Discussion Papers

Collana di E-papers del Dipartimento di Economia e Management – University of Pisa

Irene Brunetti Davide Fiaschi Lisa Gianmoena

An Index of Growth Rate Volatility: Methodology and an Application to European Regions

Discussion Paper n. 169
2013

Discussion Paper n. 169, presentato: **October 2013**

Indirizzo degli Autori:

Irene Brunetti
Dipartimento di Economia e Management, via Ridolfi 10, 56100 PISA – Italy
Email: ireneb@ec.unipi.it@ec.unipi.it

Davide Fiaschi
Dipartimento di Economia e Management, via Ridolfi 10, 56100 PISA – Italy
Email: dfiaschi@ec.unipi.it

Lisa Gianmoena
Institute of Advanced Studies (IMT), LUCCA– Italy
Email: lisa.gianmoena@imtlucca.it

Please cite as it follows
Irene Brunetti, Davide Fiaschi, and Lisa Gianmoena (2013), "*An Index of Growth Rate Volatility: Methodology and an Application to European Regions*", Discussion Papers del Dipartimento di Economia e Management – University of Pisa, n. 169 (http://www-dse.ec.unipi.it/ricerca/discussion-papers.htm).

Discussion Paper
n. 169

Irene Brunetti - Davide Fiaschi - Lisa Gianmoena

An Index of Growth Rate Volatility: Methodology and an Application to European Regions

Abstract

A novel methodology, inspired by the literature on mobility, based on Markov matrices, to measure growth rate volatility by a synthetic index is proposed. An asymmetric version of the index allows to identify how much volatility can be ascribe to negative or positive fluctuations around trend. The application of the proposed methodology to a sample of 257 European regions shows that the economic size, their output compositions, their investment rates, the inflation rate and the domestic credit of countries to which they belong to are explanatory variables of growth rate volatility. On the contrary, no role for the participation to EMU is found. Construction sector and high flows of foreign direct investment favour large negative fluctuations.

Classificazione JEL: C20, E32, O40
Keywords: Markov Matrix, Asymmetric Fluctuations, Output Composition, Size Effect, Foreign Direct Investments

Contents

I. Introduction

The study of growth rate volatility (GRV) has attracted the interest of many researchers, in particular for its impact on economic growth countries (see, e.g. Ramey and Ramey (1995)).

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 (2000)). The advantage of the use of the standard deviation is its easy interpretation, but it presents some drawbacks. Firstly , it does not distinguish between temporary or persistent fluctuations, and, secondly, it does not distinguish the frequency of fluctuation around the trend; therefore it fails to indicate *type* of fluctuations is used in the calculation of GRV (see Gelb (1979) and Temple and Malik (2008)). A final drawback it is that it deals symmetrically with negative and positive fluctuations (see e.g. Hai et al. (2013)).

The aim of this paper is twofold: 1) to propose a novel methodology to measure GRV that overcomes these drawbacks; and 2) to investigate the determinants of GRV of per capita GDP of a sample of 257 European regions.

The novel methodology is based on a synthetic index of GRV inspired by the literature on mobility indexes based on Markov matrices (see Bartholomew (1973) and Shorrocks (1978)). The advantage of this approach is that the fluctuations, their intensity and frequency are directly measured. Moreover, the addictive nature of the proposed GRV index permits to identify the share of total volatility due to negative/positive fluctuations around the trend.

Smaller European regions with low density population show a higher GRV (see, e.g Canning et al. (1998), Alesina and Spolaore (2003) and Fiaschi and Lavezzi (2011) for a similar results for countries.). At regional level in Europe higher investment rates tend to moderate GRV, a result in contrast with the evidence at country level (see Ramey and Ramey (1995)). As in Koren and Tenreyro (2007) the output composition matters, and in particular the manufacturing and non market service have a stabilizing effect in European regions. Higher inflation is correlated with higher GRV, an evidence present also at country level (see Blanchard and Simon (2001)).
In line with the findings of Kaminsky and Reinhart (1999) and Easterly et al. (2000) at country level, domestic credit has an important positive impact on GRV. Finally, we find no effect of the participation to EMU of a country on the GRV of its regions.

The prevalence of large negative fluctuations is instead explained by the output composition of regions (in particular, a negative effect from the agricultural share and a positive effect from the share of constructions) and by the presence of high flows of foreign direct investments.

The paper is organized as follows. Section II. discusses the methodology for the computation of GRV; Section III. contains the description of the database of European regions and the results of the empirical analysis. Section IV. contains some concluding remarks.

II. The Methodology

There exists a natural parallelism between the concepts of growth rate volatility (GRV) and income mobility. In this section we explore the possibility to measure GRV by a synthetic index, denoted by I_B^{α}, inspired to a mobility index firstly proposed by Bartholomew (1973). In particular, we first discuss the most salient features of I_B^{α}, and then we propose an asymmetric version of it, which aims to detect how much volatility is to ascribe to negative or positive fluctuations around the trend.

To grasp the advantage of our methodology consider the growth rates of two Regions, A and B, with zero mean but different standard deviations (s.d.), equals to 0.05 and 0.02 respectively.

Figure 1 reports the residuals from the zero trend for both regions. If we take the standard deviation of growth rates as measure of GRV, Region A is more volatile than Region B; instead according to I_B^1 we reach the opposite result (in Section II. we discuss in detail how I_B^1 is calculated). The intuitive explanation lies in the higher number of fluctuations around the trend (i.e. zero) of Region B with respect to Region A.

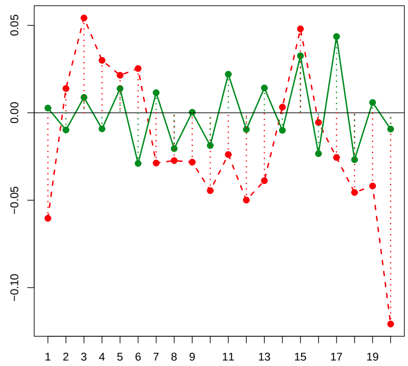
Panel (b) and (c) in Figure 1 report the estimated stochastic kernel[1]; we observe that Region B shows a clear concentration of transitions in the bottom-right and upper-left regions, but very concentrated around zero-trend. This means that Region B experimented an intensive fluctuation around its trend but of limited amplitude. The opposite holds for Region A, where there is a prevalence of observations around the bisector and a presence of observations of large deviations from trend.

Region B therefore shows high-frequently fluctuations, while Region A shows high persistently and few large fluctuations.

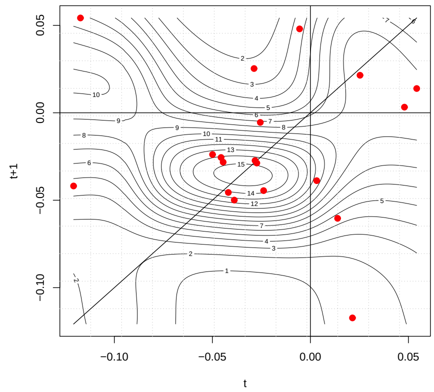
GRV should reflect the first type of phenomena (i.e. high-frequency fluctuations of income); while the second type (i.e. high persistence and large jumps) appears more adequately referred to the so called "instability", which is out of the scope of this paper (see Gelb (1979) and Temple and Malik (2008)).

[1]The stochastic kernel represents the conditional distribution of growth rate at period $t + 1$ conditioned to the growth rate of period t.

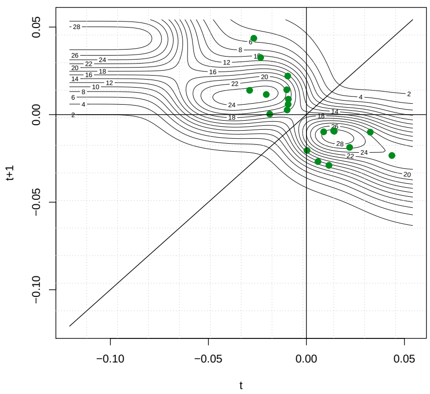
Figure 1: **A comparison between I_B^α and the standard deviation of growth rates as measures of GRV.**



(a) Time path of Regions A (red) and B (green). Region A: $s.d. = 0.05$ and $I_B^1 = 0.045$; Region B: $s.d. = 0.02$ and $I_B^1 = 0.076$.



(b) The Stochastic Kernel of Region A (gray lines) (the conditional distribution of growth rate at period $t+1$ given the GR at period t). The observations reported in red points are the transitions from period t to period $t+1$.



(c) The Stochastic Kernel of Region B (gray lines)(the conditional distribution of growth rate at period $t+1$ given the GR at period t). The observations reported in green points are the transitions from period t to period $t+1$.

II.A. 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:

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

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. $\frac{|s-q|^\alpha}{\max(|s-q|^\alpha)}$, which represents the weights of a "jump" from state q to state s. A higher α therefore 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;

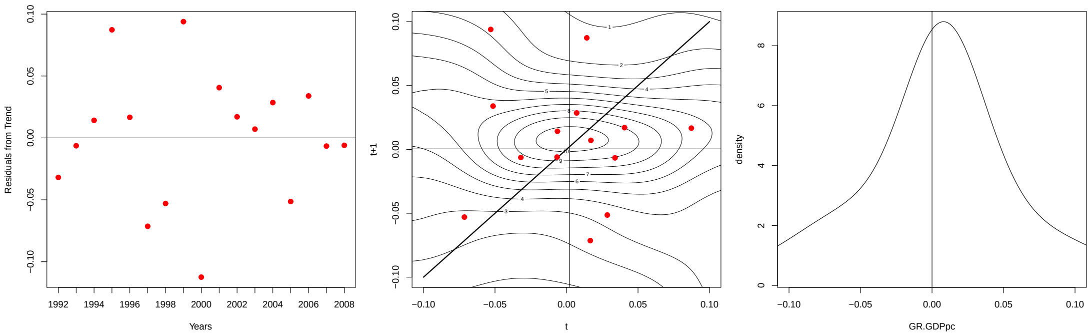
III. $\pi(q)$ is the ergodic distribution, which measures how much time is spent in state q in equilibrium.

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 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). This choice is motivated by a literature which highlights that, when the variable of interest is defined on a continuum of values, an arbitrary discretisation of the state space is almost certain to remove the Markov property of the process (see, in particular, Bulli (2001))[2].

[2] See also Kemeni and Snell (1976), Billingsley (1995) and Guihenneuc-Jouyaux and Robert (1998).

Figure 2: **European region with highest I_B^1 ($I_B^1 = 0.29$) (region code: RO42, see Section III.). From left to right: Panel 1 is the plot of the residuals from the trend; Panel 2 is the estimated stochastic kernel; and Panel 3 is the estimated ergodic distribution.**



Figures 2 and 3 provides a picture of Components II and III for two European regions selected among the sample of regions we will analyse in Section III.; these present the highest and the lowest I_B^1 (i.e. the value of I_B^α with $\alpha = 1$).

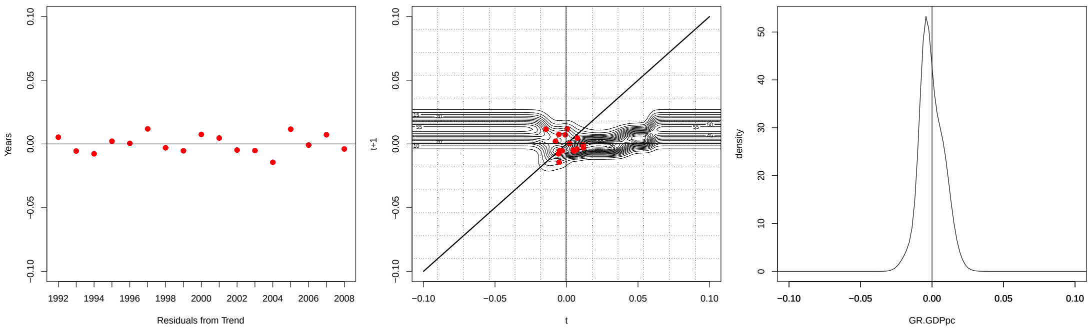
The region with the highest I_B (equals to 0.29) displays frequent and significant "jumps" around the zero-trend (see panel on the left in Figure 2)[3]. This intuition is made clearer by the estimate of the stochastic kernel reported in the middle of Figure 2, where 6 out 17 transitions are related to passages through zero-trend[4]. The stochastic kernel also highlights that the probability of large jumps is not negligible for a large range of initial states. Finally, the estimated ergodic distribution reported in the right panel of Figure 2 appears very broadly distributed, confirming that the region is likely to visit many states far from zero-trend.

Not surprisingly, region with the lowest I_B^1 displays the opposite pattern. Residuals from trend are very close to zero-trend; the estimated stochastic kernel is very concentrated around the zero-trend, as well as the estimated ergodic distribution.

[3]Residuals from trend are calculated applying a Hodrick-Prescott filter to observed growth rate of per capita GDP of regions (see Section III. for more details).

[4]These transitions are reported in upper-left and bottom-right regions in Figure 2.

Figure 3: **European region with lowest I_B^1 ($I_B^1 = 0.045$) (region code: ITG1, see Section III.). From left to right: Panel 1 is the plot of the residuals from the trend; Panel 2 is the estimated stochastic kernel; and Panel 3 the estimated ergodic distribution.**



II.B. An Asymmetric Version of I_B^α

I_B^α is a GRV index which 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.:[5]

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

where

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

and

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

$I_{B_+}^\alpha$ 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.

Figures 4 and 5 report European regions with the highest and the lowest I_{B-}^1 / I_B^1 (equals to 0.55 and 0.41 respectively). A deep jump below the trend (corresponding to a GR equals to -0.03) and several observations in the negative part of the stochastic kernel characterized the region in Figure 4, while the region in Figure 5 displays very homogeneous negative "jumps".

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

Figure 4: **European region with the highest I^1_{B-}/I^1_B (0.55) (region code: ES11). From left to right: Panel 1 is the plot of the residuals from the trend; Panel 2 is the estimated stochastic kernel; and Panel 3 the estimated ergodic distribution.**

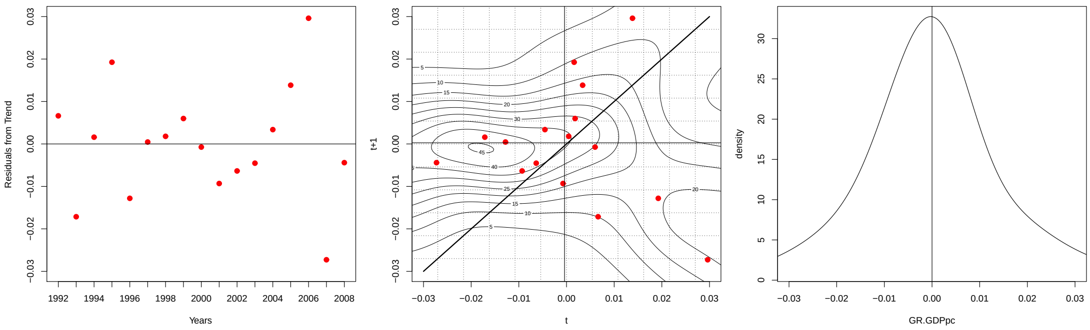
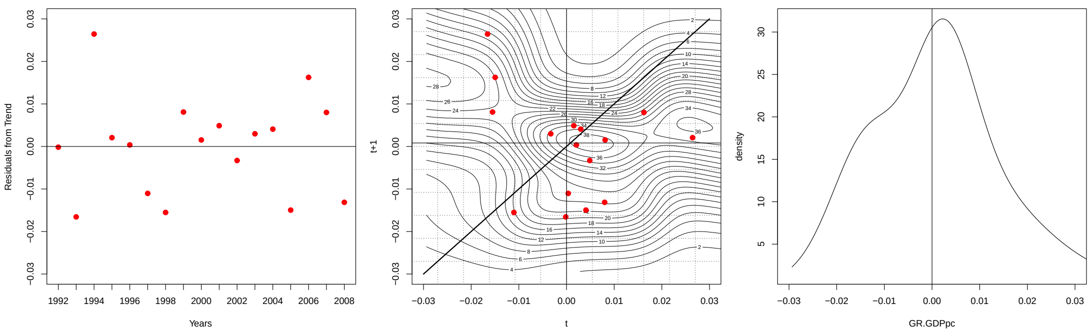


Figure 5: **European region with the lowest I^1_{B-}/I^1_B (0.41) (region code: UKH1). From left to right: Panel 1 is the plot of the residuals from the trend; Panel 2 is the estimated stochastic kernel and Panel 3 the estimated ergodic distribution.**



III. The Empirical Analysis

In this section firstly we provide a descriptive analysis of GRV index (both I^α_B and I^1_{B-}/I^1_B) for a large sample of EU regions (see Appendix E for region list). Then we test the explanatory power of some regional characteristics as determinants of GRV.

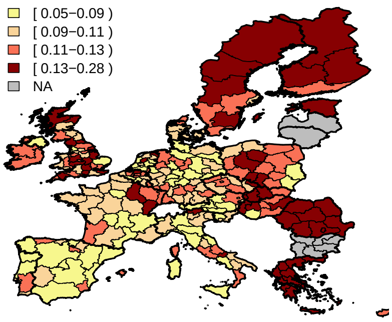
Data for EU regions are drawn from the European regions database of Cambridge Econometrics (i.e. EU 27 less Bulgaria, Latvia and Lithuania [6]). We select 257 EU regions over the time horizon $1991 - 2008$.

[6] We exclude these countries because they present evident outliers.

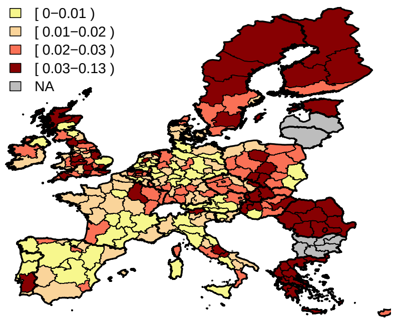
III.A. I_B^α of European Regions

Figures 6-8 show the geographical pattern of I_B^1, I_B^2, I_{B-}^1/I_B^1 (and for the standard deviations of filtered growth rates for comparison) for our sample of European regions, while Tables 5 and 6 report some descriptive statistics.

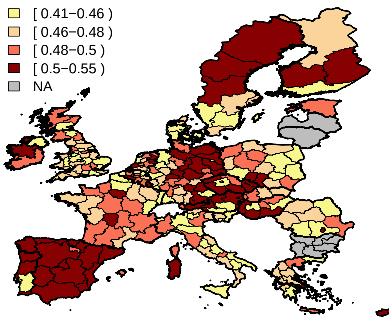
Figure 6: **Geographical pattern of I_B^1, I_B^2, I_{B-}^1/I_B^1 and $\sigma_{GR.GDP}$ for the sample of 257 European regions.**



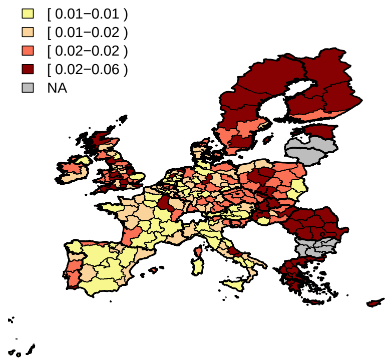
(a) I_B^1



(b) I_B^2



(c) I_{B-}/I_B



(d) $\sigma_{GR.GDP}$

The most salient features are the following:

1 Coefficient α does not play a major role in the calculation of GRV. The absolute level of I_B^α negatively depends on α (compare Panels (a) and (b)

in Figures 6 and 7) and shows a covariance equals to 0.97 (see Table 5 in Appendix F).

2 I_B^1 shows a high cross-sectional variance, with a clear country component for Greece, Romania, Spain and Scandinavian countries (see Panel (a) in Figure 6). Spatial dependence is confirmed by the estimated Moran's I and LISA.[7].

In particular, the non-parametric estimate of Moran's I scatter plot in Figure 7 Panel (a) shows that spatial dependence is present at any level of I_B^1.

3 I_{B-}^1/I_B^1 displays a very heterogeneous geographical pattern (see Panel (c) in Figure 6). Spain, Norway, East Germany, Czech Republic and Slovakia appear the countries with the highest country component; otherwise no evident spatial dependence is present.
Panel (a) in Figure 8 confirms this impression, with non-parametric estimate

[7]The Moran's I statistic has as its null hypothesis no global spatial autocorrelation. The Moran scatterplot presents the relation of the variable in the location i with respect the values of that variable in the neighboring locations. By construction the slope of the straight line in the Moran scatterplot is equal to the Moran's I coefficient. We also report the non parametric estimation of such relationship as suggested by Anselin (1988) to detect nonlinearities.

The Moran's I test for global spatial autocorrelation is based on cross-products of the deviations from the mean, in particular:

$$I = \frac{N\sum_i \sum_j w_{ij}(GRV_i - \overline{GRV})(GRV_j - \overline{GRV})}{(\sum_i \sum_j w_{ij})\sum_i (GRV_i - \overline{GRV})^2},$$

where, $\overline{GRV}$ is the mean of the GRV across regions, w_{ij} are the elements of the weight matrix $\mathbf{W}$. Therefore we have strong negative spatial autocorrelation for $I = -1$, no spatial autocorrelation for $I = 0$, and strong positive spatial autocorrelation for $I = 1$.

LISA is the local version of Moran's I. It examines the local level of spatial autocorrelation, i.e.

$$I_i = \frac{GRV_i}{m_2}\sum_j w_{ij} GRV_j \quad \text{where} \quad m_2 = \frac{\sum_i GRV_i^2}{N}.$$

Therefore we have spatial clustering of similar values (high-high) (low-low) for $I_i > 0$ and spatial clustering of dissimilar values (high-low) (low-high) for $I_i < 0$.

In the empirical analysis the row-standardized spatial matrix $\mathbf{W}$ is based on the inverse of the great circle distance (d_{ij}) between the capitals of two regions, taking as the maximum distance to have a positive weight the first quantile of the distance distribution denoted by d_{Q1}. In particular, for any couple of regions (i, j), the values of the elements of $\mathbf{W}$ are given by:

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

$$w^*(i,j) = \begin{cases} 0 & \text{if } i = j \\ d_{ij}^{-2} & \text{if } d_{ij} \le d_{Q1} \\ 0 & \text{if } d_{ij} > d_{Q1}. \end{cases} \tag{5}$$

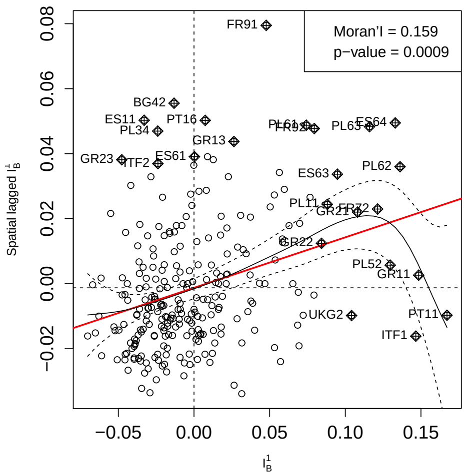
pointing out no or week spatial relationship at low/medium levels of I^1_{B-}/I^1_B and a positive relationship only at high levels.

4 I^1_B and $\sigma_{GR.GDP}$ have a high correlation equals to 0.94 (se Table 5 in Appendix F and Table 3 in Appendix A); and the geographical pattern looks very similar (compare Panels (d) and (a) in Figure 6). However $\sigma_{GR.GDP}$ appears not to catch possible extreme volatility (see Panel (b) in Figure 9 in Appendix A), and in general the spatial dependence of volatility (the non-parametric estimation is flat for low medium levels of $\sigma_{GR.GDP}$, see panel (c) in Figure 8)

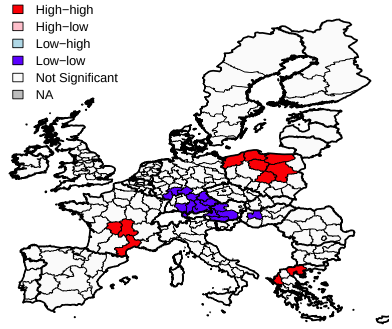
III.B. The Dataset of Potential Explanatory Variables

Table 1 contains the list of the possible explanatory variables of GRV of EU regions, and the main references to other analysis on GRV (at country level generally) that use them.

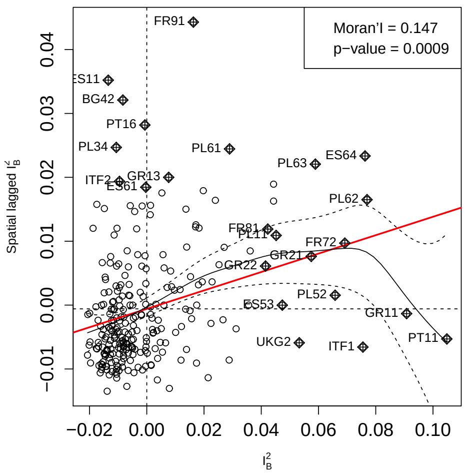
Figure 7: **Moran scatter plot and Moran's I of I_B^1 and I_B^2**



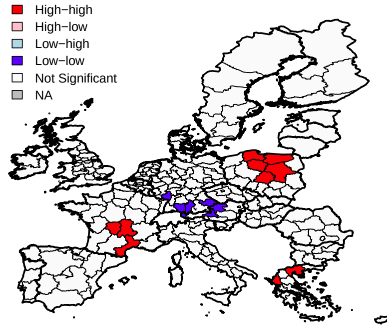
(a) Moran Scatter-plot of I_B^1



(b) Local Indicators of Spatial Association (LISA) of I_B^1

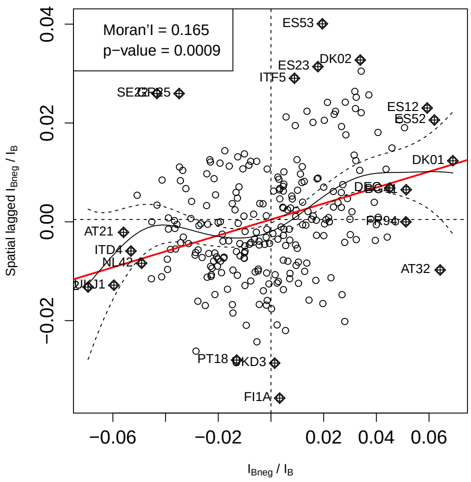


(c) Moran Scatter-plot of I_B^2

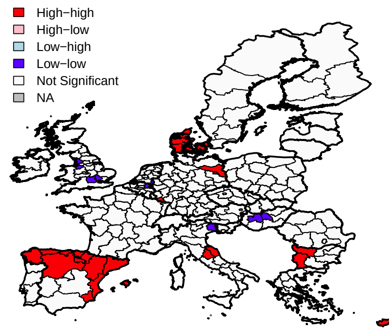


(d) Local Indicators of Spatial Association (LISA) of I_B^2

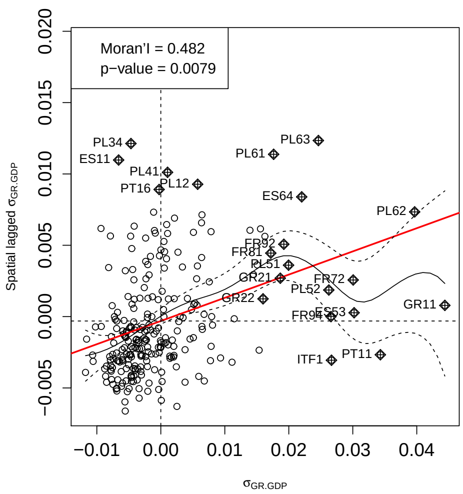
Figure 8: **Moran scatter plot and Moran's I of I^1_{B-}/I^1_B and $\sigma_{GR.GDP}$**



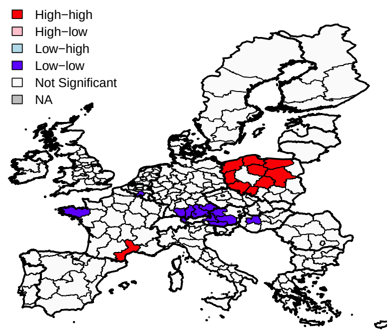
(a) Moran Scatter-plot of I^1_{B-}/I^1_B



(b) Local Indicators of Spatial Association (LISA) of I^1_{B-}/I^1_B



(c) Moran Scatter-plot of $\sigma_{GR.GDP}$



(d) Local Indicators of Spatial Association (LISA) of $\sigma_{GR.GDP}$

Table 1: **List of variables used in the analysis, their sources and references.**

Variables	Code	Description and Sources	References
Size of the economy	LOG.GDP.1992	Total GDP at constant level 2000 (mln of Euros) (Cambridge Econometrics database)	Gali (1994), Head (1995), Canning et al. (1998), Fiaschi and Lavezzi (2005), Fiaschi and Lavezzi (2011), Alesina and Spolaore (2003), di Giovanni and Levchenko (2009), di Giovanni and Levchenko (2012)
Cyclical components	EMPL.GR	Employment growth rate (Cambridge Econometrics database)	Cunat and Melitz (2011), Rumler and Scharler (2011)
	INV.RATE	Investment rate (Cambridge Econometrics database)	Aizenman and N. (1999),
Sectoral composition	ECO.DENSITY	Economic Density (Cambridge Econometrics database)	
	SHARE.AGRI	Share of agriculture on total GDP (Cambridge Econometrics database)	Koren and Tenreyro (2007), di Giovanni and Levchenko (2009)
	SHARE.MIN	Share of mining on total GDP (Cambridge Econometrics database)	
	SHARE.MANU	Share of manufacture on total GDP (Cambridge Econometrics database)	
	SHARE.FIN	Share of finance on total GDP (Cambridge Econometrics database)	
	SHARE.NMS	Share of no market services on total GDP (Cambridge Econometrics database)	
	SHARE.CONSTS	Share of construction on total GDP (Cambridge Econometrics database)	
Other reg. variables	HOUSE.EXP.on.GDP	Household Expenditure on total GDP (Cambridge Econometrics database)	
	POP.DENSITY	Population density, (Cambridge Econometrics database)	Collier (2007)
Countries variables	GOV.EXP.on.GDP	General government final consumption expenditure (World Bank national accounts data)	Rodrik (1998), Van den Noord (2000),Bejan (2006), Fatas and Mihov (2001),
	FDI.on.GDP	Total FDI on total GDP (World Bank national accounts data)	Prasad, K., Wei, and M.A. (Prasad et al.), Coric and P (2013), San Vicente Portes (2007)
	CREDIT.PRIV.SECTOR.on.GDP	Domestic credit to private sector (% of GDP) (World Bank national accounts data)	Kaminsky and Reinhart (1999), Easterly et al. (2000), Cecchetti et al. (2006),Beck et al. (2006)
	INFLATION	Inflation measured by the annual growth rate of the GDP implicit deflater (World Bank national accounts data)	Blanchard and Simon (2001), Easterly et al. (2000), Ball and Sheridan (2003), Cecchetti and Ehrmann (2002) and Leduc and Sill (2007)
EMU participation	EMU.DUMMY		De Grauwe (2007)

I_B^α is the result of two step procedure. Firstly, from the yearly annual growth rate of GDP per capita is calculated its cyclical component by Hodrick-Prescottt filter. The filtered data are then used to estimate stochastic kernel, I_B^α and I_{B-}^1/I_B^1.

The explanatory variables used in the analysis may be classified into six main groups:

1. the **Size of the economy** measured by the logarithm of the GDP in the first year, LOG.GDP.1992. In this framework, Canning et al. (1998) 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 countries are also more volatile. Imbs (2007) provides a theoretical model where large and different sectors present in large countries accounts for lesser output volatility.

2. **Cyclical components**: the average of employment growth rate and by the average of investment rate, of the period 1991-2008, AV.EM.GR, AV.INV.RATE.

3. **Sectoral composition**: the shares of agriculture, mining, manufacture, finance, non market service and construction on total GDP in the 1991. The empirical evidence shows a clear relationships between output composition and GRV. In particular, as Koren and Tenreyro (2007) and Fiaschi and Lavezzi (2011) point out, some sectors are associated with a higher level of volatility.

4. Other **Regional variables**: the average of the share of household expenditure on total GDP on the period, AV.HOUSE.EXP.on.GDP, and the average population density (in logarithm terms), LOG.AV.POP.DENSITY.

5. **Country variables**: the average size of government expenditure as share of GDP, AV.GOV.EXP.on.GDP should capture differences in fiscal policy. Large government expenditure may smooth economic shocks and reduces *GRV*, given its characteristics of automatic fiscal stabilizer Van den Noord (2000).
   As also supported by empirical evidence in Bejan (2006) and Fatas and Mihov (2001). Bejan (2006) finds that larger governments decreases volatility in developed countries, but not in developing countries. Fatas and Mihov (2001) study the relationship between growth volatility and government size in a sample of 20 OECD countries. Using different measure of output volatility and government size, they find a negative relations between the two variables, i.e. larger governments are associated with less output volatility.
   To capture the role of Foreign Direct Investment (FDI) flows shocks, we use data on FDI on tatal GDP, AV.FDI.on.GDP, see Prasad, K., Wei, and M.A. (Prasad et al.), Coric and P (2013), San Vicente Portes (2007) The average value of credit from financial intermediaries to the private sector, divided by GDP, AV.DOMESTIC.CREDIT.on.GDP is taken as measure of financial development. As suggested by Beck et al. (2006) private credit measures the most important activity of the financial intermediary sector, channelling funds from savers to investors, and more specifically, to investors in the private sector. Easterly et al. (2000) empirically show a convex ans non-monotone relationship between financial depth and output volatility. They suggest that output volatility starts to increase when credit to private sector reaches 100% of GDP. However as suggested by Kaminsky and Reinhart (1999), the fact that large financial sector may increase volatility does not necessary mean that large financial system is bad. It is possible that countries with higher financial system pay in term of volatility in the short run due to financial crises, but gain in terms of higher growth in the long-run.

Inflation proxies for the exposure of the economy to monetary shocks. The empirical evidence on the relationship between growth volatility and inflation targeting is analysed by Blanchard and Simon (2001), Ball and Sheridan (2003), Cecchetti and Ehrmann (2002) and Leduc and Sill (2007). Even though this study sheds some light on the impact of monetary policy and output volatility, a clear results is still not definitive. In fact the relationship between output and inflation varies, depending on the type of shock that hits the economy. Cecchetti and Ehrmann (2002) argue that aggregate demand shocks move inflation and output in the same direction, while aggregate supply shocks move output and inflation in opposite directions.

6. Finally **Euro dummy**, EMU.DUMMY, is used to control for the effect of European Monetary union, (see De Grauwe (2007) for a thorough discussion of the possible relevance of the EMU for countries'volatility).

III.C. Cross-region Regressions

Given the presence of spatial effects we estimate a spatial simultaneous autoregressive SAC/SARAR model, i.e. our baseline cross-region regression is given by:

$$\begin{aligned}\mathbf{y} &= \rho\mathbf{W}\mathbf{y} + \mathbf{X}\beta + u = (\mathbf{I} - \rho\mathbf{W})^{-1}(\mathbf{X}\beta + u)\\ \mathbf{u} &= \lambda\mathbf{W}\mathbf{u} + \mathbf{e} = (\mathbf{I} - \lambda\mathbf{W})^{-1}e,\end{aligned} \tag{6}$$

where $\mathbf{y}$ is the vector of observations of the dependent variable, i.e. GRV; $\mathbf{W}$ is the spatial-weighting matrices, where the weights w_{ij} are modelled as inversely related to the square distance between regions whit a cut-off equal to first quartile, $\mathbf{Wy}$ and $\mathbf{Wu}$ are the vectors referred to as spatial lags of dependent and error component, λ and ρ are the spatial-autoregressive parameters, $\mathbf{X}$ is the matrix of exogenous variables, and finally $\mathbf{e}$ is the vector of innovations assumed to be independently across time and space and identically distributed.

As pointed out by LeSage and Pace (2009) given a SARAR model like Eq.6 the total impact of each variable in $\mathbf{X}$ must take into account of the the spatial interdependencies and simultaneous feedback embodied in the model i.e: [8]

$$\frac{\partial\mathbf{y}}{\partial\mathbf{X}} = (\mathbf{I} - \rho\mathbf{W})^{-1}\mathbf{I}\beta \tag{7}$$

Table 2 reports the estimated total effects with different specification of the dependent variable y.

The estimated β coefficients are instead reported in Appendix D. In model (1), where $y = I_B^1$, as expected, LOG.GDP.1992 has a negative and strong significant effect, therefore exist a *size effect* on volatility, i.e. region with higher level of total

[8] From Eq. (6) we have $(\mathbf{I} - \lambda\mathbf{W})^{-1}(\mathbf{X}\beta + u)$; hence it easily follows that $\partial\mathbf{y}/\partial\mathbf{X} = (\mathbf{I} - \rho\mathbf{W})^{-1}\mathbf{I}\beta$.

Table 2: **The estimated total impacts of variables**

	Dependent variable:			
	$y = I_B^1$	$y = I_B^2$	$y = I_{B-}/I_B$	$y = \sigma_{GR.GDP}$
	(1)	(2)	(3)	(4)
LOG.GDP.1992	-0.033^{***}	-0.017^{***}	-0.0004	-0.001^{***}
	(0.006)	(0.003)	(0.002)	(0.001)
LOG.AV.POP.DENSITY	-0.01^{***}	-0.004^{***}	-0.001	0.001
	(0.002)	(0.001)	(0.002)	(0.000)
AV.EMPL.GR	0.292	-0.137	-0.084	0.015
	(0.480)	(0.241)	(0.07)	(0.042)
AV.INV.RATE	-0.447^{***}	-0.294^{***}	0.048	-0.006
	(0.123)	(0.074)	(0.043)	(0.018)
SHARE.AGRI.1992	-0.125	-0.051	-0.104^{**}	-0.006
	(0.117)	(0.059)	(0.046)	(0.01)
SHARE.MIN.1992	0.330	0.05	0.015	0.028^{***}
	(0.191)	(0.105)	(0.038)	(0.02)
SHARE.MAN.1992	-0.177^{***}	-0.093^{***}	-0.037	0.007
	(0.060)	(0.033)	(0.025)	(0.006)
SHARE.FIN.1992	-0.15	0.059	0.020	0.017
	(0.197)	(0.093)	(0.058)	(0.011)
SHARE.NMS.1992	-0.316^{***}	-0.128^{***}	-0.059	-0.001
	(0.095)	(0.048)	(0.037)	(0.012)
SHARE.CONST.1992	0.088	0.141	0.16^{**}	0.031^{**}
	(0.154)	(0.097)	(0.068)	(0.023)
AV.HOUSE.EXP.on.GDP	-0.002	-0.011	-0.005	-0.002
	(0.027)	(0.015)	(0.012)	(0.002)
AV.INFLATION	0.225^{**}	0.075	0.001	0.028^{***}
	(0.091)	(0.043)	(0.029)	(0.011)
AV.GOV.EXP.on.GDP	0.041	-0.074	-0.04	0.006
	(0.171)	(0.073)	(0.074)	(0.016)
AV.DOMESTIC.CREDIT.on.GDP	0.067^{***}	0.030^{***}	0.005	-0.001
	(0.016)	(0.007)	(0.006)	(0.002)
AV.FDI.on.GDP	-0.022	-0.021^{***}	0.014^{*}	-0.001
	(0.017)	(0.008)	(0.004)	(0.001)
EMU.DUMMY	0.006	0.007	0.004	0.001
	(0.008)	(0.004)	(0.004)	(0.012)
Constant	0.519^{***}	0.273^{***}	0.550^{***}	0.027^{***}
	(0.098)	(0.056)	(0.077)	(0.012)
Note:				*p<0.1; **p<0.05; ***p<0.01

output are also those which lower output volatility. LOG.AV.POP.DENSITY has negative and strong significant effect; those regions with higher population density, like the one containing metropolis or big cities, are also those whit less output volatility. This result could be considered a second *size effect* related to demographic features[9]. An higher investment rate, (AV.INV.RATE) is associated to a strong reduction in GRV. This evidence points to a negative relationship between GRV and growth rate (the opposite found by Ramey and Ramey (1995) at country level. Like in Koren and Tenreyro (2007), for countries output composition matters: manufacturing, (SHARE.MANU), and non market services, (SHARE.NMS) have a stabilizing effect; this is an expected results for SHARE.NMS because it collects the most of the output derived by public expenditure.

Among the variables at country level, inflation (AV.INFLATION) has a positive impact on GRV (see Easterly et al. (2000) and citeAcemogluZilipotti1997). The common explanation in literature refers to bad macroeconomic policies whose effects are both high GRV and inflation.

As in Easterly et al. (2000) the size of credit positively affects GRV (in their analysis this effect is non linear).

Large financial sector increase volatility. The size of the domestic credit to private sector has a statistically significant ans positive effect, as suggested by Kaminsky and Reinhart (1999) and Easterly et al. (2000).

Finally, the participation of a country to European Monetary Union has not any impact of GRV of its regions.

As expected the estimated model (2) with $y = I_B^2$, produces the same results, with the exception of inflation, which is no more statistically significant, and foreign direct investments (AV.FDI.on.GDP) which appear to stabilize regions' GDP.

The estimated of model (3) with $y = I_{B-}^1 / I_{B^1}$ shows how agriculture sector prevents to experiment large negative "jumps" in growth rate of per capita GDP, while the opposite holds for construction sector. These findings agree with the common wisdom that construction is a potential source of strong downturn of economic of economic activity.

Finally, foreign direct investment seems to favor large negative deviation from trend. The view of this type of investment as highly volatility and, therefore possible sources of significant economic recession, finds here a corroboration Prasad, K., Wei, and M.A. (Prasad et al.).

The estimate of model (4) with $y = \sigma_{GR.GDP}$ is reported for comparison with Model (1). Size of a country and inflation are statistically significant as in Model (1); the share of mining (SHARE.MIN) and construction (SHARE.CONST) on GDP are instead significant only in Model (4).

[9]For a discussion on the effect on countries' volatility of their population see Alesina and Spolaore (2003).

IV. Concluding Remarks

We have proposed a new methodology to measure the GRV of regions/countries based on the estimated of Markov matrices. This measure allows also to decompose the total GRV index between the volatility due to negative or positive fluctuations around the trend. We claim that our index of GRV is more adapt to measure growth volatility than the standard deviation of the growth rate generally used in literature.

The application of methodology to a large sample of European regions identifies the sources of GRV of these regions in their size, investment rates, output composition, and inflation and levels of credit at country level. No role for the participation EMU has been found. The main sources of large negative fluctuations are instead represented by the share of constructions on total output and on the flows of foreign direct investments.

Future research should be take into account possible non-linearities in the econometric model as well as the introduction in the analysis of the other variables as the quality of institutions (see Acemoglu et al. (2003)) and some measures related to the characteristic of good and labour market (see Andolfatto (1996), Rumler and Scharler (2011), and Cunat and Melitz (2011)).

Acknowledgements We are very grateful to PRIN meeting participants in Pisa and Alessandria for their comments. We are also grateful to Angela Parenti for her help in the computational analysis. The usual disclaimers apply. I. B. and D.F. have been supported by the Italian Ministry of University and Research as a part of the PRIN 2009 program (grant protocol number 2009H8WPX5).

Affiliation and Address of the Authors

Irene Brunetti: Dipartimento di Economia e Management, University of Pisa, Pisa, Italy.

Davide Fiaschi: Dipartimento di Economia e Management, University of Pisa, Pisa, Italy.

Lisa Gianmoena: Institute of Advanced Studies (IMT), Lucca, Italy

References

Acemoglu, D., S. Johnson, J. Robinson, and Y. Thaicharoen (2003). Institutional causes, macroeconomic symptoms: Volatility, crises and growth. *Journal of Monetary Economics 50*, 49–123.

Aizenman, J. and M. N. (1999). Volatility and investment: Interpreting evidence from developing countries. *Economica* (66), 15779.

Alesina, A. and E. Spolaore (2003). *The size of Nations.* Cambridge:MIT Press.

Andolfatto, D. (1996). Business cycles and labor-market search,. *American Economic Review* (86), 112–32.

Anselin, L. (1988). *Spatial Econometrics: Methods and Model.* Dordrecht: Kluwer.

Ball, L. and N. Sheridan (2003). Does inflation targeting matter. *NBER Working Paper 45* (9577).

Bartholomew, D. J. (1973). *Stochastic Models for Social Processes.* London: John Wiley & Son.

Beck, T., M. Lundberg, and G. Majnoni (2006). Financial intermediary development and growth volatility: Do intermediaries dampen or magnify shocks? *Journal of International Monetary and Finance 25*, 1146–1167.

Bejan, M. (2006). Trade openness and output volatility. *MPRA Paper*.

Billingsley, P. (1995). *Probability and Measure.* London: John Wiley & Son.

Blanchard, O. and J. Simon (2001). The long and large decline in u.s. output volatility. *Brookings Papers on Economic Activity 2001* (1), 135–164.

Bulli, S. (2001). Distribution dynamics and cross-country convergence: a new approach. *Scottish Journal of Political Economy 48* (2), 226–243.

Canning, D. L., Y. L. Amaral, M. Meye, and H. Stanley (1998). Scaling the volatility of gdp growth rate. *Economics Letters* (60), 335–341.

Cecchetti, S. and M. Ehrmann (2002). *Does Inflation Targeting Increase Output Volatility?: An International Comparison of Policymakers' Preferences and Outcomes*, Volume 4 of *Monetary Policy: Rules and Transmission Mechanisms*, Chapter 9, pp. 247–274. Banco Central de Chile, Santiago.

Cecchetti, S., A. Flores-Lagunes, and S. Kraus (2006). Has monetary policy become more efficient? a cross-country analysis. *Economic Journal* (116), 408–433.

Collier, P. (2007). *The Botton Billion.*

Coric, B. and G. P (2013). Foreign direct investment and output growth volatility: A worldwide analysis. *International Review of Economics & Finance 25* (C), 260–271.

Cunat, A. and M. Melitz (2011). Volatility, labor market flexibility, and the pattern of comparative advantage. *Journal of the European Economic Association 2* (10), 225254.

De Grauwe, P. (2007). *Economics of Monetary Union.*

di Giovanni, J. and A. Levchenko (2009, August). Trade openness and volatility. *The Review of Economics and Statistics 91*(3), 558–585.

di Giovanni, J. and A. Levchenko (2012). Country size, international trade, and aggregate fluctuations in granular economies. *Journal of Political Economy 120*(6), 1083 – 1132.

Easterly, W., R. Islam, and J. Stiglitz (2000). Shaken and stirred: Explaining growth volatility. *Working Paper*.

Elhorst, J. P. (2012). Matlab software for spatial panels. *International Regional Science Review*.

Fatas, A. and I. Mihov (2001). Government size and automatic stabilizers: international and intranational evidence. *Journal of International Economics 55*(1), 3–28.

Fiaschi, D. and A. M. Lavezzi (2005). An empirical analysis of growth volatility: a markov chain approach. *Department Working Paper*.

Fiaschi, D. and A. M. Lavezzi (2011). *Growth Volatility and the Structure of the Economy* (in Olivier de La Grandville ed. Economic Growth and Development Frontiers of Economics and Globalization, Volume 11 ed.), Volume 2, Chapter 8, pp. 203–245. Emerald Group Publishing Limited.

Furceri, D. and G. Karras (2007). Country size and business cycle volatility: Scale really matter? *Journal of the Japanese and International Economies 21*, 424–434.

Furceri, D. and G. Karras (2008). Business cycle volatility and country size: Evidence for a sample of oecd countries. *Economics Bulletin 5*, 1–17.

Gali, J. (1994, January). Government size and macroeconomic stability. *European Economic Review 38*(1), 117–132.

Gelb, A. (1979). On the definition and measurement of istability and the costs of buffering export fluctuations. *The Review of Economic Studies 46*(1), 149–162.

Guihenneuc-Jouyaux, C. and C. Robert (1998). Discretization of continuous markov chain and markov chian monte carlo convergence assessment. *Journal of the Amercian Statistical Association 93*, 1055–67.

Hai, V. T., A. K. Tsui, and Z. Zhang (2013). Measuring asymmetry and persistence in conditional volatility in real output: Evidence from three east asian tigers using a multivariate garch approach. *Applied Economics 45*(20).

Imbs, J. (2007). Growth and volatility. *Journal of Monetary Economics 54*(7), 1848–1862.

Kaminsky, G. L. and C. M. Reinhart (1999). The twin crises: the causes of banking and balance-of-payments problems. *American Economic REview 89*(3), 473–500.

Kemeni, J. and L. Snell (1976). *Finite Markov Chain*. New York, Springer Verlag.

Koren, M. and S. Tenreyro (2007). Volatility and development. *Quarterly Journal of Econometrcs* (55), 244–287.

Kormendi, R. C. and P. G. Meguire (1985). Macroeconomic determinants of growth: Cross-country evidence. *Journal of Monetary Economics 16*(2), 141–163.

Leduc, S. and K. Sill (2007). Monetary policy, oil shocks, and tfp: Accounting for the decline in us volatility. *Review of Economic Dynamics 10*(4), 595 – 614.

LeSage, J. and K. Pace (2009). *Introduction to Spatial Econometrics*. Boca Raton, FL: CRC Press.

LeSage, J. and R. Pace (2008). Spatial econometric modeling of origin-destination flows. *Journal of Regional Science 48*(5), 941–967.

LeSage, J. P. (2008). An introduction to spatial econometrics. *Revue d'économie industrielle* (3), 19–44.

Martin, P. and C. A. Rogers (2000). Long-term growth and short-term economic instability. *European Economic Review 44*(2), 359–381.

Prasad, E., R. K., S.-J. Wei, and K. M.A. *Financial Globalization, Growth and Volatility in Developing Countries*, pp. 457–516. University of Chicago Press.

Ramey, G. and V. A. Ramey (1995). Cross country evidence on the link between volatility and growth. *American Economic Review 85*(5), 1138–51.

Rodrik, D. (1998). Why do more open economies have bigger governments? *Journal of Political Economy 106*(5), pp. 997–1032.

Rumler, F. and J. Scharler (2011). Labor market institution and macroeconomic volatility in a panel for oecd countries. *Scottish Journal of Political Economy* (58).

San Vicente Portes, L. (2007, December). Aggregate gains of international diversification through foreign direct investment: An inquiry into the moderation of u.s. business cycles. *Global Economy Journal 7*(4), 1–38.

Shorrocks, A. (1978). The measurement of mobility. *Econometrica 46*(5), 1013–1024.

Temple, J. and A. Malik (2008). The geography of output volatility. *Journal of Development Economics 90*, 163–178.

Van den Noord, P. (2000). The size and role of automatic stabilizers in the 1990s and beyond. oecd economics. *Department Working Paper* (230).

A *The Standard Deviation of Growth Rates* $\sigma_{GR.GDP}$ *Versus* I_B^1

Table 3: The results of the regression of $\sigma_{GR.GDP}$ versus I_B^1

	Dependent variable:	
	$\sigma_{GR.GDP}$	*s.e.*
I_B^1	0.192^{***}	(0.004)
Constant	-0.003^{***}	(0.001)
Observations	257	
Adjusted R^2	0.881	
Residual Std. Error	0.003 (df = 255)	
Note:	*p<0.1; **p<0.05; ***p<0.01	

Figure 9: Standard deviation of (filtered) growth rates, $\sigma_{GR.GDP}$, versus I_B^1 (Panel (a)), the estimated linear relationship and distribution of residuals from regression of $\sigma_{GR.GDP}$ versus I_B^1 (Panel (b)). Normal distribution reported in blue as reference.

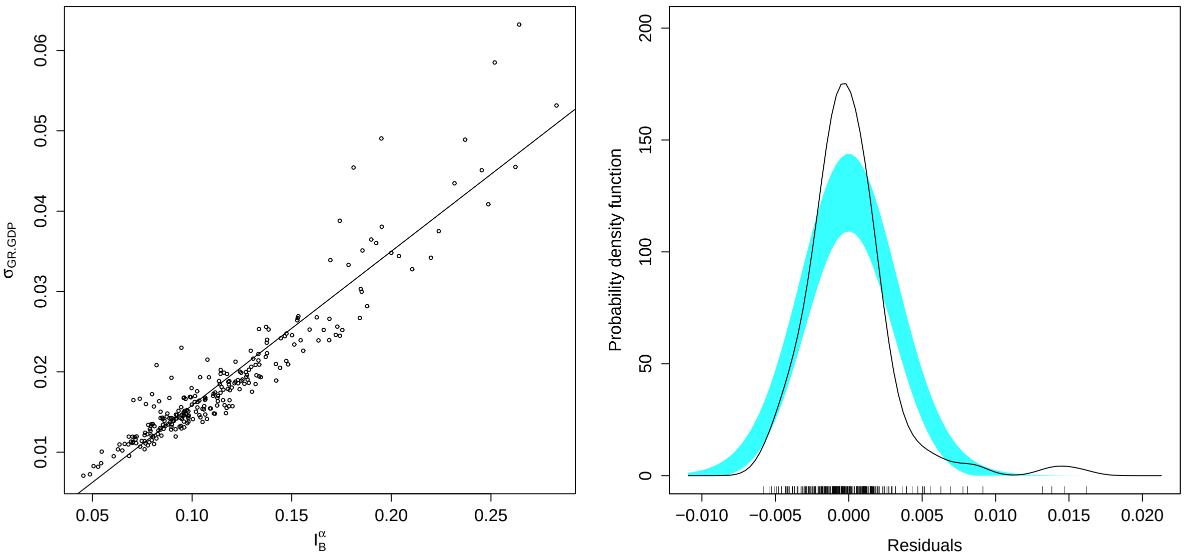


Table 3 reports the results of the regression of $\sigma_{GR.GDP}$ versus I_B^1. Figure 9 plots $\sigma_{GR.GDP}$ versus I_B^1 for the sample of 257 EU regions (Panel (a)), and their estimated linear relationship and the distribution of residuals of regression (Panel (b)).

B *The Estimate of Average Effects*

In the spatial growth regression that includes both the spatial lag of the dependent and independent variables (as in the SDM) the least-squares interpretation of estimated parameters is no longer valid because the dependence expands the information set to include information from neighboring regions. To see this rewrite Eq. 6 as (see LeSage and Pace (2008)):

$$\mathbf{GRV} = (\mathbf{I_N} - \rho\mathbf{W})^{-1}[\alpha + \mathbf{X}\beta + (\mathbf{I}_N - \lambda\mathbf{W})^{-1}\epsilon] \tag{8}$$

where $\mathbf{I}_N$ is the $N \times N$ identity matrix, λ is the spatial autoregressive parameter, α is the constant, $\mathbf{GRV}$ is the vector of dependent variable, $\mathbf{X}$ is the matrix of explanatory variables, β is the vector of coefficients, and ϵ is the vector of error component.

The matrix of partial derivatives of the dependent variable in the different units with respect to the $k-th$ explanatory variable in the different units (say, x_{ik} for $i = 1,,N$) is give by:

$$\begin{aligned}\left[\frac{\partial\mathbf{GRV}}{\partial x_{1k}} \cdots \frac{\partial\mathbf{GRV}}{\partial x_{Nk}}\right] &= \begin{bmatrix} \frac{\partial GRV_1}{\partial x_{1k}} & \cdots & \frac{\partial GRV_1}{\partial x_{Nk}} \\ \vdots & \ddots & \vdots \\ \frac{\partial GRV_N}{\partial x_{1k}} & \cdots & \frac{\partial GRV_N}{\partial x_{Nk}} \end{bmatrix} = \\ &= (\mathbf{I_N} - \lambda\mathbf{W})^{-1} \begin{bmatrix} \beta_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \beta_N \end{bmatrix} = \mathbf{S}_k(\mathbf{W}). \end{aligned} \tag{9}$$

LeSage (2008) define the direct, indirect and total effect: In particular:

- The *Average Direct Effect*: is constructed as an average of the diagonal elements of the matrix $\mathbf{S}_k(\mathbf{W})$ and provides a summary measure of the impact arising from changes in the i-th observation of variable k.

- The *Average Indirect Effect*: is constructed as an average of the off-diagonal elements of of the matrix $\mathbf{S}_k(\mathbf{W})$ and provides a summary measure of the impact arising from changes in the $j = 1, ..., N$, $j \neq i$, observations of variable k.

- The *Average Total Effect*: is constructed as the sum of the *Average Direct effect* and the *Average Indirect effect* and measures the impact arising from changes in the explanatory variables of the model average over all regions in the sample, also accounting for the feedback influences that arise as a result of impacts passing through neighbours.

Since the matrix on the right-hand side of Eq. (9) is independent of the time index t, the calculations are equivalent to LeSage (2008) for a cross-sectional setting (see Elhorst (2012)).

For inference regarding the significance of these impacts, LeSage and Pace (2008) propose either to simulate impacts based on the model estimates or to compute Bayesian Markov Chain Monte Carlo estimation. Differently, we use the wild bootstrap procedure illustrated in Appendix C.

C Wild Bootstrap for the Inference on the Estimated Average Effects

We apply a wild bootstrap procedure to get inference on the estimated average effects. Given the model:

$$\mathbf{GRV} = (\mathbf{I_N} - \lambda\mathbf{W})^{-1}[\alpha_N + \mathbf{X}\beta + (\mathbf{I}_N - \rho\mathbf{W})^{-1}\epsilon] \tag{10}$$

where $\mathbf{I}_N$ is the $N \times N$ identity matrix, λ is the spatial autoregressive parameter, α_N is the $N \times 1$ vector of fixed effects, $\mathbf{GRV}$ is the vector of dependent variable, $\mathbf{X}_t$ is the matrix of explanatory variables, β is the vector of coefficients, and ϵ is the vector of error component, the bootstrap procedure consists in the following steps.

1. Estimate model (10) via G2SLS and take the estimated parameters $\hat{\lambda}$, $\hat{\beta}$.

2. Calculate for each explanatory variable, $k = 1, ..., K$, the estimated the average direct effect (ADE_k), the average indirect effect (AIE_k) and the average total effect (ATE_k) using the following equations:

$$\begin{aligned} ADE_k &= \frac{1}{N}\sum_{i=1}^{N}\hat{\mathbf{S}}_k(\mathbf{W})_{ii} \\ AIE_k &= \frac{1}{N}\sum_{i=1}^{N}\left(\sum_{j=1}^{N}\hat{\mathbf{S}}_k(\mathbf{W})_{ij} - \hat{\mathbf{S}}_k(\mathbf{W})_{ii}\right) \\ ATE_k &= ADE_k + AIE_k \end{aligned} \tag{11}$$

   where $\hat{\mathbf{S}}_k(\mathbf{W}) = (\mathbf{I} - \hat{\lambda}\mathbf{W})^{-1}(\mathbf{I}_N\hat{\beta}_k)$.

3. Generate B independent bootstrap samples of the dependent variable $\{\underline{\mathbf{GRV}}^1, ..., \underline{\mathbf{GRV}}^B\}$ in two steps:

   (a) draw with replacement N residuals $\underline{u}_i = \hat{u}_i\eta_i$ $(i = 1, ..., N)$ where $\hat{u}_i$ are the residuals of the estimated model (10) and η_i are independent drawings from the following two-point distribution:

$$\eta = \begin{cases} \frac{(1-\sqrt{5})}{2} & \text{with } p = (5+\sqrt{5})/10 \\ \frac{(1+\sqrt{5})}{2} & \text{with } 1-p \end{cases} \tag{12}$$

(b) generate $\underline{\mathbf{GRV}} = \mathbf{G\hat{R}V} + \underline{\mathbf{u}}$;

4. Estimate Model (10) for each $\{\underline{\mathbf{GRV}}^1, ..., \underline{\mathbf{GRV}}^B\}$.

5. Compute for each bootstrap sample, $b = 1, ..., B$, and for each explanatory variable, $k = 1, ..., K$, the ATE_k^b, ADE_k^b and AIE_k^b using Eq. (12).

6. Compute the corresponding symmetric bootstrap p-values:

$$P_{boot} = \begin{cases} 2 \times \left(\frac{1}{B}\sum_{b=1}^{B} \#\{ATE_r^b > 0\}\right) & \text{if } \frac{1}{B}\sum_{b=1}^{B} \#\{ATE_r^b > 0\} \leq 0.5 \\ 2 \times \left(1 - \frac{1}{B}\sum_{b=1}^{B} \#\{ATE_r^b > 0\}\right) & \text{if } \frac{1}{B}\sum_{b=1}^{B} \#\{ATE_r^b > 0\} > 0.5 \end{cases} \tag{13}$$

In our estimates we set B=1000.

D The Estimated β Coefficients of SARAR Model

	Dependent variable:			
	$y = I_B^1$	$y = I_B^2$	$y = I_{B-}^1/I_B^1$	$y = \sigma_{GR.GDP}$
	(1)	(2)	(3)	(4)
LOG.GDP.1992	-0.012^{***}	-0.006^{***}	-0.0004	-0.002^{***}
	(0.002)	(0.001)	(0.002)	(0.001)
LOG.AV.POP.DENSITY	-0.01^{***}	-0.001^{**}	-0.001	0.001
	(0.002)	(0.001)	(0.002)	(0.000)
AV.EMPL.GR	0.11	-0.044	-0.091	0.024
	(0.227)	(0.098)	(0.232)	(0.056)
AV.INV.RATE	-0.169^{***}	-0.094^{***}	0.052	-0.011
	(0.048)	(0.021)	(0.046)	(0.011)
SHARE.AGRI.1992	-0.047	-0.016	-0.112^{**}	-0.01
	(0.061)	(0.026)	(0.056)	(0.013)
SHARE.MIN.1992	0.125^{**}	0.066^{***}	0.015	0.045^{***}
	(0.053)	(0.023)	(0.051)	(0.013)
SHARE.MAN.1992	-0.066^{**}	-0.029^{**}	-0.040	0.012
	(0.027)	(0.012)	(0.028)	(0.007)
SHARE.FIN.1992	-0.057	0.019	0.022	0.027
	(0.101)	(0.044)	(0.091)	(0.022)
SHARE.NMS.1992	-0.119^{***}	-0.041^{**}	-0.064	-0.001
	(0.041)	(0.017)	(0.042)	(0.011)
SHARE.CONST.1992	0.033	0.045	0.136^{**}	0.048^{***}
	(0.067)	(0.029)	(0.068)	(0.017)
AV.HOUSE.EXP.on.GDP	-0.001	-0.003	-0.005	-0.003
	(0.014)	(0.006)	(0.014)	(0.003)
AV.INFLATION	0.085^{**}	0.024	0.002	0.045^{***}
	(0.036)	(0.015)	(0.043)	(0.014)
AV.GOV.EXP.on.GDP	0.016	-0.023	-0.043	0.01
	(0.084)	(0.036)	(0.105)	(0.034)
AV.DOMESTIC.CREDIT.on.GDP	0.025^{***}	0.01^{***}	0.005	-0.001
	(0.006)	(0.003)	(0.008)	(0.003)
AV.FDI.on.GDP	-0.008	-0.006^{***}	0.015	-0.001
	(0.012)	(0.005)	(0.011)	(0.003)
EMU.DUMMY	0.006	0.002	0.004	0.001
	(0.008)	(0.001)	(0.005)	(0.002)
Constant	0.196^{***}	0.087^{***}	0.534^{***}	0.043^{***}
	(0.046)	(0.02)	(0.048)	(0.013)
ρ	0.624^{***}	0.681^{***}	-0.074^{**}	-0.605^{***}
	(0.064)	(0.056)	(0.035)	(0.106)
λ	-0.636^{***}	-0.802^{***}	0.418^{***}	0.852^{***}
	(0.123)	(0.087)	(0.092)	(0.038)
Log likelihood	540.52	737.22	612.84	968.21
AIC	-1041.1	-1434.4	-1185.7	-1886.4
Note:				*p<0.1; **p<0.05; ***p<0.01

E Region List

Table 4: **List of 257 EU regions in the sample.**

Austria	DE24	ES11	FR61	NL13	PL43	UKD1
AT11	DE25	ES12	FR62	NL21	PL51	UKD2
AT12	DE26	ES13	FR63	NL22	PL52	UKD3
AT13	DE27	ES21	FR71	NL23	PL61	UKD4
AT21	DE3	ES22	FR72	NL31	PL62	UKD5
AT22	DE41	ES23	FR81	NL32	PL63	UKE1
AT31	DE42	ES24	FR82	NL33	Portugal	UKE2
AT32	DE5	ES3	FR83	NL34	PT11	UKE3
AT33	DE6	ES41	Greece	ITC3	PT15	UKE4
AT34	DE71	ES42	GR11	ITC4	PT16	UKF1
Belgium	DE72	ES43	GR12	ITD1	PT17	UKF2
BE1	DE73	ES51	GR13	ITD2	PT18	UKD4
BE21	DE8	ES52	GR14	ITD3	Romania	UKD5
BE22	DE91	ES53	GR21	ITD4	RO11	UKE1
BE23	DE92	ES61	GR22	ITD5	RO12	UKE2
BE24	DE93	ES62	GR23	ITE1	RO21	UKE3
BE25	DE94	ES63	GR24	ITE2	RO22	UKE4
BE31	DEA1	ES64	GR25	ITE3	RO31	UKF1
BE32	DEA2	ES7	GR3	ITE4	RO32	UKF2
BE33	DEA3	Finland	GR41	ITF1	RO41	UKF3
BE34	DEA4	FI13	GR42	ITF2	RO42	UKG1
BE35	DEA5	FI18	GR43	ITF3	Slovenia	UKG2
Cypro	DEB1	FI19	Hungary	ITF4	SE11	UKG3
Czech Rep.	DEB2	FI1A	HU1	ITF5	SE12	UKH1
CZ01	DEB3	FI2	HU21	ITF6	SE21	UKH2
CZ02	DEC	France	HU22	ITG1	SE22	UKH3
CZ03	DED1	FR1	HU23	ITG2	SE23	UKI1
CZ04	DED2	FR21	HU31	NL41	SE31	UKI2
CZ05	DED3	FR22	HU32	NL42	SE32	UKJ1
CZ06	DEE	FR23	HU33	Poland	SE33	UKJ2
CZ07	DEF	FR24	Ireland	PL11	Slovakia	UKJ3
CZ08	DEG	FR25	IE01	PL12	SI01	UKJ4
Germany	Denmark	FR26	IE02	PL21	SI02	UKK1
DE11	DK01	FR3	Italy	PL22	SK01	UKK2
DE12	DK02	FR41	ITC1	PL31	SK02	UKK3
DE13	DK03	FR42	Luxemburg	PL32	SK03	UKK4
DE14	DK04	FR43	Malta	PL33	SK04	UKL1
DE21	DK05	FR51	Netherlands	PL34	United Kingdom	UKL2
DE22	Estonia	FR52	NL11	PL41	UKC1	UKM2
DE23	Spain	FR53	NL12	PL42	UKC2	UKM3

F Descriptive Statistics

Table 5: **Descriptive Statistics**

	Min	Max	Mean	Std. Dev.
I_B^1	0.05	0.28	0.12	0.04
I_B^2	0	0.13	0.02	0.02
I_{B-}^1/I_B^1	0.41	0.55	0.48	0.03
$\sigma_{GR.GDP}$	0.01	0.06	0.02	0.01
LOG.GDP.1992	6.44	12.72	9.76	1.08
LOG.AV.POP.DENSITY	-5.77	2.16	-1.87	1.2
AV.EMPL.GR	0.01	0.09	0.06	0.01
AV.INV.RATE	0.13	0.4	0.22	0.05
SHARE.AGRI.1992	0	0.23	0.05	0.04
SHARE.MIN.1992	0	0.36	0.04	0.04
SHARE.MAN.1992	-0.04	0.36	0.18	0.07
SHARE.FIN.1992	0	0.23	0.04	0.03
SHARE.NMS.1992	0.08	0.49	0.24	0.06
SHARE.CONST.1992	0.02	0.19	0.07	0.03
AV.INFLATION	0.96	39.43	4.23	6.74
AV.GOV.EXP.on.GDP	10.41	26.82	19.96	2.94
AV.DOMESTIC.CREDIT.on.GDP	25.43	173.8	91.63	35.35
AV.FDI.on.GDP	0.65	177.29	3.82	11.85
DUMMY.EMU	0	1	0.63	0.48

Table 6: **Correlation Matrix**

	I_B^1	I_B^2	I_{B-}^1/I_B^1	$\sigma_{GR.GDP}$	LOG.GDP.1992 POP.DENSITY	LOG.AV.	AV.EMPL.GR	AV.INV.RATE AGRI.1992	SHARE. MIN.1992	SHARE. MAN.1992	SHARE. FIN.1992	SHARE. NMS.1992	SHARE. CONST.1992	SHARE.	AV.INFLATION EXP.on.GDP	AV.GOV. CREDIT.on.GDP	AV.DOMESTIC.	AV.FDI.on.GDP DUMMY	EMU.
I_B^1 t	1	0.971	-0.13	0.939	-0.503	-0.252	-0.318	0.039	0.426	0.373	-0.157	0.093	-0.232	-0.077	0.48	-0.227	-0.341	0	-0.282
I_B^2	0.971	1	-0.1	0.962	-0.489	-0.231	-0.341	0.041	0.427	0.362	-0.18	0.139	-0.25	-0.05	0.503	-0.27	-0.36	-0.016	-0.232
I_{B-}^1/I_B^1	-0.13	-0.1	1	-0.035	-0.039	-0.069	0.142	0.282	-0.073	-0.001	-0.071	0.12	-0.093	0.231	-0.084	-0.048	0.063	0.127	0.209
$\sigma_{GR.GDP}$	0.939	0.962	-0.035	1	-0.491	-0.229	-0.339	0.063	0.438	0.336	-0.138	0.155	-0.277	0.002	0.548	-0.315	-0.374	-0.01	-0.249
LOG.GDP.1992	-0.503	-0.489	-0.039	-0.491	1	0.38	0.203	-0.382	-0.537	-0.287	0.276	0.059	0.115	-0.14	-0.383	0.224	0.477	-0.05	0.221
LOG.AV.POP.DENSITY	-0.252	-0.231	-0.069	-0.229	0.38	1	0.149	-0.282	-0.473	-0.079	0.084	0.112	0.075	-0.231	-0.097	-0.061	0.272	0.035	-0.009
AV.EMPL.GR	-0.318	-0.341	0.142	-0.339	0.203	0.149	1	0.081	-0.343	-0.394	0.051	-0.012	0.178	0.014	-0.55	-0.011	0.421	0.145	0.414
AV.INV.RATE	0.039	0.041	0.282	0.063	-0.382	-0.282	0.081	1	0.176	0.051	-0.144	0.02	-0.218	0.49	0.009	-0.162	-0.178	0.001	0.263
SHARE.AGRI.1992	0.426	0.427	-0.073	0.438	-0.537	-0.473	-0.343	0.176	1	0.162	-0.167	0.058	-0.3	0.057	0.591	-0.394	-0.571	-0.063	-0.167
SHARE.MIN.1992	0.373	0.362	-0.001	0.336	-0.287	-0.079	-0.394	0.051	0.162	1	-0.145	-0.111	-0.207	-0.087	0.206	0.088	-0.174	-0.001	-0.393
SHARE.MAN.1992	-0.157	-0.18	-0.071	-0.138	0.276	0.084	0.051	-0.144	-0.167	-0.145	1	-0.223	-0.308	-0.001	-0.046	-0.138	0.106	-0.1	-0.005
SHARE.FIN.1992	0.093	0.139	0.12	0.155	0.059	0.112	-0.012	0.02	0.058	-0.111	-0.223	1	-0.3	-0.241	0.35	-0.241	-0.151	0.437	0.154
SHARE.NMS.1992	-0.232	-0.25	-0.093	-0.277	0.115	0.075	0.178	-0.218	-0.3	-0.207	-0.308	-0.3	1	0.022	-0.386	0.342	0.516	-0.123	-0.048
SHARE.CONST.1992	-0.077	-0.05	0.231	0.002	-0.14	-0.231	0.014	0.49	0.057	-0.087	-0.001	-0.241	0.022	1	-0.14	-0.059	-0.054	-0.082	0.095
AV.INFLATION	0.48	0.503	-0.084	0.548	-0.383	-0.097	-0.55	0.009	0.591	0.206	-0.046	0.35	-0.386	-0.14	1	-0.587	-0.59	-0.008	-0.373
AV.GOV.EXP.on.GDP	-0.227	-0.27	-0.048	-0.315	0.224	-0.061	-0.011	-0.162	-0.394	0.088	-0.138	-0.241	0.342	-0.059	-0.587	1	0.272	-0.013	-0.044
AV.DOMESTIC. CREDIT.on.GDP	-0.341	-0.36	0.063	-0.374	0.477	0.272	0.421	-0.178	-0.571	-0.174	0.106	-0.151	0.516	-0.054	-0.59	0.272	1	0.027	0.161
AV.FDI.on.GDP	0	-0.016	0.127	-0.01	-0.05	0.035	0.145	0.001	-0.063	-0.001	-0.1	0.437	-0.123	-0.082	-0.008	-0.013	0.027	1	0.012
DUMMY.EMU	-0.282	-0.232	0.209	-0.249	0.221	-0.009	0.414	0.263	-0.167	-0.393	-0.005	0.154	-0.048	0.095	-0.373	-0.044	0.161	0.012	1