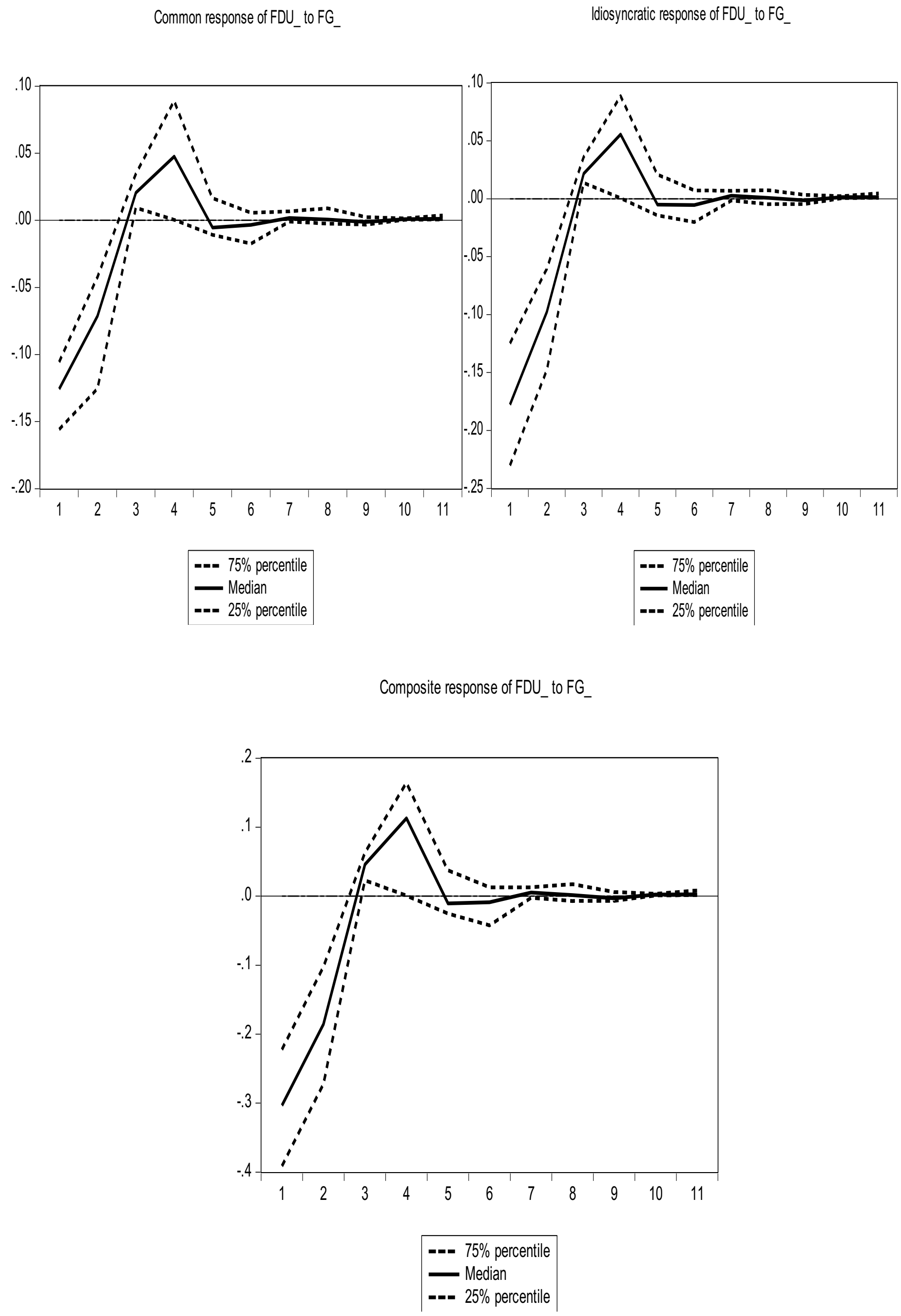
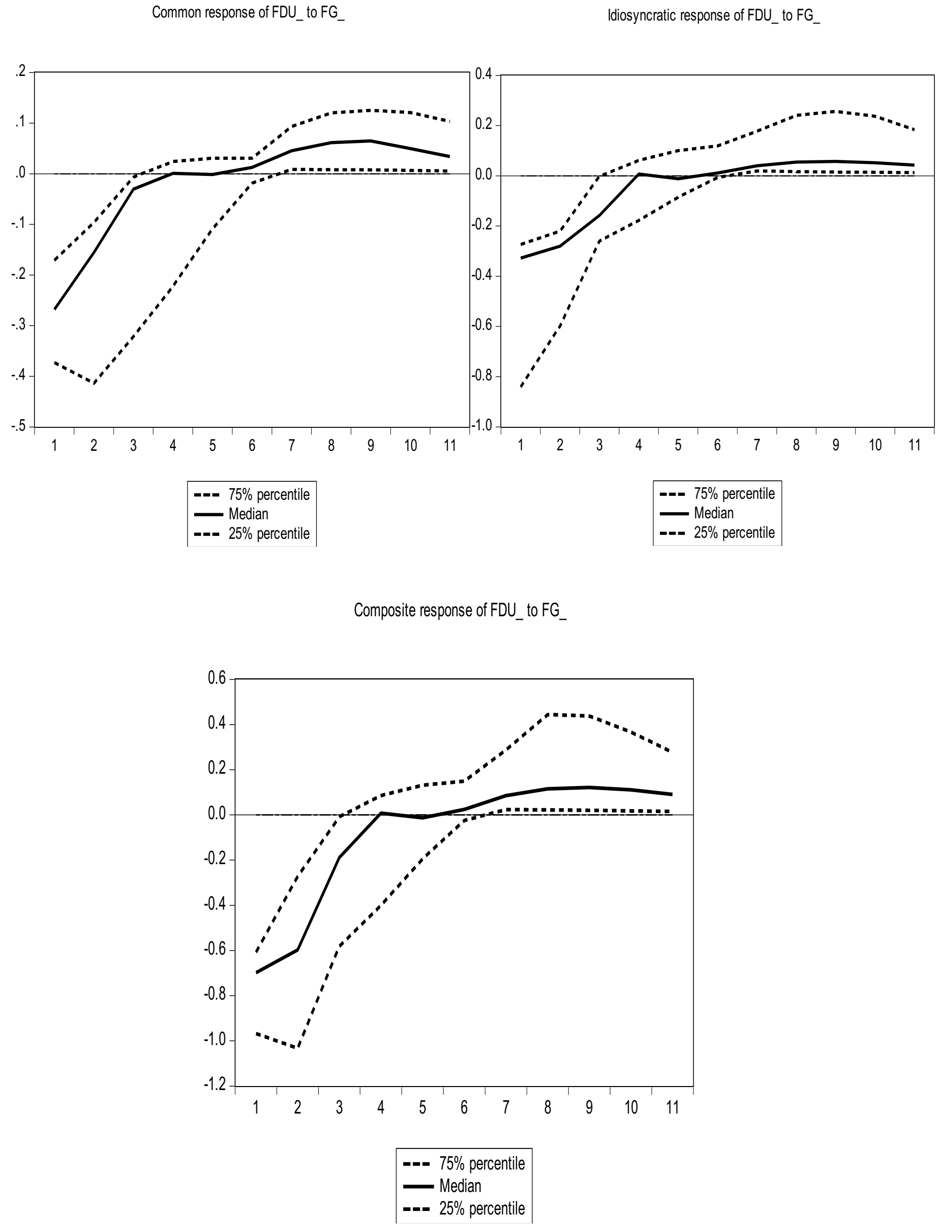


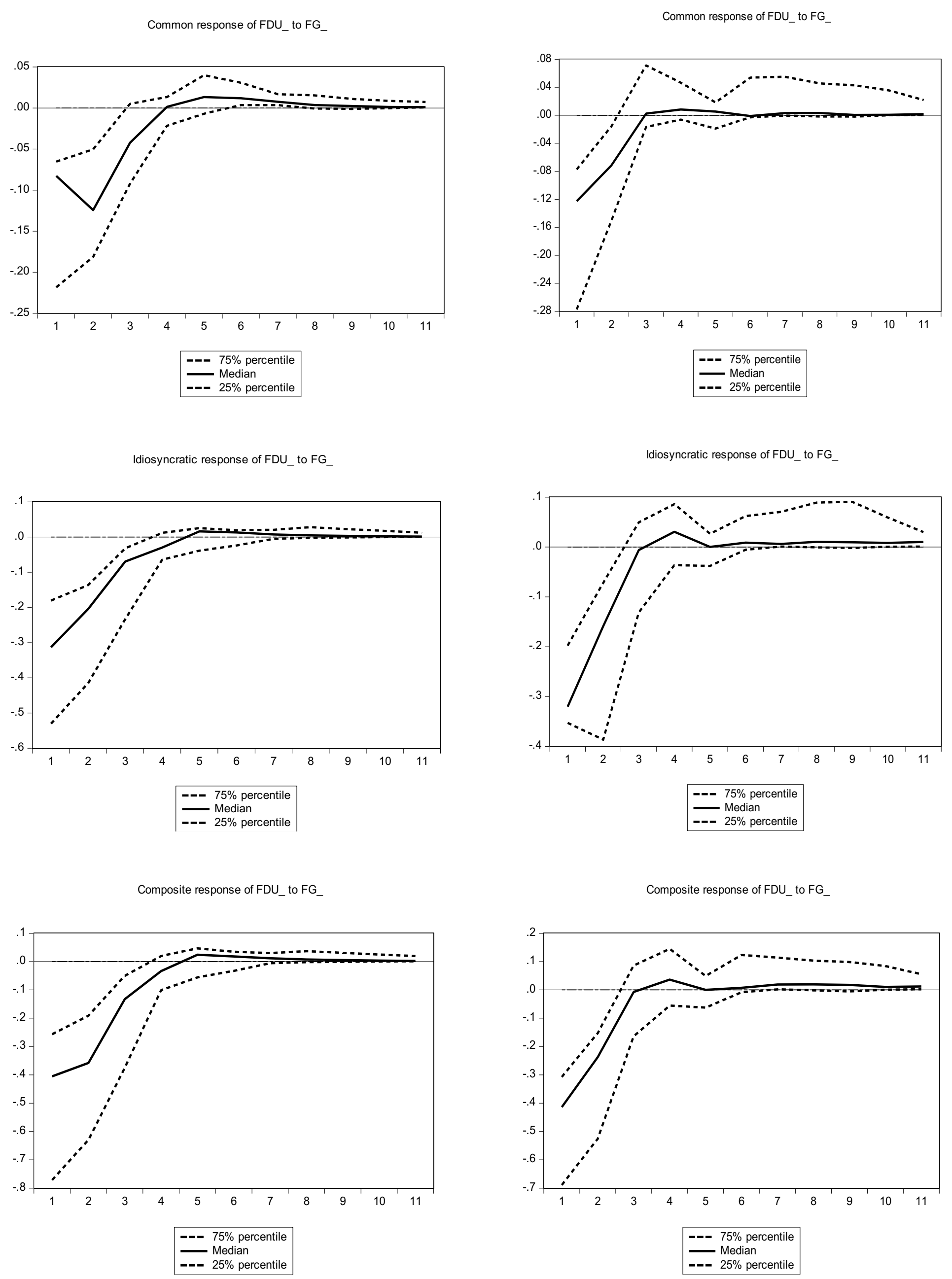
Figure 11 - (b) Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **peripheral countries**), conditional on **CBC**




*Note:* The median, averages, and interquartile ranges were calculated from the distribution of IRFs of the 11 cross-sections.

Figure 12 – Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **11-euro countries**)

**FULL SAMPLE** **SINCE COMMON CURRENCY**




*Note:* The median, averages, and interquartile ranges were calculated from the distribution of IRFs of the 11 cross-sections.

Figure 13 – (a) Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **core countries**), **eurozone period 2000-2019**

**FULL SAMPLE** | **SINCE COMMON CURRENCY**

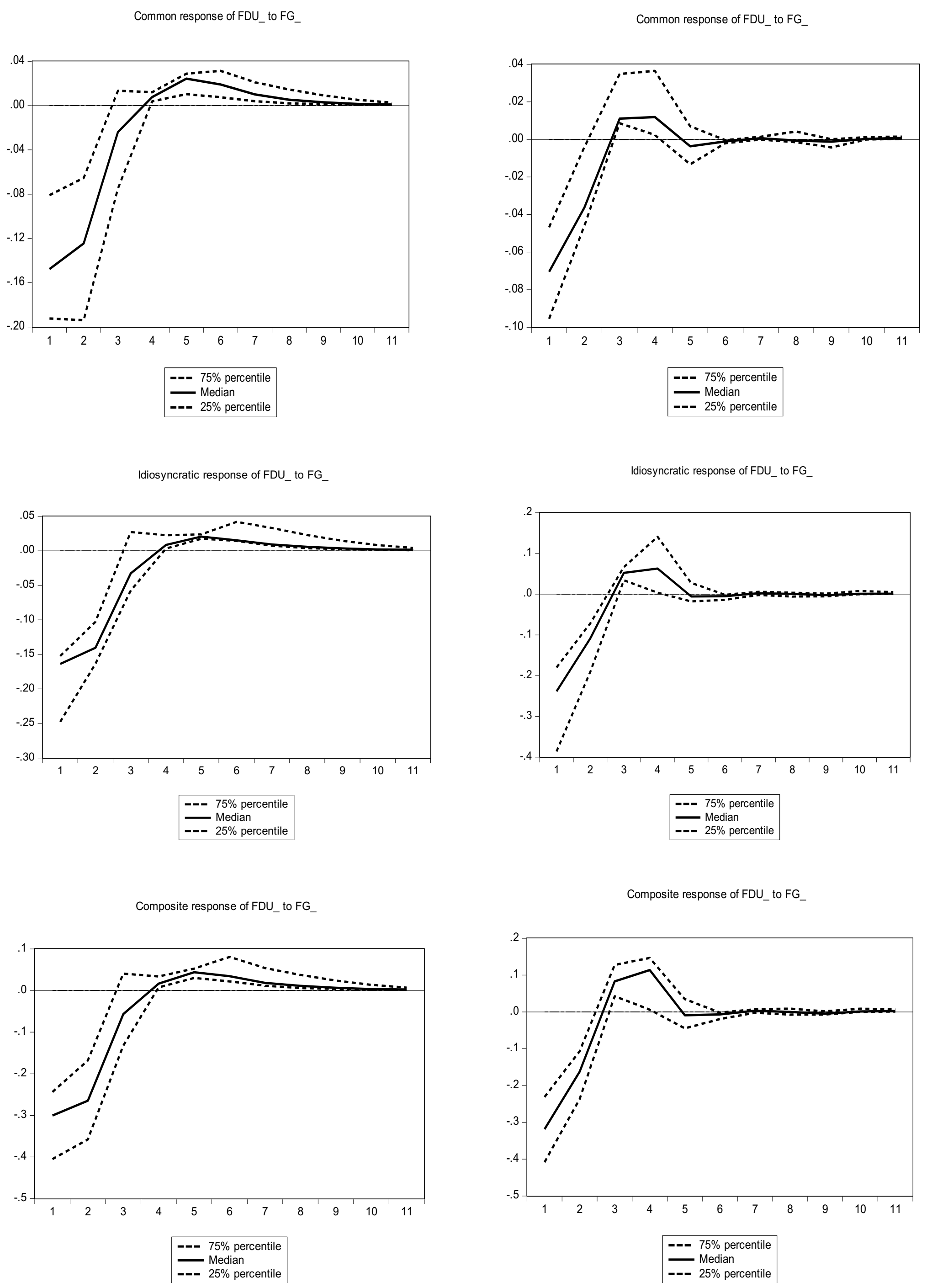
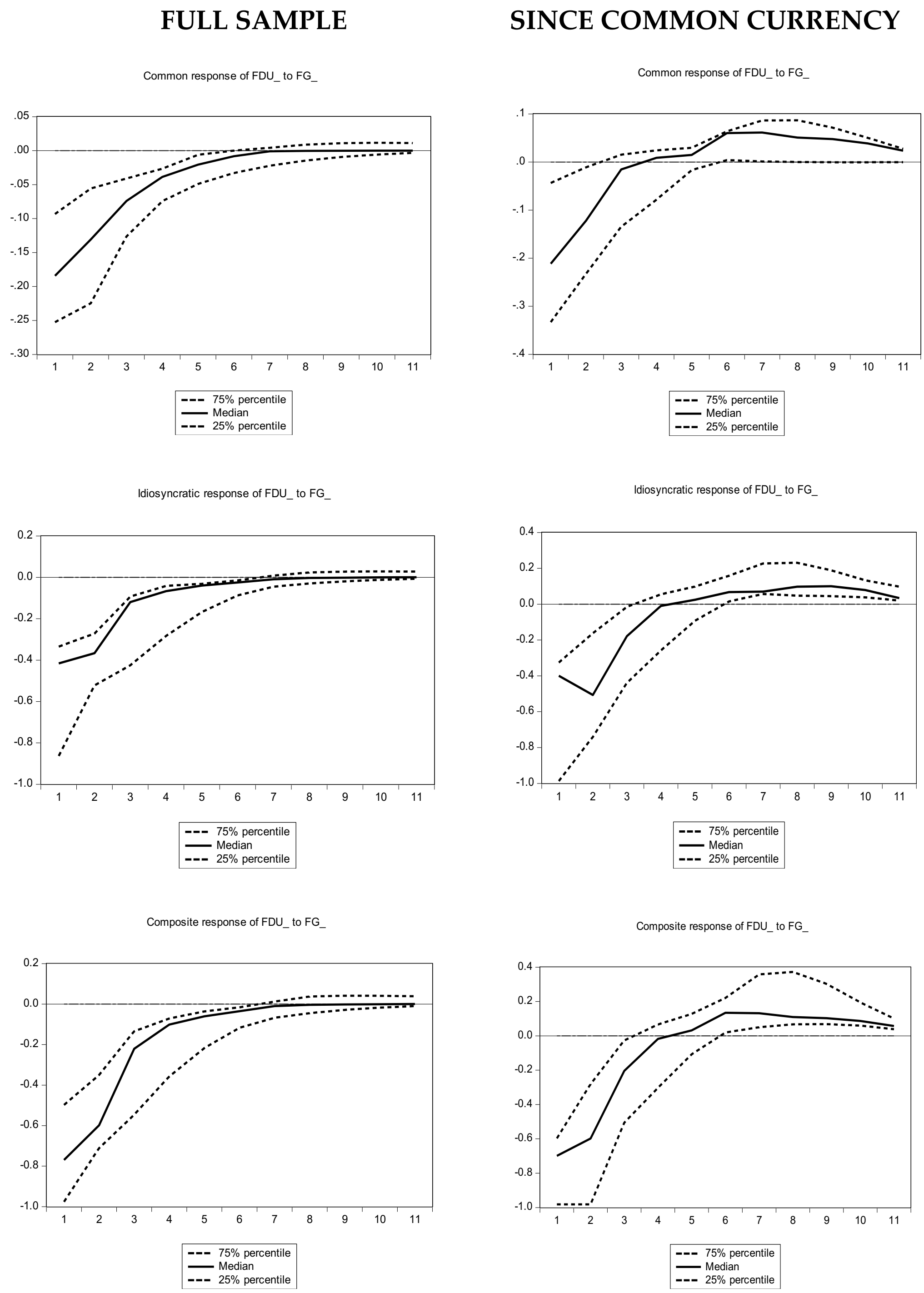
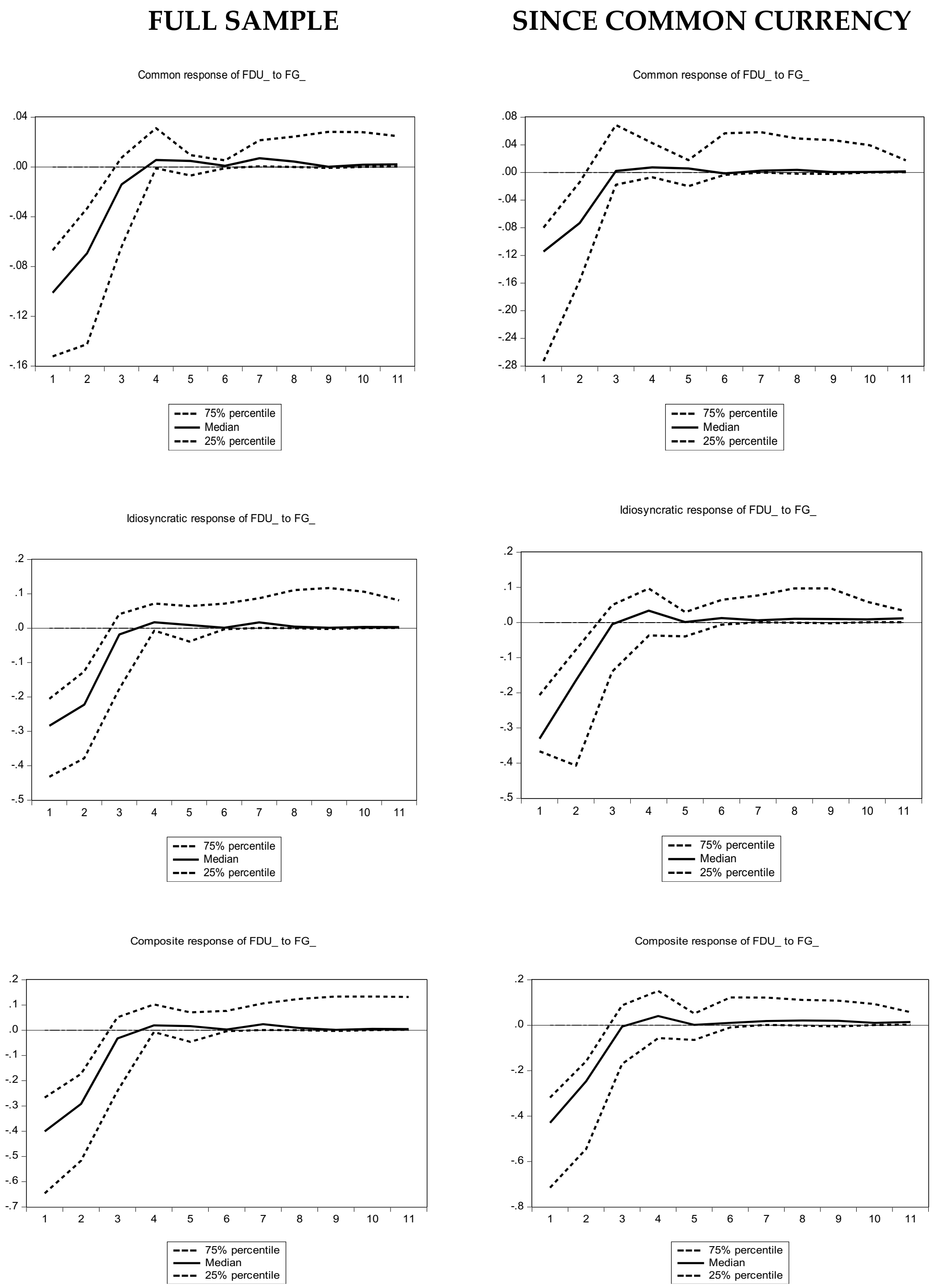


Figure 13 – (b) Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **peripheral countries**)




*Note:* The median, averages, and interquartile ranges were calculated from the distribution of IRFs of the 11 cross-sections.

Figure 14 - Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **11-euro countries**), **conditional on PMR**




*Note:* The median, averages, and interquartile ranges were calculated from the distribution of IRFs of the 11 cross-sections.

Figure 15 – (a) Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **core countries**), **conditional on PMR**

**FULL SAMPLE** **SINCE COMMON CURRENCY**

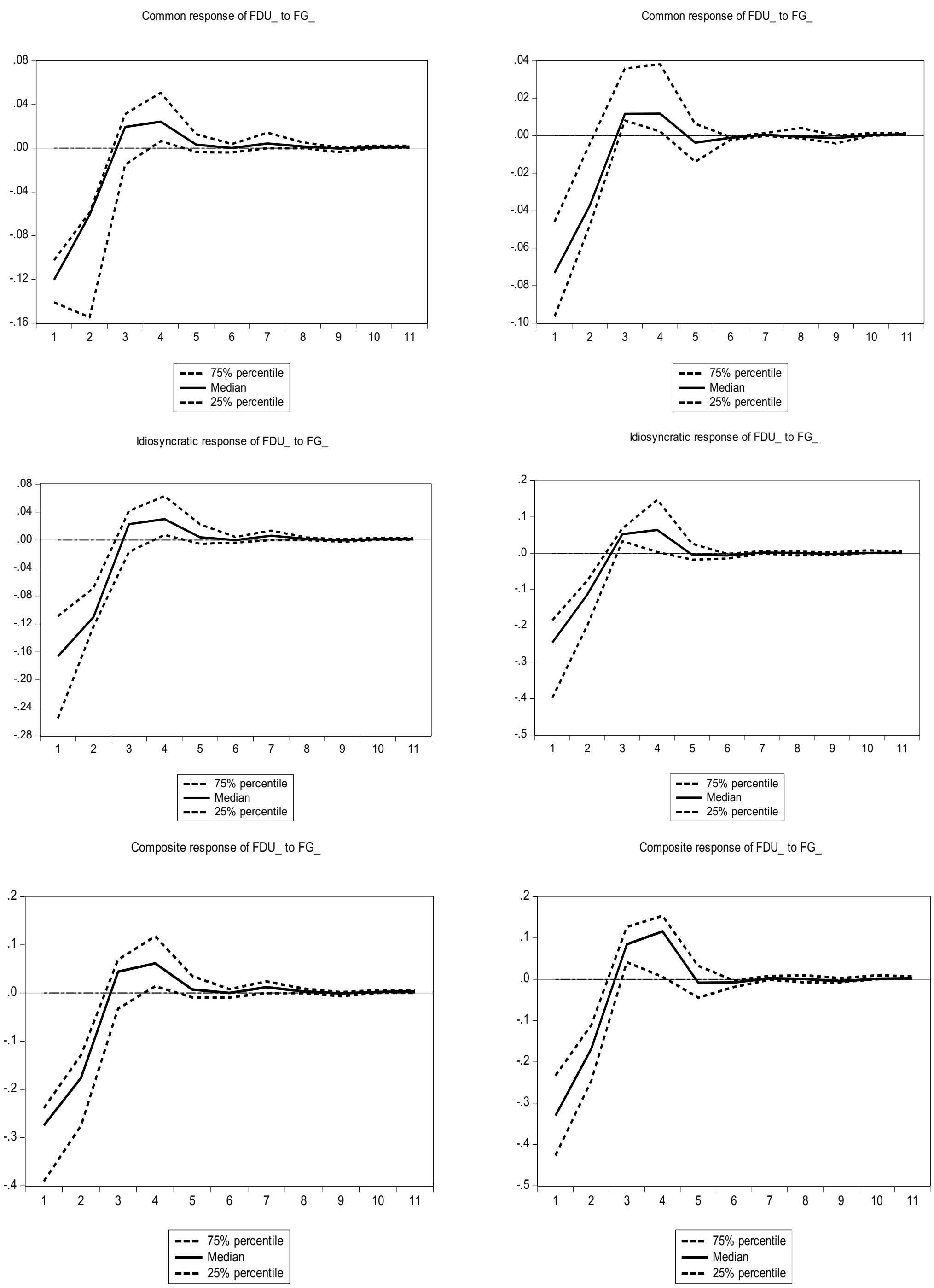
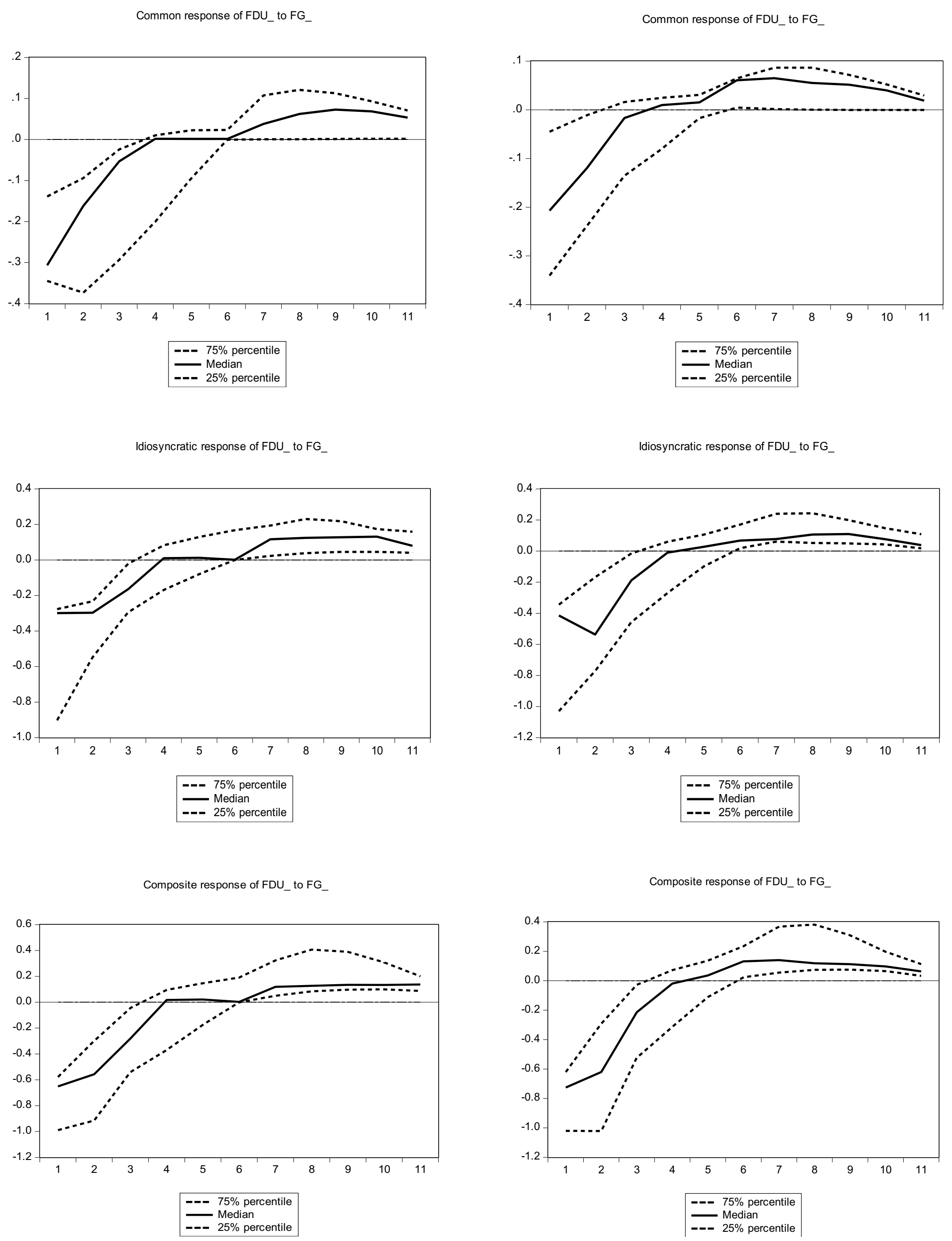


Figure 15 – (b) Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **peripheral**), **conditional on PMR**

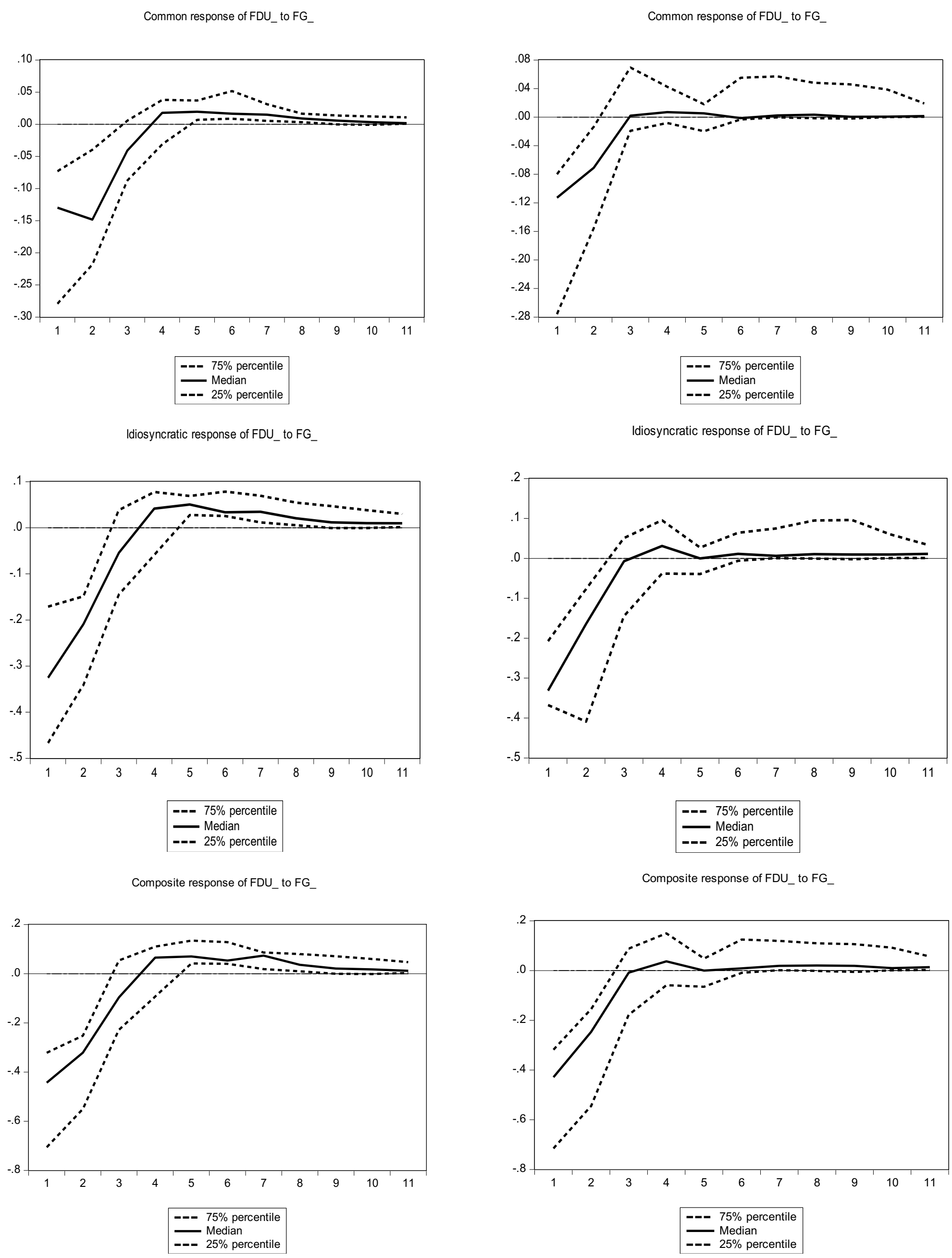
**FULL SAMPLE** | **SINCE COMMON CURRENCY**




*Note:* The median, averages, and interquartile ranges were calculated from the distribution of IRFs of the 11 cross-sections.

Figure 16 - Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **11-euro countries**), **conditional on EPL**

**FULL SAMPLE** **SINCE COMMON CURRENCY**




*Note:* The median, averages, and interquartile ranges were calculated from the distribution of IRFs of the 11 cross-sections.

Figure 17 – (a) Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **core countries**), **conditional on EPL**

**FULL SAMPLE** | **SINCE COMMON CURRENCY**

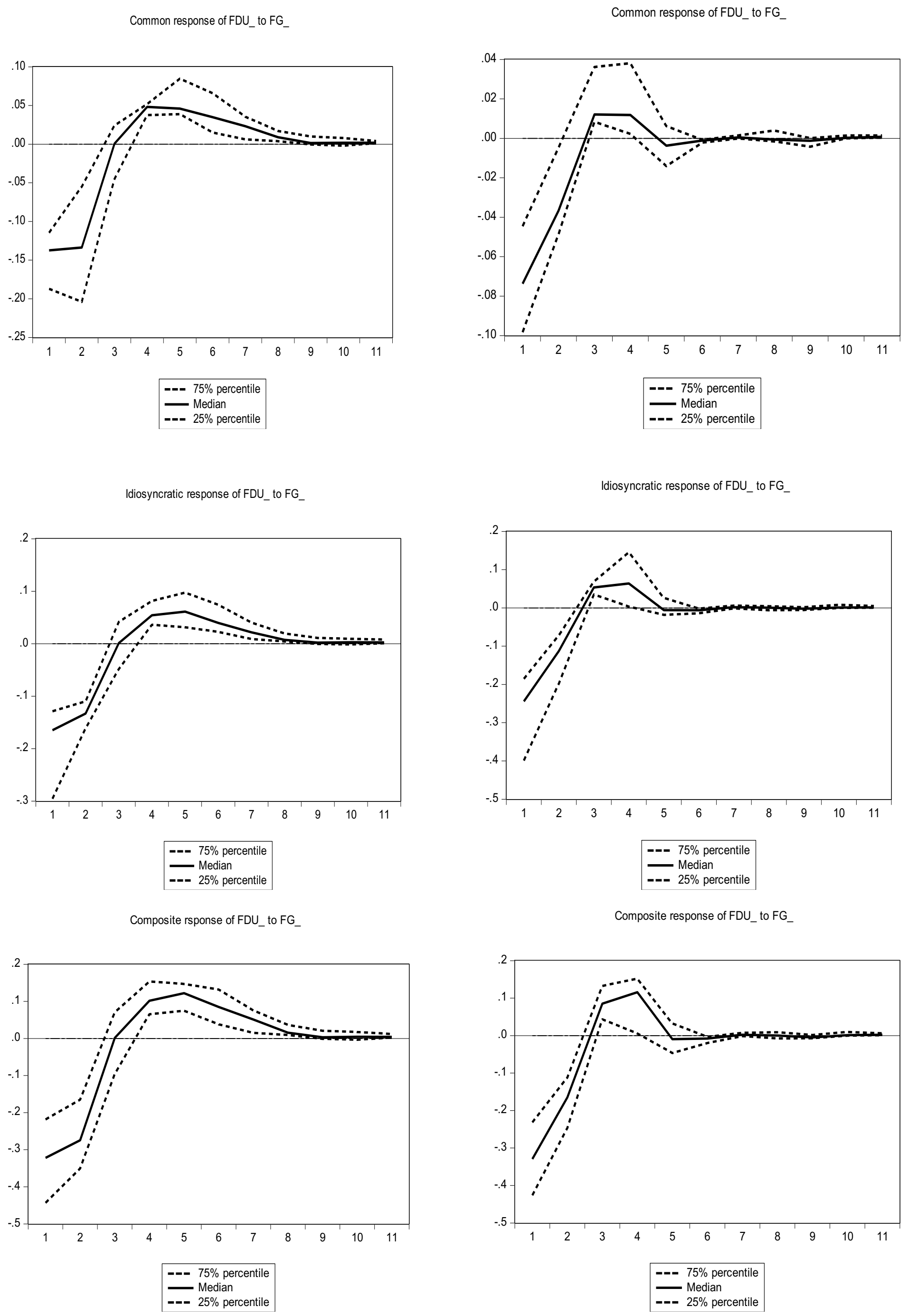
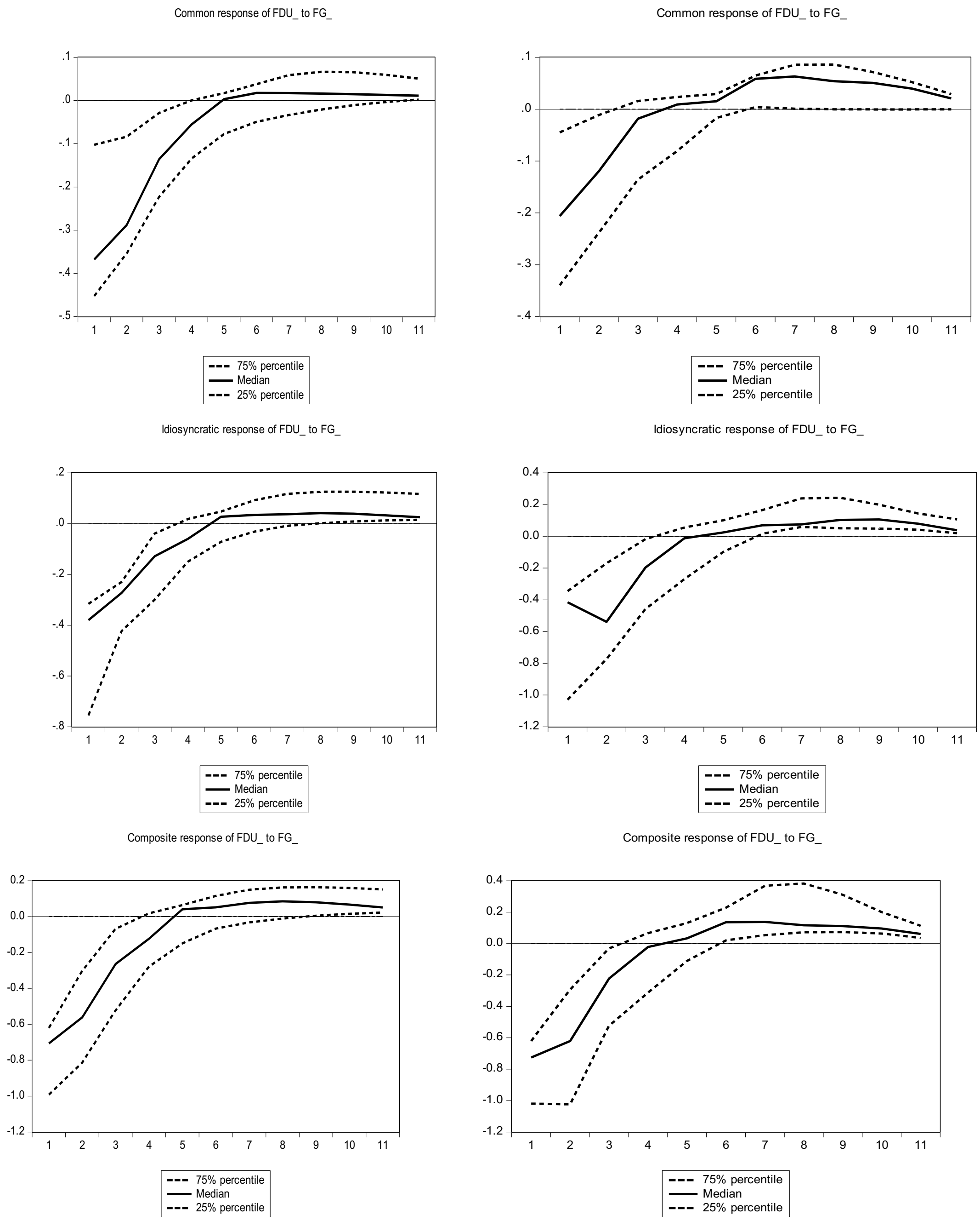


Figure 17 – (b) Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **peripheral countries**), **euro zone period 2000-2019, conditional on EPL**

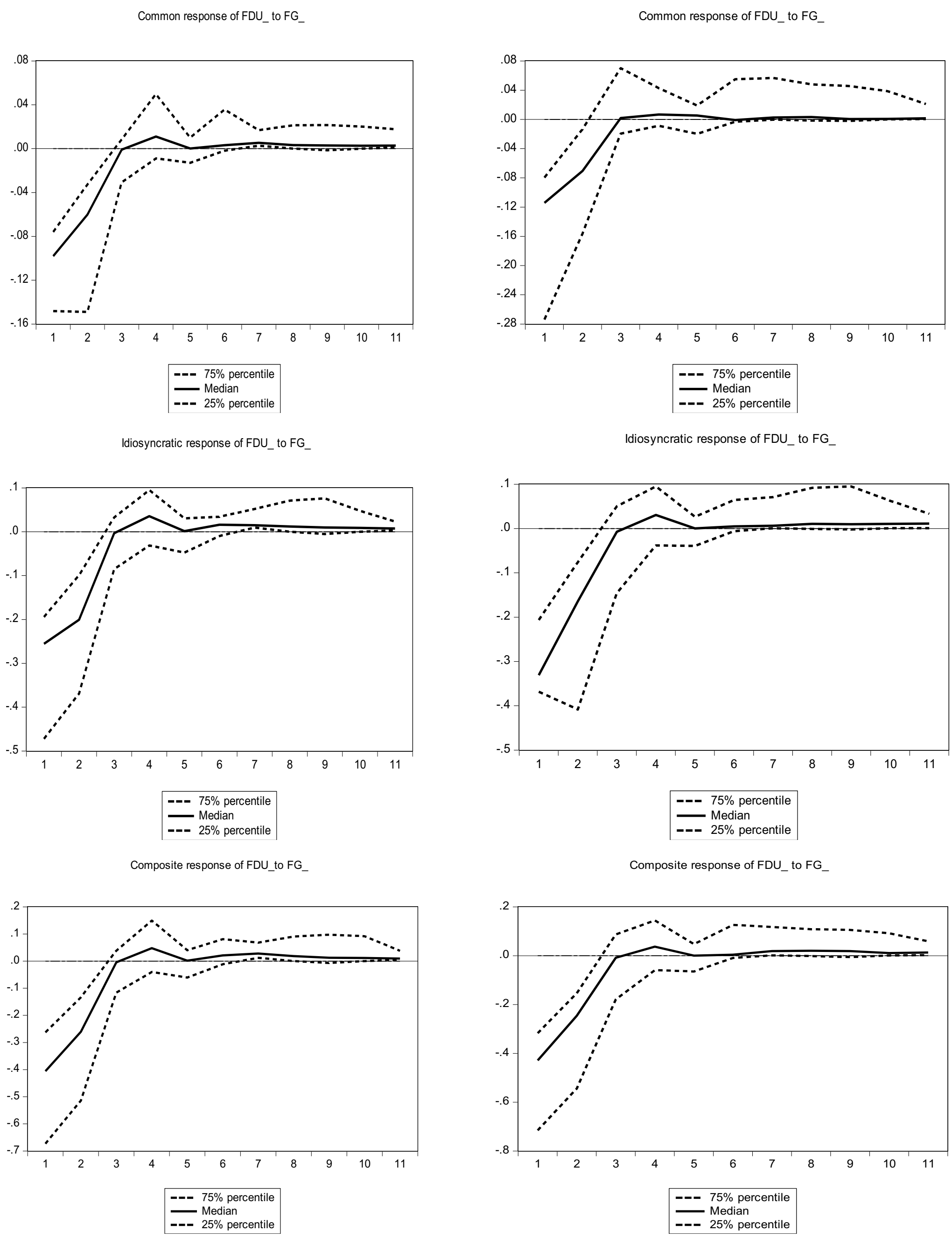
**FULL SAMPLE** **SINCE COMMON CURRENCY**




*Note:* The median, averages, and interquartile ranges were calculated from the distribution of IRFs of the 11 cross-sections.

Figure 18 - Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **11-euro countries**), **conditional on TU**

**FULL SAMPLE** **SINCE COMMON CURRENCY**




*Note:* The median, averages, and interquartile ranges were calculated from the distribution of IRFs of the 11 cross-sections.

Figure 19 – (a) Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **core countries**), **conditional on TU**

**FULL SAMPLE** **SINCE COMMON CURRENCY**

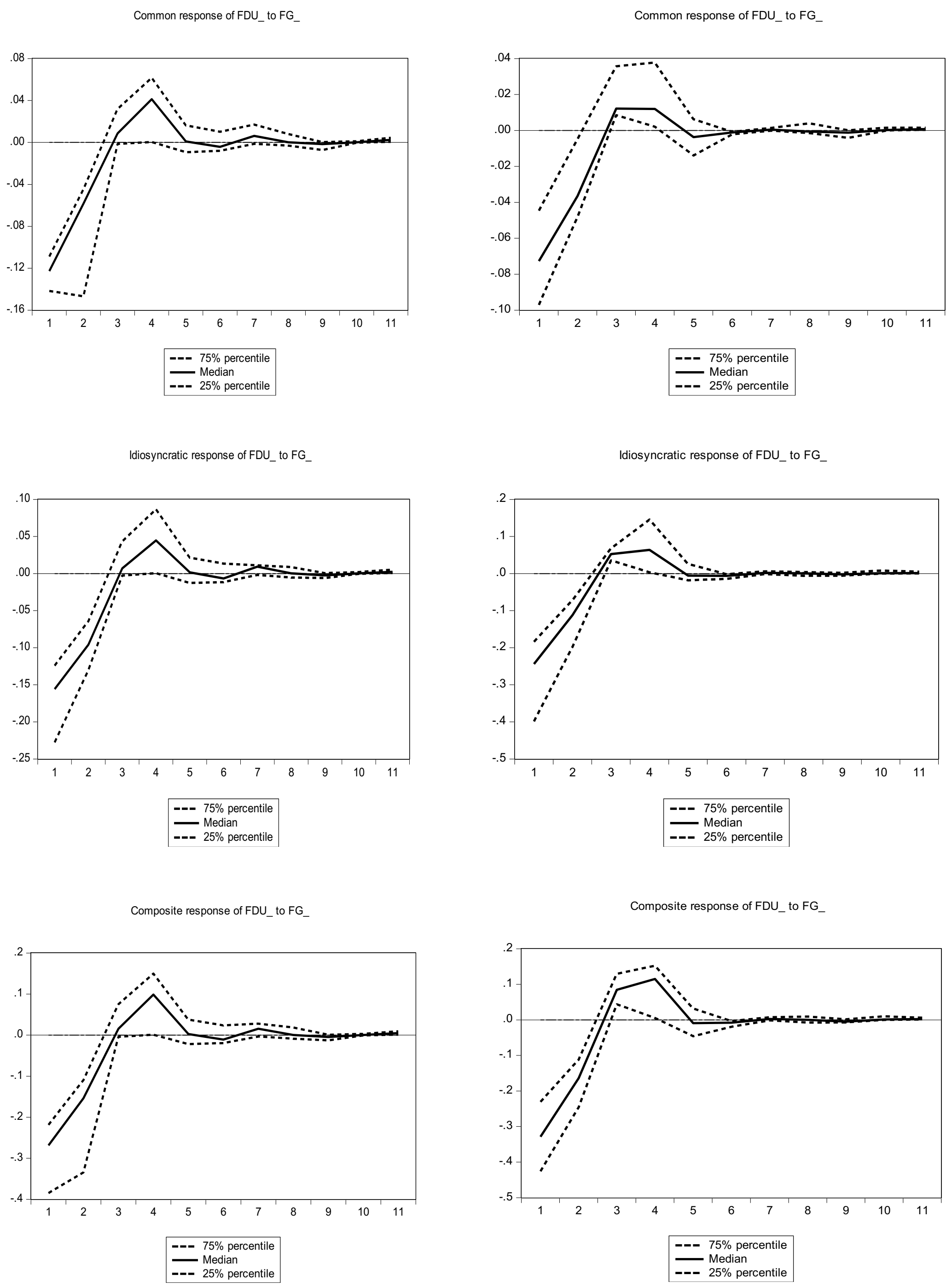
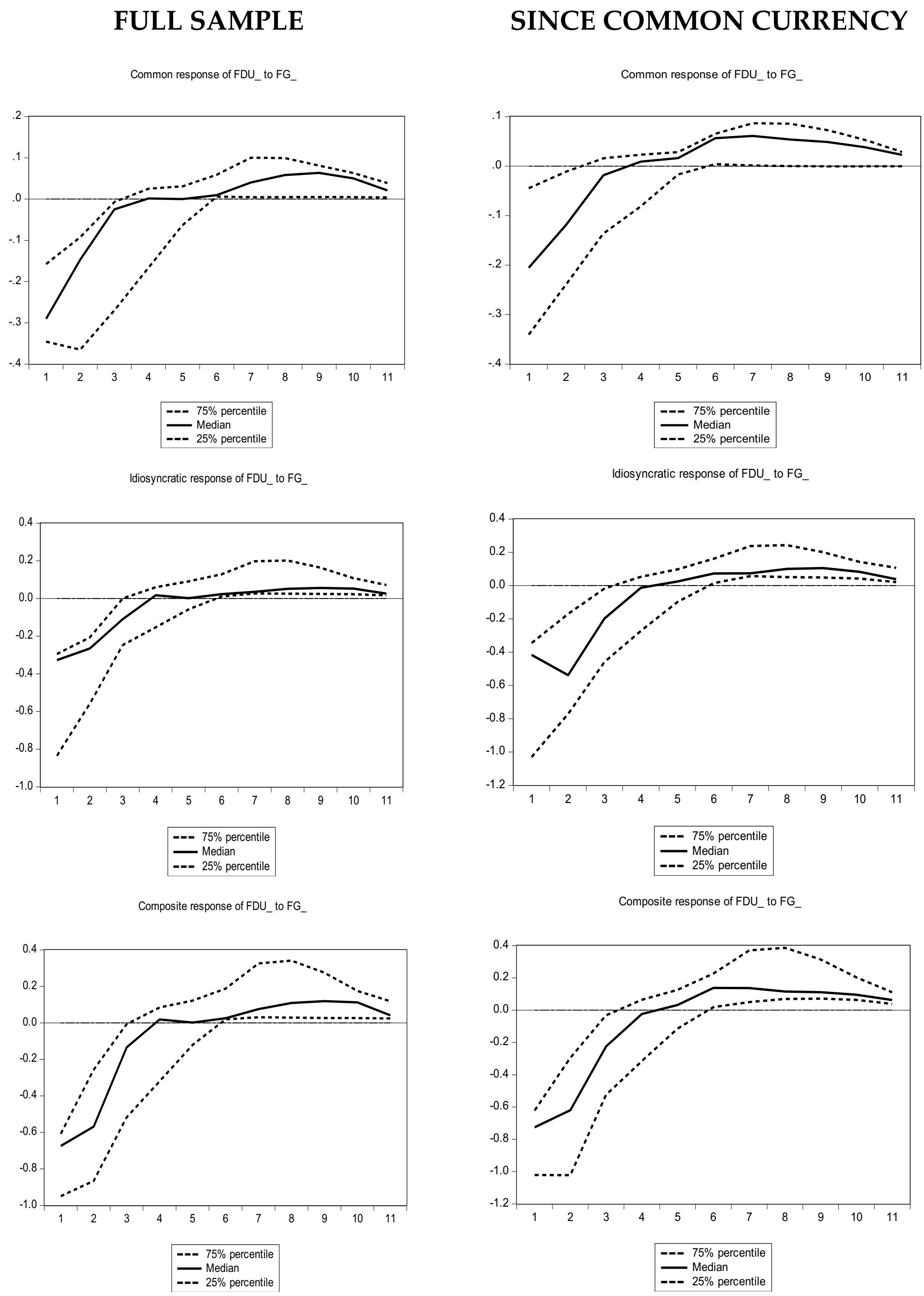
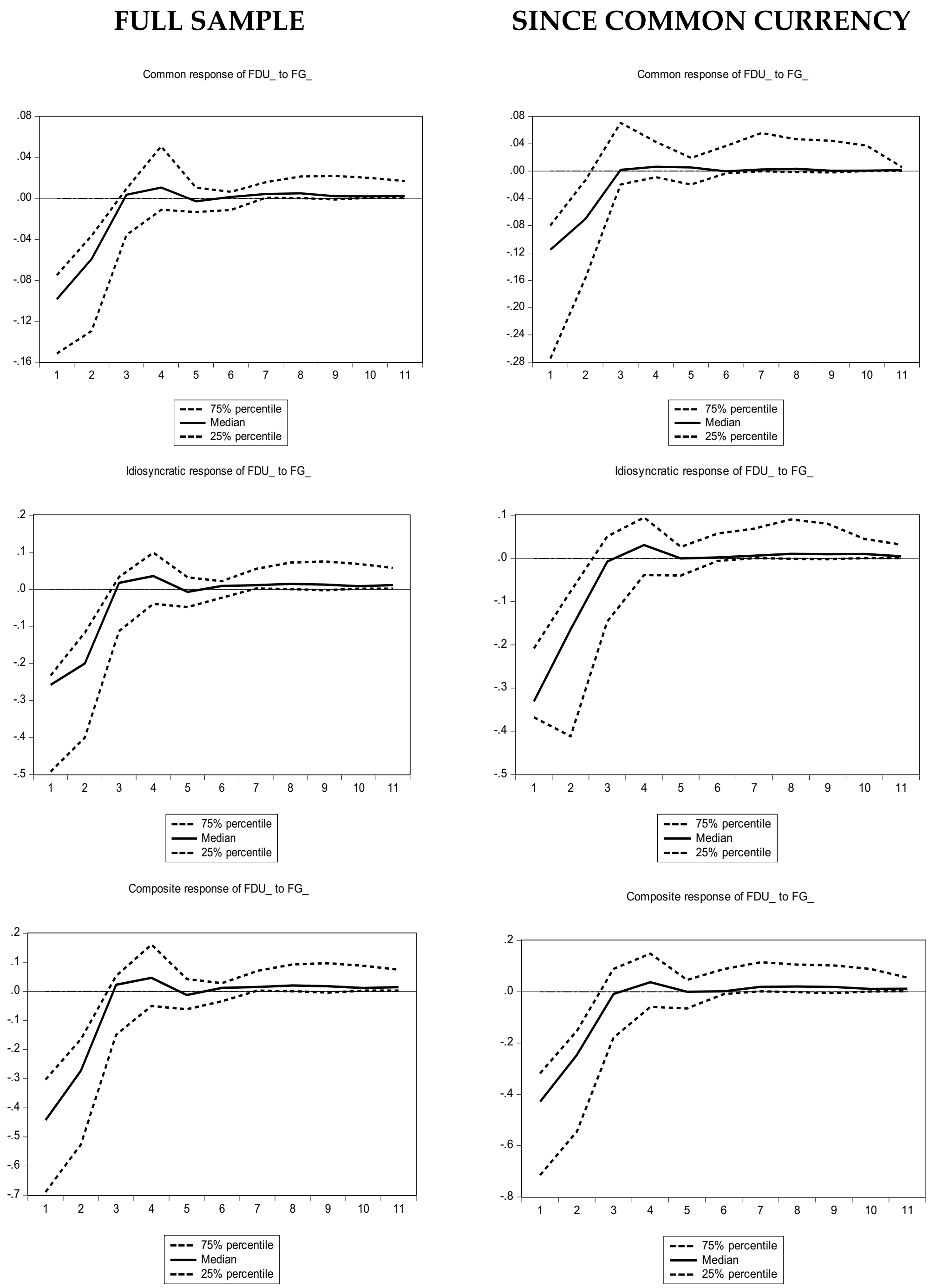


Figure 19 – (b) Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **peripheral**), **conditional on TU**




*Note:* The median, averages, and interquartile ranges were calculated from the distribution of IRFs of the 11 cross-sections.

Figure 20 - Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **11-euro countries**), **conditional on CBC**




*Note:* The median, averages, and interquartile ranges were calculated from the distribution of IRFs of the 11 cross-sections.

Figure 21 – (a) Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **core countries**), **conditional on CBC**

**FULL SAMPLE** | **SINCE COMMON CURRENCY**

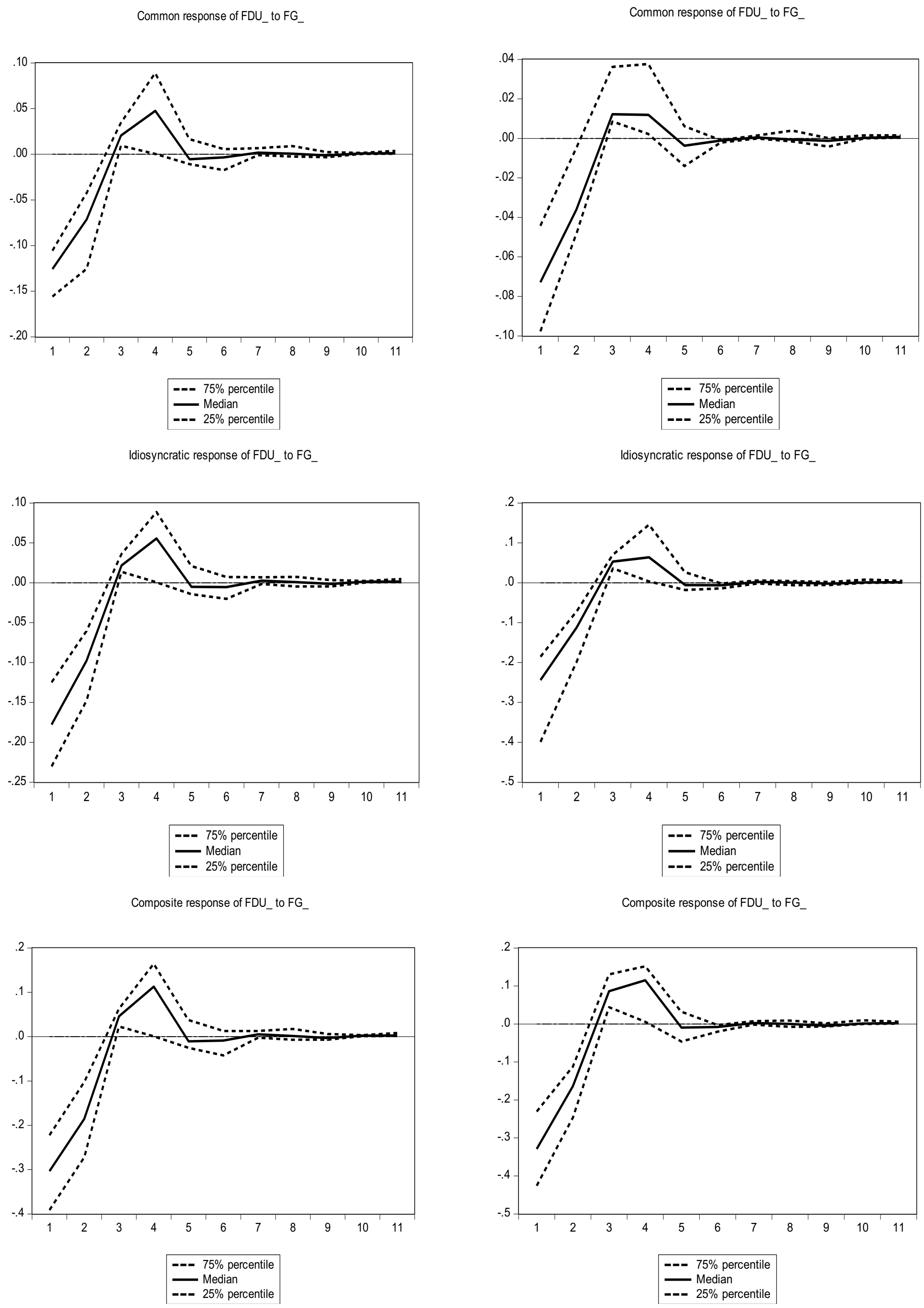
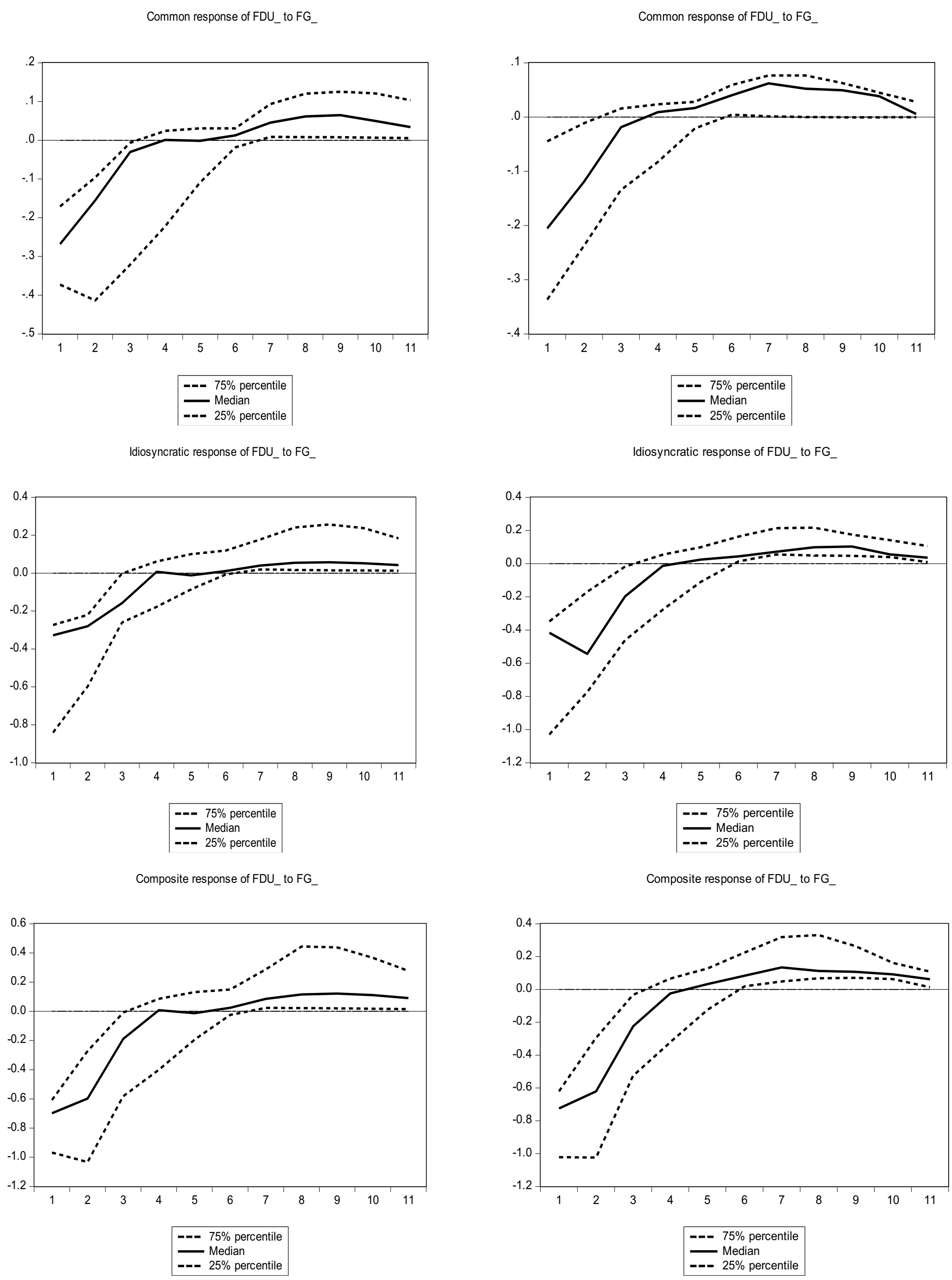


Figure 21 – (b) Heterogeneous composite impulse responses across sample of unemployment to output growth (SP-VAR for **peripheral countries**), **conditional on CBC**

**FULL SAMPLE** | **SINCE COMMON CURRENCY**




*Note:* The median, averages, and interquartile ranges were calculated from the distribution of IRFs of the 11 cross-sections.

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