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GROWTH RATE OF VOLATILITY IN EUROPEAN REGIONS: TWO METHODOLOGIES IN COMPARISON

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SOMMARIO

The aim of this paper is to study the growth rate volatility of GDP per capita (GRV) and its determinants for a sample of European regions in the period 1992-2008, with a specific attention to the asymmetry of business cycle fluctuations. The paper approaches the subject of growth rate volatility from two different points of view ascribing to the different methodologies involved into the analysis.
We propose an index of GRV based on Markov matrices which allows us to take directly into account the intensity and symmetry of the fluctuation.
Then an estimation of the GRV following the methodology proposed by (McConnell and Perez Quiros, 2000) and (Stock and Watson, 2003) allows us to obtain a measure of GRV in a panel setting.
The volatility issue is analysed in an asymmetric sense, elaborating a comprehensive framework for the assessment of GRV due to positive and negative fluctuations from the trend and its determinants in the light of spatial influences, and therefore by explicit use of spatial techniques.

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1. Intoduction

Following the recent contributions of (Brunetti et al., 2016) and (Fiaschi et al., 2014), this paper examine the growth rate volatility of GDP per capita (GRV) and its determinants for a sample of European regions in the period 1992-2008, with a specific attention to the asymmetry of business cycle fluctuations. In the recent years the volatility of countries' growth rates has gained the interest of many researchers. There exist a large consensus in the literature that GRV favours uncertainty and therefore, it impairs growth, investment and welfare especially in poor countries, see (Ramey and Ramey, 1995), (Fatas, 2002), (Acemoglu et al., 2003), (Imbs, 2007), (Abate, 2016).

Given the significant effects that the volatility could have on welfare, the recent literature has started focusing on the determinants of volatility in order to lead more effective government policy. Moreover, the recent financial crisis has posed the challenge of understanding the channels through which different economic sectors can affect the propagation of the shock, trying to identify what "architecture" can make the economy resilient to global crisis.

The literature has stressed the role played by various factors on regional volatility, including: i) the *size of the economy*, ii) *macroeconomic policies*, iii) *government size* and iv) *sectoral composition* with particular regard to the *financial sector*.

In this framework, (Canning et al., 1998), (Easterly and Kraay, 2000), (Furceri and Karras, 2007) and (Furceri and Karras, 2008) find a clear and robust inverse relationship between country size and output volatility, suggesting that smaller states have higher per capita GDP then other states but are also more volatile, due to their greater volatility in terms of trade or in capital flows.

The reduction of output growth volatility has also been linked to the effectiveness of *macroeconomic policies*. Focusing on the role of macroeconomic policies and institutional framework, (Acemoglu et al., 2003) find that countries with high inflation, large budget deficits, and misaligned exchange rates are those with higher macroeconomic volatility. The effects of monetary and fiscal policy are analysed by (Cecchetti and Ehrmann, 2002) and (Posch, 2009).

Concerning the relationship between *government size* and volatility, (Gali, 1994), (Fatas and Mihov, 2001) as well as (Van der Noord, 2000) find a close link between the size of government expenditure and volatility. In particular, they find a positive effect of the public sector in the reduction of growth volatility so that, it acts as automatic stabilizer.

As regard the link between volatility and *sectoral composition*, (Koren and Tenreyro, 2007) and (Fiaschi and Lavezzi, 2011), identify a clear rank in terms of volatility. They show that the presence of some sectors which are more volatile, like agriculture and mining, are associated to higher growth volatility; manufacture to intermediate volatility and services to low volatility.

Finally, volatility of neighbouring regions is another potential source of volatility as suggested by the evidence reported in (Ezcurra and Rios, 2015) and (Abate, 2016), but not yet investigated. An economy can be affected by neighbouring economies in different ways: on the one hand, a positive spatial dependence can arise from the intensity of inter-regional trade, see (De Haan et al., 2008); on the other, a negative spatial dependence can be induced by competition in the allocation of productive factors in the same vein as the *backwash effect* discussed in (Myrdal, 1957).

While much of the existing works rely on cross countries analysis, regional analysis has not received much attention in the literature. In the last years, the EU has undergone the most significant enlargement in its history. New countries in the eastern part of the European continent are became EU members, and this has inevitably impacted on the relations and the performances with intra-EU and between-EU countries.

We contribute to the literature in many respects. First, with respect to the existing literature which propose as measure of volatility the standard deviation of per capita GDP, we propose two different methods in order to analyses the asymmetric behaviour of GRV(see (Morley and Piger, 2012), who document recessions as periods of relatively large and negative fluctuations in output).

The first methodology is based on a synthetic index of GRV inspired by the literature on mobility based on Markov matrices (Bartholomew, 1973), the second one follows the approach proposed by (McConnell and Perez-Quiros, 2000).

The two approaches allows us to capture different aspects of the GRV. The cross-section analysis of GRV conducted with the measure of GRV based on our index, let us carefully consider positive and negative fluctuations around the trend separately and the variation in frequency and magnitude of fluctuations. On the other hand, panel data techniques allow to take into account unobserved heterogeneity which is particularly useful in this context, since region-specific factors are likely to affect regional GRV.

Our two measures of GRV are then regressed over a set of potential explanatory variables in order to identify the main determinates of GRV. The differences of our findings when we consider positive and negative fluctuations suggest that the asymmetries on GRV are remarkable.

Our empirical evidence shows the important role played in this contest by the spatial spillovers introduced by volatility in neighbouring regions. The observed results, can be summarized as follows: i) the size of the economy has a stabilizers effects, in particular when volatility is ascribe to negative shocks; ii) output composition matters with remarkable difference between the two models, iii) monetary policies play a negligible rule, while iv) labour market flexibility exert a stabilizing impact. Finally, the financial deepening acts like an accelerator of recession, given its positive impact due to negative shocks, which confirms the hypothesis that regions with a developed financial system pays in terms of volatility in the short run.

The analysis is relevant from many viewpoints. Concentrating on the second moment of the growth rates for each region, this analysis provides a framework for the assessment of a characteristic which has become all the more important in the recent years of economic crisis: i.e., the stability of growth rates and, therefore, the sensitivity to changes in economic conditions and, ultimately, the resilience of living standards in the face of adversity. From a methodological viewpoint, the contribution is twofold: firstly, new tools to measure volatility are proposed and, not least important, the importance of spatial spillovers is highlighted in all the analysis.

The paper is organized as follows. After this introduction, Section 2 the two methodologies for the computation of GRV. Section 3 describes the data and the econometric approach used in the analysis and the empirical findings. The final section offers the main conclusions from this work and future research.

2. The GRV measures

Generally, GRV is measured by the standard deviation of the growth rate of per capita GDP (see, e.g. (Kormendi and Meguire, 1985), (Ramey and Ramey, 1995) and (Martin and Rogers, 2000a)). The advantage of the standard deviation is its easy interpretation, but it presents some drawbacks. Firstly, it does not consider the frequency of fluctuations failing to indicate the *type* of fluctuations (see (Gelb, 1979) and (Temple and Malik, 2008)). Secondly, the standard deviation does not distinguish between temporary or persistent fluctuations because it considers only the distance of each growth rate from the trend. Finally, it deals symmetrically with negative and positive fluctuations around the trend, see e.g. (Hai et al., 2013). In this view, in the following subsection, we describe the methodology to measure GRV that overcomes these drawbacks. The novel methodology, based on Markov matrices, introduces a synthetic index inspired by the literature on mobility (see (Bartholomew, 1973) and (Shorrocks, 1978)). Among the advantages of this approach, it helps to consider the impact of large fluctuations of the business cycle, and compute the contribution of negative/positive fluctuations around the trend.

However, the cross section measure of GRV obtained with this synthetic index does not allow to take into account i) the time-series dimension and ii) unobserved heterogeneity which is particular useful in the EU regional contest, since region specific factor are likely determinants of regional GRV.

In this view, in the following subsection we present the methodology in order to obtain a panel of GRV.

Estimation of a Cross section of Regional GRV: An Index of GRV: I_B^α

Consider y as the cyclical component of the growth rates series; our proposed index of GRV, denoted by I_B^α, is defined as it follows:

$$I_B^\alpha \equiv \int_{\underline{y}}^{\bar{y}} \underbrace{\pi(q)}_{\text{III}} \int_{\underline{y}}^{\bar{y}} \underbrace{g(s|q)}_{\text{II}} \underbrace{\frac{|s-q|^\alpha}{\max\left(|s-q|^\alpha\right)}}_{\text{I}} dsdq, \tag{1}$$

with $\alpha > 0$, where q and s are the states at periods t and $t+1$ respectively. I_B^α is the result of three different components:

I. $\frac{|s-q|^\alpha}{\max\left(|s-q|^\alpha\right)}$ represents the weights of a "jump" from state q to state s. A higher α means a higher weight to large "jumps";

II. $g(s|q)$ is the stochastic kernel, i.e. the conditioned probability to jump to state s starting from state q;

III. $\pi(q)$ is the ergodic distribution, which measures how much time is spent in state q in equilibrium.

The sum of components I and II provides a sub-index of GRV of the state q; hence I_B^α can be see as a weighted mean of all sub-indexes of all possible states, where the weights of these different states are their mass in the ergodic distribution. We have therefore that $I_B^\alpha \in [0,1]$ and a higher value of I_B^α implies higher GRV.

An important difference with respect to original Bartholomew index is that I_B^α is defined in a continuous state space (i.e. transition matrix is replaced by stochastic kernel).

As the standard deviation also our index I_B^α does not distinguish between positive or negative "jumps" around the zero-trend. This information can be crucial since a prevalence of negative jumps, or more precisely a prevalence of deep negative jumps, is generally considered a further negative feature of GRV. However, given its additivity properties it is possible to decompose the overall index into two types of transitions, i.e.[1]:

$$I_B^\alpha = I_{B_+}^\alpha + I_{B_-}^\alpha, \tag{2}$$

where

$$I_{B_+}^\alpha \equiv \int_{\underline{y}}^{\bar{y}} \pi(q) \int_0^{\bar{y}} g(s|q) \frac{|s-q|^\alpha}{\max\left(|s-q|^\alpha\right)} dsdq, \tag{3}$$

and

$$I_{B_-}^\alpha \equiv \int_{\underline{y}}^{\bar{y}} \pi(q) \int_{\underline{y}}^{0} g(s|q) \frac{|s-q|^\alpha}{\max\left(|s-q|^\alpha\right)} dsdq; \tag{4}$$

$I_{B_+}^\alpha$ measures the GRV due to jumps to positive states (independent of initial state), while $I_{B_-}^\alpha$ to the jumps to negative states. In this regard the ratio $I_{B_-}^\alpha / I_B^\alpha$ measures to what extent the total GRV is explained by negative jumps; or, alternatively, the relative intensity of negative jumps, given that we are dealing with residuals from trend.

See ((Brunetti et al., 2016) Figure 1 pag.5) for a graphical representation of the I_B^α components for a sample of European regions selected among the sample.

Estimation of a Panel of Regional GRV: A Panel of GRV

In this section we present a different methodology to measure the GRV. We follow the methodology proposed by (McConnell and Perez-Quiros, 2000), (Stock and Watson, 2002) and (Fiaschi et al., 2016), which exploits both the cross-sectional and time-series dimension of the panel of per capita GDP growth. In particular, assume that the dynamics of per capita GDP growth can be represented as an AR(p) process:

$$\gamma_{it} = \mu_i + \phi_1 \gamma_{i,t-1} + \dots + \phi_p \gamma_{i,t-p} + \varepsilon_{it}, \tag{5}$$

where ε_{it} is assumed to be normally distributed. Given that ε_{it} follows a normal distribution, an unbiased estimator of the standard deviation of ε_{it}, σ_{it}^ε, is given by (McConnell and Perez-Quiros, 2000):

$$\hat{\sigma}_{it}^\varepsilon = \sqrt{\frac{\pi}{2}} |\hat{\varepsilon}_{it}|. \tag{6}$$

[1] We are implicitly assuming that $\underline{y} \le 0 \le \bar{y}$, this is trivial when y are residuals from trend.

As pointed out in the literature (see McConnell and Perez-Quiros, 2000), the absolute value specification is more robust to departures from conditional normality.

Once we set the order of AR process from Eq.(6) we can derive the unbiased estimator of the standard deviation of per capita GDP growth σ_{it}^{γ}. For example, if the per capita GDP growth follows an AR(1) process, the standard deviation of the growth rate is given by (Hamilton, 1994, p. 53):

$$\hat{\sigma}_{it}^{\gamma} = \frac{\hat{\sigma}_{it}^{\varepsilon}}{\sqrt{1-\phi_1^2}} = \frac{\sqrt{\frac{\pi}{2}}|\hat{\varepsilon}_{it}|}{\sqrt{1-\phi_1^2}}. \tag{7}$$

Hamilton (1994, pp. 58-59) provides a general equation for higher-order AR models.

In the empirical analysis the best order of AR for each region is selected by using the EIC criteria, that is a bootstrap version of the *Akaike Information Criteria* for small samples (see Ishiguro et al., 1997).

In contrast with the common approach using the standard deviation of the time-series per capita GDP growth rates, this methodology allows to build a *panel* of regional GRVs.

In addition, the methodology allows for separately considering GRV due to positive (denoted by GRV$^+$) and negative (denoted by GRV$^-$) fluctuations. In particular, GRV$^+$ only considers the fluctuations above the trend, i.e. all the observations for which the residuals of the AR process in Eq.(5) are positive (i.e. $\hat{\varepsilon}_{it} > 0$). On the contrary, GRV$^-$ are all the GRV for which the residuals are negative (i.e. $\hat{\varepsilon}_{it} < 0$).

3. Empirical framework

Based on the results obtained so far in the existing literature, the aim of this section is to examine further the determinants of GRV focussing on the asymmetric behaviour due to due to postive and/or negative fluctuations around the trend of per capita GDP of a sample of European regions belongs to 25 EU countries in the period 1992-2008. The two measures of GRV obtained in the previous section allow us to analyse the phenomena in a cross-sectional and panel setting. In the subsection below we describe the dataset and the empirical strategy used in the study.

Data

The sample for the empirical exercises covers a total of 217 NUTS-2 regions in the cross section analysis and 257 in the panel setting for a large sample of EU states for a period running from 1992 to 2008. NUTS-2 level regions are used in the analysis instead of other possible alternatives because NUTS-2 (i) is the territorial unit most commonly employed in European regional economics literature and (ii) is particularly relevant in terms of EU regional policy, given that it is the level at which cohesion and regional policy funds are assigned. The data for this study are drawn from different data sources. Table 1 contains the list of the possible explanatory variables of GRV, and the main references.

In general terms, GRV depends from a variety of factors that can be broadly categorized as (i) *monetary policy*, (ii) *volatility from the demand side*, (iii) *volatility from the supply side*, (iv) *regional characteristics*. The control variables in the analysis have been selected on the basis of existing studies. In particular:

as *monetary policy* determinants we include the inflation volatility and the participation to European Monetary Union.[2] These two proxies would take into account the fluctuations of individuals' expectation on the central bank target inflation (see, (Blanchard and Simon, 2001), (Sheridan and Ball, 2003), (Cecchetti and Ehrmann, 2002) and (Leduc and Sill, 2007)).

As *demand side* determinants we consider the composition of aggregate demand. Aggregate demand would affect the income volatility by affecting the volatility of the random component ε_{it}. Standard Keynesian argument suggests that the resilience of an economy to exogenous fluctuations depends on the composition of aggregate demand ((Blanchard et al., 2010)). In particular, a higher share of consumption is expected to dampen negative fluctuations, while large government expenditure may smooth economic shocks and reduces GRV, given its characteristics of automatic fiscal stabilizer (Van der Noord, 2000), (Bejan, 2006), (Fatas and Mihov,

[2] A Euro dummy is used to control for the effect of European Monetary Union.

2001), (Bejan, 2006) and (Fatas and Mihov, 2001). We therefore include the investment rate, the share of household expenditure on total GDP, and the share of government expenditure.[3]

On the other hand, for the *supply side* we control for sectoral concentration using the normalised Herfindahl index. Genarally, a higher concentration is associated with higher volatility as pointed out by (Tase, 2013) and (Mobarak, 2005).[4] In particular, the effect of sectoral concentration would affect the volatility through the random component of the supply side. The output composition of GDP is measured by the shares of agriculture, mining, manufacturing, finance, non market service, construction, wholesale, hotel, other and transport on total GDP given that some sectors are associated with a higher level of volatility, (Koren and Tenreyro, 2007) and (Fiaschi and Lavezzi, 2005).

We consider also external shocks due to the volatility of raw materials, proxied by the volatility of petroleum price at world level[5] would affect the volatility through the random component of the supply side v_{it} (Blanchard and Galí, 2010).

For the sake of completeness other *regional variables* are considered in the analysis. In particular: the size of the economy proxied by the (log of) GDP at regional level, on the idea that small countries experience higher output volatility than large ones, see (Canning et al., 1998), (Easterly and Kraay, 2000), (Furceri and Karras, 2007) and (Furceri and Karras, 2008).

The value of credit from financial intermediaries to the private sector divided by GDP is taken as measure of financial deepening, and finally, labour marker flexibility at regional level by the ratio of part-time workers to total employment.

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[3]Unfortunately no data on the imports and exports are available at regional level for a such large sample.

[4]The Herfindahl Index, (HI), is defined as, $HI_{it} = \sum_{j=1}^{J} s_{ijt}$ where s_{ijt} is the sector share to GDP in region i at time t. The normalised Herfindahl index is computed as: $HI^*_{it} = \frac{(H-1/J)}{1-1/J}$, with J the total number of sector in the economy. A decrease in the Herfindahl index corresponds to an increase in diversification, implying that the economic activity is more equally spread across sectors.

[5]The volatility of petroleum price at world level is estimated by using the same methodology to estimate output volatility.

Table 1: *Summary of the determinants of regional GRV.*

Determinants	Code	Cross section	Panel	Expected Effect	Units	Data Source	Main References
Regional volatility							
Volatility of per capita GDP	GRV	yes	yes	(dip.var.)	Regions	Cambridge Econometrics	McConnell and Perez-Quiros (2000), Stock and Watson (2002) Fiaschi and Lavezzi (2005)
B. Monetary policy							
Inflation Volatility [(a)]	GRV.INFLATION	yes	yes	(+)	Country	World Bank	Blanchard and Simon (2001), Easterly and Kraay (2000), Sheridan and Ball (2003), Cecchetti and Ehrmann (2002) and Leduc and Sill (2007)
Participation to EMU [(b)]	EMU.DUMMY		yes	(?)	Country		De Grauwe (2007), Sala-i Martin and Sachs (1992) Buettner (2006), Mélitz and Vori (1992), and Bayoumi and Masson (1995),Masson (1996), Uhlig (2003)
C. Volatility from the demand side							
Shares aggregate demand	INV.RATE	yes	square value	(-/+)	Region	Cambridge Econometrics	Aizenman and Marion (1999),Blanchard et al. (2010)
	HOUSEHOLD.EXP.on.GDP	yes	square value	(-)	Region	Cambridge Econometrics	
	GOV.EXP.on.GDP	yes	square value	(-)	Country	World Bank	Rodrik (1998), Van der Noord (2000) Bejan (2006), Fatas and Mihov (2001)
D. Volatility from the supply side							
D.1 Sectoral Concentration							
Herfindahl index[(c)]	HERFINDAHL	yes	yes	(+)	Region	Cambridge Econometrics	Tase (2013), Mobarak (2005)
D.2 Output compositions of GDP							
Share Agriculture on total GDP	SHARE.AGRI	yes	square value	(+)	Region	Cambridge Econometrics	Koren and Tenreyro (2007), di Giovanni and Levchenko (2009)
Share Mining on total GDP	SHARE.MIN	yes	square value	(+)	Region	Cambridge Econometrics	
Share Manufacturing on GDP	SHARE.MANU	yes	square value	(+/-)	Region	Cambridge Econometrics	
Share Finance on GDP	SHARE.FIN	yes	square value	(+/-)	Region	Cambridge Econometrics	
Share Non Market Services on GDP	SHARE.NMS	yes	square value	(-/+)	Region	Cambridge Econometrics	
Share Constructions on GDP	SHARE.CONST	yes	square value	(-/+)	Region	Cambridge Econometrics	
Share Wholesale on GDP	SHARE.WHOLESALE	yes	square value	(-/+)	Region	Cambridge Econometrics	
Share Hotel on GDP	SHARE.HOTEL	yes	square value	(-/+)	Region	Cambridge Econometrics	
Share Transport on GDP	SHARE.TRANSP	no	square value	(-/+)	Region	Cambridge Econometrics	
Share Other on GDP	SHARE.OTHER	yes	no	(-/+)	Region	Cambridge Econometrics	
D.3 External shocks							
Volatility of petroleum price[(d)]	GRV.log.PETROLEUM.PRICE	no	yes	(+)	Country	UNCTADStat	Fiaschi and Lavezzi (2005)
E. Regional time-varying characteristics (RC)							
E.1 Size of the economy							
Log of GDP	LOG.GDP	yes	yes	(-)	Region	Cambridge Econometrics	Gali (1994), Canning et al. (1998),Easterly and Kraay (2000)
E.2 Financial depth							
Domestic Credit to private sector on GDP	CREDIT.PRIV.SECTOR.on.GDP	yes	yes	(?)	Country	World Bank	Kaminsky and Reinhart (1999), Easterly and Kraay (2000), Aghion et al. (2005), Cecchetti et al. (2006), Beck et al. (2006)
E.3 Labour Market Flexibility							
Share of the part-time workers	PART.TIME	log term	no	(-/+)	Region	ELFS	Gnocchi et al. (2015)

Notes: *a*) Dummy for regions belonging to European Monetary Union. *c*) (Normalized) Herfindahl index: it ranges from 0 to 1, with a value equal to 0 implying maximum diversification, and a value equal to 1 minimum diversification.
c) Estimated volatility of the petroleum price.

A Cross Sectional Approach

Given the presence of spatial effects,[6] we estimate a spatial simultaneous autoregressive model that includes spatially lagged dependent variable and spatially lagged independent variable, but exclude the spatially autocorrelated error term.

$$\begin{aligned} \mathbf{y} &= \mathbf{c} + \lambda \mathbf{W}\mathbf{y} + \mathbf{X_1}\beta_1 + \mathbf{W}\mathbf{X_1}\theta_1 + \mathbf{X_2}\beta_2 + \mathbf{e} \\ \mathbf{e} &\sim iid\left(0, \sigma^2 \mathbf{I}\right), \end{aligned} \tag{8}$$

where $\mathbf{y}$ denotes a $(N \times 1)$ vector including the dependent variable,[7] i.e. GRV; $\mathbf{c}$ is the constant; $\mathbf{W}$ is the $(N \times N)$ spatial weight matrix.[8] As can be observed, in this specification the regional growth rates depend on the spatial lag of the dependent variable, $\mathbf{Wy}$, which captures the spatial effects working through the dependent variable; λ is the spatial-autoregressive parameters; $\mathbf{X_1}$ is the $(N \times k_1)$ matrix of regressors at regional level while $\mathbf{WX_1}$ denotes the interaction effects among the regional independent variables; $\mathbf{X_2}$ is the $(N \times k_2)$ matrix of regressors at country level, β_1 as θ_1 are the $(N \times k_1)$ vectors of fixed but unknown parameters for regional determinants and its spatially specification, while β_2 the $(N \times k_2)$ vector of parameters for country determinants, and, finally, $\mathbf{e}$ is the $(N \times 1)$ vector of innovations assumed to be independently identically distributed with variance σ^2. We exclude the interaction effects among the independent variables at country level $\mathbf{X_2}$ due to the high collinearity problem deriving by the geographical definition of the W matrix. In the model selection we follow LeSage and Pace 2009 and sequentially test for the presence of spatial lag dependence and spatial lags of the explanatory variable. The possible presence of endogeneity coming from some explanatory variables, (i.e investment rates, household expenditure, government consumption expenditure and domestic credit) leads to estimate Eq.(8) via Two-Stage Maximum Likelihood (TSML).[9]

Moreover, the presence of spatial lags of the dependent and explanatory variables complicates the interpretation of the parameters in Eq.(8). Therefore, some caution is required when interpreting the estimated coefficients.

As shown by (LeSage and Pace, 2009) in a spatial model the impact on $\mathbf{y}$ of each determinant included in $\mathbf{X}$ must take into account the spatial interdependencies and simultaneous feedback embodied in the model.

In particular, a change in an explanatory variable in region i has a direct effect on that region, but also an indirect effect on the remaining regions. In this context, the *direct effect* captures the average change in the GRV of a particular region caused by a one unit change in that region's explanatory variable. In turn, the *indirect effect* can be interpreted as the aggregate impact on the growth rate of a specific region of the change in an explanatory variable in all other regions. Finally, the total effect is the sum of the direct and *indirect impacts*. Averaging out across different regions the *direct* and *indirect* effects we get the *average direct effect* (ADE) and the *average indirect effect* (AIE); in turn, the sum of these two effects gives the *average total effect* (ATE).

Table 2 reports the second stage of the estimated model under different specification of y. In particular we estimate three models. The first one with $\alpha = 1$, i.e. $y = I_B^1$, the second one with $\alpha = 2$, that is $y = I_B^2$, allow us to take into account large fluctuations, and finally I_{B-}^1/I_B^1 which analyse the relative contribution of negative fluctuations to GRV. According to Hausman test, endogeneity is present in all the three specifications and the instruments used in the first stage are always valid according the Sargan test. Focusing on the main aim of the paper, results reveal significant differences among the three specifications. Considering $y = I_B^1$ and $y = I_B^2$ we found that the best specification include only the spatial lag of the regional explanatory variables, but not the spatial lag in the dependent variable. As mentioned in the previous section, correct interpretation of the parameter estimates in the models require to take into account the direct, indirect and total effects associated with changes in the regressors.[10] In particular, the estimates of *Model 1* show that the participation to EMU has a positive effect on GRV, conforming to the idea that a fixed exchange-rate regime makes economies more vulnerable to shocks (De Grauwe, 2007). In this regard, (De Grauwe, 2007) discusses how the macroeconomic

[6] See (Brunetti et al., 2016) pagg 11:13 for a deep analysis of the geographical pattern of the $y = I_B^1$, $y = I_B^2$ and $y = I_{B-1}^1/I_B^1$

[7] In particular, $\mathbf{y}$ will be specified as I_B^1, I_B^2, and I_{B-}^1/I_B^1.

[8] See Appendix B for the description of the spatial weight matrix applied in the empirical analysis

[9] The Two-Stage Maximum Likelihood (TSML) estimator allows us to obtain results robust to endogeneity, see Appendix A

[10] For the sake of completeness we also report the coefficients

implications of the participation to a monetary union crucially depends on the characteristics of good and labour markets; in particular, flexible labour market increases the capacity of an economy to absorb shocks in a fixed exchange-rate regime. In this view, labour market flexibility has the expected negative sign on GRV: economies with a more efficient labour market adjust more promptly to shocks as reported by (Gnocchi et al., 2015) for countries.

Household expenditure has a negative impact on GRV in accordance with the expected stabilizing role of consumption; however, this finding should be consider with caution because crucially derives from the estimated negative indirect effect (AIE). Government expenditure favours fluctuations; this suggests that our proxy for fiscal policy could also reflect the impact of public debt on GRV (that is expected to be positive, (Spilimbergo et al., 2009)), and not only the stabilizing role of government consumption expenditure generally founded in the cross-country literature, (Fatas and Mihov, 2001). Unfortunately, public debt is not available for all countries in the sample for the whole period 1992-2008. As expected the high significance of the share of GDP when direct effects are calculated, suggest that most of the effects of these variables are confined into the region itself. The average GDP share of non-market services have the highest direct negative effect (ATE) on the GRV of all its neighbouring regions (the omitted category is transport sector); its stabilizing effect plausibly derives from the fact that these services mostly refer to the public sector, where fluctuations are generally small. Whereas, the average GDP share of financial intermediation has the highest negative direct effect (ADE) and total effect (ATE), pointing out that regions with a specialization in the financial and banking services should be less subject to fluctuations. Agricultural and construction sectors emerge as the most conducive sector to GRV; the indirect effect shows that this increase influences negatively and significantly the GRV of neighboring regions. A part of explanation should be found in the very large fluctuations of food prices like in (Fiaschi and Lavezzi, 2011). As expected, logarithm of the gdp has a negative and strong significant effect, therefore exist a size effect on volatility, i.e. region with higher level of total output are also those which lover output volatility. Finally the financial development measured by the domestic credit increase volatility, a result in line with the empirical research in literature ((Easterly and Kraay, 2000)).

The estimation of *Model 2* with $y = I_B^2$ produce similar results, with the exception of household expenditure, government consumption and participation to EMU which are no longer significant, suggesting that the two measures capture a different phenomena.

A different scenario emerges with $y = I_{B-}^1 / I_B^1$. In the estimate of *Model 3* we find evidence of negative spatial dependence, although of very limited magnitude ($\hat{\lambda} = -0.132$), The results concerning the output composition on GRV are remarkable. With the exception of the wholesale sector, all the other ones, lost the significant. Household expenditure has a negative and significant effect, confirming the stabilizer role of consumption on the contribution of negative fluctuations. The higher significance when direct effects are calculated, suggest that most of the effects of this variable is confined into the region itself. On the other hand, even if the effect is closer to the regions itself, we find a destabiliser role for the investment rate. [11]

[11] The interpretation of the effects of INV.RATE is more complex. By disentangling the effects of permanent and temporary shocks on investment and precautionary saving, (Cherif and Hasanov, 2012a) find that investment is a nonlinear function of volatility of permanent/persistent shocks with an inverted U-shaped curve. Their results suggest that with higher volatility of permanent shocks, investment tend to increase until a certain threshold after which investment drops. In contrast, with higher volatility of temporary shocks, investment falls.

Table 2: *The estimated coefficients and the average direct, indirect, and total effects via TSML.*

	Model (1). Dependent variable: $y = I_B^1$					*Model (2). Dependent variable: $y = I_B^2$*					*Model (3). Dependent variable: $y = I_{B-}^1 / y = I_{B-}^1$*				
	coeff.	W coeff.	ADE	AIE	ATE	coeff.	W coeff.	ADE	AIE	ATE	coeff.	W coeff.	ADE	AIE	ATE
B. Monetary policy:															
INFLATION	1.261	–	1.261	–	1.261	0.267	–	0.267	–	0.267	0.363	–	0.363	−0.045	0.319
EMU	0.255**	–	0.255**	–	0.255**	0.077	–	0.077	–	0.077	−0.070	–	−0.070	0.009	−0.061
C. GRV of Aggregate Demand:															
INV.RATE	0.003	−0.126	0.003	−0.126	−0.123	−0.031	−0.093	−0.031	−0.093	−0.124	0.212***	−0.136	0.215***	−0.148	0.068
HOUSE.EXP.on.GDP	0.094	−0.246***	0.094	−0.245***	−0.152*	0.035	−0.093**	0.035	−0.092	−0.057	−0.115**	0.022	−0.116**	0.034	−0.082
GOV.EXP.on.GDP	2.161**	–	2.161**	–	2.161**	0.612	–	0.612	–	0.612	−1.105	–	−1.108	0.137	−0.972
D. GRV of Aggregate Supply:															
HERFINDAHL	0.236	0.693*	0.236	0.690*	0.926***	0.132*	0.260	0.132*	0.259	0.391***	−0.006	−0.197	−0.002	−0.176	−0.178
SHARE.AGRI	−0.413*	0.943***	−0.414*	0.939***	0.526	−0.163	0.416***	−0.163	0.414***	0.251*	0.028	0.071	0.027	0.060	0.087
SHARE.MIN	−0.075	1.425***	−0.075	1.419***	1.344***	−0.046	0.501***	−0.046	0.499***	0.453***	−0.119	0.032	−0.120	0.043	−0.077
SHARE.MAN	−0.593***	−0.178	−0.593***	−0.177	−0.771***	−0.273***	−0.070**	−0.273***	−0.070	−0.343***	−0.034	0.153	−0.037	0.141	0.104
SHARE.FIN	−1.088***	−2.707***	−1.088***	−2.695***	−3.784***	−0.374**	−0.897**	−0.374**	−0.893	−1.267**	−0.094	1.539*	−0.123	1.386*	1.263
SHARE.NMS	−1.090***	−0.338	−1.090***	−0.337	−1.426***	−0.456	−0.120	−0.456***	−0.119	−0.575***	0.279	0.323*	0.273	0.254	0.528*
SHARE.CONST	−1.188***	1.273***	−1.188***	1.268***	0.080	−0.42***	0.582***	−0.421***	0.579***	0.158	0.200	0.362	0.194	0.298	0.492
SHARE.WHOLESALE	−0.303	1.047**	−0.303	1.042**	0.739	−0.189**	0.326	−0.189**	0.324	0.135	−0.275*	−0.956**	−0.257*	−0.820**	−1.077***
SHARE.HOTEL	−0.710***	−0.219	−0.711***	−0.219	−0.929***	−0.326***	−0.120	−0.326***	−0.120	−0.446***	0.027	−0.127	0.029	−0.116	−0.087
SHARE.OTHER	−0.468***	0.371*	−0.468***	0.369*	−0.098	−0.221	0.096	−0.221***	0.096	−0.126	−0.095	0.139	−0.098	0.136	0.038
E. Regional Characteristics:															
LOG.GDP	−0.020***	−0.002	−0.021***	−0.002	−0.023**	−0.008***	0.001	−0.008***	0.001	−0.007	0.008**	−0.003	0.008**	−0.004	0.005
DOM.CREDIT.on.GDP	0.248**	–	0.249**	–	0.249**	0.072	–	0.072	–	0.072	−0.064	–	−0.064	0.008	−0.056
LOG.PART.TIME	−0.014	−0.031**	−0.014	−0.030**	−0.045**	−0.003	−0.011	−0.003	−0.011	−0.014	0.023**	0.010	0.023**	0.006	0.029**
Constant	0.036	–	–	–	–	0.118	–	–	–	–	0.799***	–	–	–	–
λ	–	–	–	–	–	–	–	–	–	–	−0.138***	–	–	–	–
$H_0 : \theta_1 = 0$	58.234***					56.23***					34.83***				
Hausman test	23.26***					17.85**					34.38***				
Sargan test	0.213					0.010					0.522				
$\bar{R}^2$	0.524					0.551					0.268				

Note: *p<0.1; **p<0.05; ***p<0.01

A Panel Approach

As mentioned in the introduction, earlier studies on the volatility in the European regions use a cross-sectional approach (Martin and Rogers, 2000b); (Falk and Sinabell, 2009). Nevertheless, the nature of our dataset allows us to employ panel data techniques in this context, thus extending modelling possibilities as compared to the single equation cross-sectional setting employed so far. In view of this, we begin by considering in our empirical analysis the spatial fixed-effects model.

The choice of fixed effect is motivated by the fact that possible unobserved regional factors that may affect the growth rate of volatility are very likely to be correlated with other regressors. In this case, fixed effect can be superior to pooled OLS or random effects.[12] To take into account spatial dependence, we model our baseline regression as a SARAR model (spatial-autoregressive model with spatial-autoregressive disturbances, (Anselin and Florax, 1995). The SARAR model augments the linear-regression model by including an additional right-hand-side, that is the spatially lagged dependent variable (WGRV). When the spatial weight matrix is row-standardized (as in our case), each observation of the spatially lagged dependent variable is a weighted average of the values of the dependent variable observed for the other cross-sectional units. Moreover, the SARAR model also allows for the disturbances to be generated by a spatial-autoregressive process.

Our SARAR model is therefore given by:

$$\begin{aligned} GRV_{it} &= c_i + \sum_{j=1}^{9} \eta_j s_{ijt}^2 + \boldsymbol{\beta}_X \mathbf{X}_{it} + \lambda \mathbf{W}_i \boldsymbol{GRV}_t + u_{it} \\ u_{it} &= \rho W_i u_{it} + \varepsilon_{it}, \end{aligned} \tag{9}$$

where GRV_{it} is the GRV of region i at time t, c_i is region's i fixed effect, s_{ijt} the output shares of all sectors reported in Table 1 ($J = 9$), $\mathbf{X}_{it}$ includes all the other variables listed in Table 1, and $\mathbf{W}_i\mathbf{GRV}_t$ is the spatially lagged dependent variable ($\mathbf{W}_i$ is the i-th row of the spatial weight matrix discussed in Appendix B). We have assumed that u_{it} is a spatially autocorrelated error term, and ε_{it} is an $IID(0, \sigma_\varepsilon^2)$ error. The spatial weight matrix is the same both for the spatial lag of the dependent variable and for the error term.

Model (9) is the starting point of our analysis, but in addition we also investigate the asymmetric "behaviour" of the GRV when positive and negative fluctuations are considered separately. In particular, *GRV* due to positive fluctuations (denoted by GRV_{it}^+) considers all the jumps above the trend, i.e. all the observations for which the residuals obtained by the estimation of the AR process in Eq.(5) are positive (i.e. $\hat{\varepsilon}_{it} > 0$). On the contrary, negative fluctuations (denoted by GRV_{it}^-) are all the GRV_{it} for which the estimate residuals are negative (i.e. $\hat{\varepsilon}_{it} < 0$). The idea is that some explanatory variables can change their impact on GRV when the economy experiences fluctuations below or above the trend of the growth rate of per capita GDP. Therefore we also estimate:

$$\begin{aligned} GRV_{it}^s &= c_i + \sum_{j=1}^{9} \eta_j s_{ijt}^{2s} + \boldsymbol{\beta}_X \mathbf{X}_{it}^s + \lambda \mathbf{W}_i \boldsymbol{GRV}_t^s + u_{it} \\ u_{it} &= \rho W_i u_{it} + \varepsilon_{it}, \end{aligned} \tag{10}$$

with $s \in \{+, -\}$.

In modelling the GRV of each region as dependent on a weighted average of the GRV of other regions ($WGRV$), the SARAR model determines outcomes simultaneously. This simultaneity implies that the ordinary least squares (OLS) estimator is no longer consistent (Anselin, 1988). Therefore, we estimate all models using a modified version of the generalized spatial two-stage least squares (GS2SLS) developed by the (Kelejian and Prucha, 1998)[13] and proposed by (Fingleton and Le Gallo, 2008), which takes into accounts of endogeneity problems due to: i) simultaneous spatial interaction introduced by the spatial lag parameter, (i.e. endogeneity of

[12] Indeed, in our empirical analysis, the random effect specification is systematically rejected in favour of the fixed effect specification by the Hausman test for spatial panel.

[13] See Appendix A for details.

WGRV) and due to: *ii*) an unknown or imprecisely known set of structural equation, (i.e. potential endogeneity of some regressors due to reverse causality). In particular, the GS2SLS estimate the ρ and the σ_ε^2 (the variance of the error term) by GM, and the model coefficients by a feasible GLS estimator.[14] Following the spatial econometrics literature we use the spatially lagged exogenous variables WX and W^2X as instruments of the spatially lagged dependent variable $WGRV$. As regard the other potential endogenous regressors, investment rate, household expenditure, government expenditure and credit in private sectors we use as instrument their lagged values.

As expected, we find a a strong and significant spatial dependence both for GRV^+ and GRV^- ($\lambda = 0.7412$ and $\lambda = 0.8717$ respectively), implying that, on average, the macroeconomic volatility due to positive or negative fluctuations of a region positively depends on the average volatility (due to the same kind of fluctuations) of its neighbouring regions.[15]

Looking at other determinants, we find no role of the monetary policy in explaining both the volatility due to positive fluctuations GRV^+ and the volatility due to negative fluctuations GRV^-.

On the contrary, the composition of aggregate demand significantly affects the macroeconomic volatility and, in particular, GRV^+. Specifically, the (square of) investment rate has a negative and significant impact on GRV^+ but not on GRV^-. By disentangling the effects of permanent and temporary shocks on investment, (Cherif and Hasanov, 2012b) find that during periods characterized by high level of volatility due to permanent shocks, investments tend to increase but only up to a certain threshold after which they fall, while during periods characterized by high volatility due to temporary shocks investments tend to decrease. Controlling for this reverse causality that volatility may have on investment, our results suggest an asymmetric effect of the investment rate on the macroeconomic volatility, acting as a smoother only for the volatility due to positive fluctuations.

The same asymmetric effect is found for the government expenditure, which turns to have a high negative impact on GRV^+ and a not significant impact on GRV^-. This suggests that the characteristic of automatic stabilizer usually found in the literature for the government expenditure can be ascribed only to its effect in reducing the volatility due to positive fluctuations; see for example (Van der Noord, 2000), (Bejan, 2006) and (Fatas and Mihov, 2001).

Also the share of household expenditure on GDP, has an asymmetric effect on macroeconomic volatility, but of the opposite sign. In particular, it amplifies the GRV^+ while it reduces GRV^-. This result is in line with the literature showing that higher share of consumption may dampen negative fluctuations.

As regards the determinants from aggregate supply, our results point on asymmetric effect of the Herfindahl index as well as of the output composition, while no significant impact is found for the volatility of petroleum price proxying for external shocks. Partially in line with (Tase, 2013) and (Mobarak, 2005), higher concentration (measured by the Herfindahl index) leads to higher volatility when only the negative fluctuations are considered, while it reduces the volatility due to positive fluctuations. However, only the direct effect of the Herfindahl index is statistically significant for both GRV^+ and GRV^-, implying that only the own-sector concentration is relevant for the volatility of a region.

The total effects of the output composition show that only two out nine sectors considered in the analysis, share in agriculture and constructions have a significant effect on GRV^+, while only the share in transports affect GRV^-. In particular, agriculture sector strongly amplifies the volatility due to positive fluctuations while constructions tends to smooth it. On the other hand, transport reduces the volatility associated with negative fluctuations. The high significance of the (square of) shares when direct effects are considered, suggests that most of the effect of these variables are confined into the region itself. Moreover, significant asymmetries appear: having a higher share of mining tends to exacerbate GRV^+ but, at the same time, to attenuate GRV^-; having a higher share of manufacturing and transport positively affect GRV^+ of the region, but it does not have any effect on GRV^-; finally, having a higher share of wholesale has no impact on GRV^+ while tends to

[14] In the estimation we use a modified version of the *spgm* function of the R *splm* package (see (Millo and Piras, 2012) for details) for unbalanced panel.

[15] The standard errors for the spatial coefficient in the error term ρ are not reported due to the impossibility to estimate it. However, according to the GS2SLS, the estimation of the ρ parameter is only used to filter the variables via a Cochrance-Orcutt type transformation withouth having an economic interpretation (see Appendix A for details).

intensify GRV^-. Our result therefore confirm the empirical evidence that output composition of GDP matters as provided in (Koren and Tenreyro, 2007), who define a rank of sectors in terms of their volatility (agriculture, mining and quarrying are those with high volatility levels, manufactures intermediate volatility and services sectors are those with the lower volatility level) and show that the presence of some sectors which are more volatile are associated to higher growth volatility.

In line with the literature size matters, although only in reducing GRV^-. This implies that regions with higher level of GDP also experience lower output volatility due to negative fluctuations, (Canning et al., 1998), (Easterly and Kraay, 2000) and Fiaschi and Lavezzi, 2011 for the evidence on the total output volatility.

Finally, financial deepening proxied by credit of private sector on GDP acts like an accelerator of recession, given its positive impact on the volatility due to negative shocks. This result seems to confirm the hypothesis that regions with higher financial system pay in terms of volatility in the short run (see Kaminsky and Reinhart, 1999).

Overall, almost 50% of the variability of macroeconomic volatility due both to positive and negative fluctuations is explained by our regressions.

4. Conclusion

In this paper, we present an empirical analysis on the determinants of growth rate volatility of per capital GDP (GRV) in Europe. Two different methodologies are describe to obtain measures of GRV, which allow to considerer the impact on the GRV due to business cycles as opposed to large fluctuations, and to compute the contribution of negative fluctuations to overall GRV, i.e. to evaluate the importance of asymmetries in business cycle. At this point it needs to be recalled that the variability of macroeconomic fluctuations, which generate the volatility in the output growth rates, have typically been perceived as a negative phenomenon. Nevertheless, the studies on the asymmetry of business cycle fluctuation and the role played by spatial spillover on GRV have received little attention in this contest. In this view, spatially econometric models are estimate to take into account spatial interdependence across regions, which implies that the GRV of a particular region is affected not only by its own degree of volatility but also by the output fluctuations of the remaining regions.

The results reported in the paper have potentially interesting policy implications. In particular, the size of the economy has the expected stabiliser effect; the output composition matters with remarkable differences between the models. An asymmetric effect of higher sector concentration is confirmed in both the analysis. However only the direct effect is statistically significant, suggesting that most of the effects of this variable is confined into the region itself. The concentration index has the positive relationship with GRV due to negative fluctuations, but the opposite hold for the postive fluctuation suggesting that diversifications can have an ambiguous impact on GRV and finally, the financial deepening tend to amplify the volatility in particular when it is generate by negative shocks.

The analysis can be extended in many respects. Firstly, other variables can be included in the analysis as the quality of institutions (proposed as possible explanations of GRV of country by the literature, see (Acemoglu et al., 2003), (Andolfatto, 1996), (Rumler and Scharler, 2011), and Cunat and Melitz (2011), along with specific controls for the local fiscal policy (e.g., the amount of Structural and Cohesion Funds) to assess the possible short-term stabilizing effects of counter-cyclical fiscal policy. Secondly, the econometric model should allow for non-linearities to take into account possible threshold effects in the explanation of GRV. Finally, the use of smaller regions (e.g., NUTS 3 regions) can provide further insight into what happens at local level, allowing the formulation of more targeted policy conclusions.

Although further research is required to understand deeply the business cycle fluctuations, our results of the asymmetric effect of some economic variables when volatility is generate by positive or negative shocks, suggest that policy makers should not forget and overlook this aspect in the EU regional policy.

Table 3: *Estimation of Model (10) under the two specifications with GRV^{+} and GRV^{-} by the GS2SLS.*

Dependent variable:	y = GRV^{+}				y = GRV^{-}			
	Coeff.	ADE	AIE	ATE	Coeff.	ADE	AIE	ATE
B. Monetary policy:								
GRV.INFLATION	-0.0002	-0.0002	-0.0005	-0.0007	-0.0033	-0.0043	-0.0213	-0.0256
EMU.DUMMY	0.0018	0.0020	0.0048	0.0068	0.0014	0.0018	0.0090	0.0109
C. GRV from the demand side:								
$(\text{INV.RATE})^2$	-0.1135^{***}	-0.1298^{***}	-0.3090^{*}	-0.4388^{**}	0.0776^{**}	0.1004^{**}	0.4950	0.5953
$(\text{HOUSEHOLD.EXP.on.GDP})^2$	0.1119^{***}	0.1279^{***}	0.3045^{**}	0.4323^{***}	-0.1020^{***}	-0.1318^{***}	-0.6501	-0.7819^{*}
$(\text{GOV.EXP.on.GDP})^2$	-0.5541^{***}	-0.6334^{***}	-1.5083^{**}	-2.1417^{***}	-0.4292^{***}	-0.5549^{***}	-2.7365	-3.2913
D. GRV from the supply side:								
HERFINDAHL	-0.1503^{**}	-0.1718^{**}	-0.4090	-0.5808	0.1158^{**}	0.1497^{*}	0.7385	0.8883
$(\text{SHARE.AGRI})^2$	1.3403^{***}	1.5323^{***}	3.6486^{**}	5.1809^{**}	-0.0380	-0.0491	-0.2421	-0.2912
$(\text{SHARE.MIN})^2$	0.5882^{***}	0.6725^{***}	1.6012	2.2736	-0.3795^{*}	-0.4906^{*}	-2.4194	-2.9100
$(\text{SHARE.MAN})^2$	0.2370^{***}	0.2710^{***}	0.6453	0.9163	-0.0796	-0.1029	-0.5077	-0.6106
$(\text{SHARE.FIN})^2$	0.0561	0.0641	0.1527	0.2169	0.0771	0.0996	0.4914	0.5910
$(\text{SHARE.NMS})^2$	0.1148	0.1312	0.3125	0.4438	0.0041	0.0054	0.0264	0.0318
$(\text{SHARE.CONST})^2$	-0.6609^{***}	-0.7556^{***}	-1.7990	-2.5546^{*}	-0.0789	-0.1020	-0.5031	-0.6051
$(\text{SHARE.WHOLE.squareSALE})^2$	-0.1207	-0.1380	-0.3285	-0.4664	0.4593^{***}	0.5938^{***}	2.9285	3.5222
$(\text{SHARE.HOTEL})^2$	0.8412^{***}	0.9617^{***}	2.2900	3.2518	-0.3828	-0.4949	-2.4406	-2.9355
$(\text{SHARE.TRANSP})^2$	0.0671	0.0767	0.1825	0.2592	-1.0086^{***}	-1.3038^{***}	-6.4301	-7.7339^{*}
GRV.log.PETROLEUM.PRICE	-0.0002	-0.0002	-0.0006	-0.0008	-0.0006	-0.0007	-0.0036	-0.0043
E. Regional characteristics:								
LOG.GDP	-0.0035	-0.0040	-0.0096	-0.0136	-0.0247^{***}	-0.0319^{***}	-0.1573^{*}	-0.1892^{**}
CREDIT.PRIV.SECTOR.on.GDP	0.0027	0.0031	0.0074	0.0105	0.0170^{***}	0.0220^{***}	0.1086^{*}	0.1306^{*}
F. GRV of neighbouring regions:								
λ	0.7413^{***}				0.8717^{***}			
ρ	-0.0146				-0.0660			
F-test of endogeneity	464.53^{***}				358.74^{***}			
AICc	-347.6547				657.2101			
R^2_{adj}	0.49				0.50			

Note. Dependent variable: macroeconomic volatility of per capita GDP at regional level, taking into account separately positive and negative fluctuations (GRV^{+} and $GRRV^{-}$, respectively). F-test of endogeneity: test of the null hypothesis of jointly exogeneity of INV.RATE, HOUSEHOLD.EXP.on.GDP, GOV.EXP.on.GDP and DOMESTIC.CREDIT.on.GDP. Significance levels: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$. and t-values in parenthesis. (Kelejian and Prucha, 1998)' procedure does not allow to directly calculate the standard errors (t-values) of ρ.

A. Generalized Spatial Two-Stage Least Squares (GS2SLS)

Consider the following SARAR model, where for the sake of simplicity we have summarized any determinant in the vector $\mathbf{X}$:

$$\begin{aligned} \text{GRV}_{it} &= c_i + \lambda \mathbf{W}_i \mathbf{GRV}_t + \boldsymbol{\beta} \mathbf{X}_{it} + u_{it} \\ u_{it} &= \rho \mathbf{W}_i u_{it} + \varepsilon_{it} \end{aligned} \tag{11}$$

The generalized spatial two-stage least squares (GS2SLS) to estimate a SARAR model developed by the (Kelejian and Prucha, 1998) consists in the following three steps:

1. **First step**: Model (11) is estimated by two-stage least squares (2SLS), using as instrumental variables $\mathbf{X}$, $\mathbf{WX}$, and $\mathbf{W^2X}$, i.e. regress $\mathbf{WGRV}$ on $\mathbf{X}$, $\mathbf{WX}$, and $\mathbf{W^2X}$; then use the fitted values $\mathbf{W\widehat{GRV}}$ in the second stage.

2. **Second step**: estimate the spatial autoregressive parameter in the error term ρ by GMM using the residuals $\hat{u}_{it}$ calculated in the first step, assuming $E[\varepsilon_{it}] = 0$, $E[\varepsilon_{it}^2] = \sigma_\varepsilon^2, \forall i,t$.

3. **Third step**: re-estimate Model (11) by 2SLS after filtering the variables via a Cochrane-Orcutt type transformation, i.e. use $\mathbf{GRV}^* = \mathbf{GRV} - \hat{\rho}\mathbf{WGRV}$, $\mathbf{X}^* = \mathbf{X} - \hat{\rho}\mathbf{WX}$, and $\mathbf{WGRV}^*$ instead the original ones.

B. Spatial Matrix

In the empirical analysis we consider the row-standardized spatial matrix, $\mathbf{W}$, which is based on the inverse of the great circle distance (d_{ij}) between the capitals of two regions with a cut-off equal to the first quantile of the distance distribution (denoted by d_{Q1}) equal to 648 kilometres. In particular, for any pair of regions i and j, the value of the element $w(i,j)$ of $\mathbf{W}$ is given by:

$$w(i,j) = w^*(i,j) / \sum_j w^*(i,j),$$

$$w^*(i,j) = \begin{cases} 0 & \text{if } i = j \\ d(i,j)^{-2} & \text{if } d(i,j) \leq d_{Q1} \\ 0 & \text{if } d(i,j) > d_{Q1}. \end{cases} \tag{12}$$

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