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Spatial Clubs in European Regions

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Abstract

This paper finds evidence of spatial clubs in a sample of 254 European regions in the period 1991-2008. A dynamic extension of the Moran scatter plot, consisting in a non parametric estimate of the joint dynamics of GDP per worker and its spatial lag, suggests the emergence of three spatial clubs: one populated by regions belonging to the former Eastern Bloc countries, one by regions of PIGS countries (Portugal, Italy, Greece and Spain) and the last one by regions of other EU countries (notably Germany, France, UK and Northern Europe countries). In the long run the convergence process is evident only to two spatial clubs with Eastern regions converging to PIGS regions. Spatial spillovers are present across European regions, and their contribution to the emergence of spatial clubs is crucial. On the contrary, cross-region heterogeneity in human capital has a very limited impact on the distribution of GDP per worker. Finally, unobserved heterogeneity explains a substantial share of inequality and polarization.

Classificazione JEL: C21, R11, O52, F41
Keywords: Moran scatter plot, spatial panels, spatial spillovers, bipolarization, core-periphery pattern
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I. Introduction

This paper analyses the emergence of spatial clubs in a sample of 254 European regions in the period 1991-2008, and estimate the contribution of spatial spillovers (SS) to this spatial pattern.\(^1\)

Figures 1 and 2 provide the starting point of the analysis.\(^2\)

The estimated densities in 1991 and 2008 reveal the presence of a stable twin-peaked distribution. Gini and BIPOL (bipolarization) indexes of GDP per worker distribution point to a slightly decrease both in dispersion and polarization in the period, although polarization remains very high in the last year.\(^3\)

Figure 2 provides a picture of the spatial pattern in 2008: a cluster of regions at the core of Europe with relatively high levels of GDP per worker are contrasted by a cluster of regions at the southern borders of Europe with a medium GDP per worker, belonging to so-called PIGS countries (Portugal, Italy, Greece and Spain); and by a cluster of regions at the eastern borders with a low GDP per worker, belonging to the countries of former Eastern Bloc. Regions of countries not belonging to EMU (Denmark, Sweden, and UK) do not show any specific

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\(^1\)See Appendix C for the regions list.

\(^2\)Density estimations are made by an adaptive kernel estimator with optimal normal band-width (see Fiaschi and Romanelli, 2009 for more details).

\(^3\)BIPOL is defined in the range \([0,1]\), with 1 representing maximum polarization (see Anderson et al., 2012 for more details).
pattern with respect of the regions of high-per-worker GDP cluster. The core-periphery theory seems to find a further confirm (see Fujita et al., 1999), and the emerge of spatial clubs is confirmed. Spatial clubs are therefore defined as spatial clusters of regions with similar levels of GDP per workers.

II. Spatial Clubs in European Regions

The starting point to identify the emergence of spatial clubs is the Moran scatter plot. The advantage of Moran scatter plot is its easy interpretation giving a graphical representation of the relation of the variable, in our case the (relative) GDP per worker in the location \( j \) with respect the values of that variable in the neighbouring locations, i.e the spatial lag variable. Figure 3 depicted the Moran scatter plot for the initial year (1991). X-axis reports the (relative) GDP per worker, \( y \), while y-axis reports its spatial lag, \( W_{ij} y \) (\( y \) is the vector of GDP per worker of all regions in the sample). \(^4\)

The Moran’s \( I \) \(^5\) test in 1991 is positive (equal to 0.764) and statistically significant at 10%, suggesting the presence of spatial dependence. Moreover, the distribution in 1991 appears characterized by three spatial clubs of regions (indicated by three yellow circles identified by a k-median algorithm \(^6\)), where spatial clubs should be meant in this case, as clusters of regions with similar levels both of GDP per worker \( y \) and spatially lagged GDP per worker \( W_{ij} y \). \(^7\) These three clubs of regions have a clear correspondence with the spatial pattern

\[^4\]The spatial lag of GDP per worker for region \( i \), \( W_{ij} y \), consists in the average value of GDP per worker of neighbours of region \( i \) (under the assumption that \( W \) is row-standardized). \( W \) is the spatial matrix, see A for more details. We control that our results are robust to alternative definition of \( W \), as the first-order and second-order contiguity.

\[^5\]Moran’s \( I \) is a measure of spatial autocorrelation, and tells us how related the values of a variable are based on the location where they are measured and respect to the values of the nearby locations. In particular, the Moran’s \( I \) measures the global spatial autocorrelation, that is the overall spatial clustering of the data. It is given by:

\[
I = \frac{N}{S_0} \sum_i \sum_j w_{ij} Z_i Z_j \sum_i Z_i^2
\]

where \( Z_i \) is the deviation of the variable of interest from its mean (\( GRV_i \)), \( w_{ij} \) are the spatial weights capturing the potential spatial interaction which are different from zero if regions \( i \) and \( j \) are neighbors (according to some distance measure), \( N \) is the number of regions and \( S_0 = \sum_i \sum_j w_{ij} \) (when the \( W \) matrix of spatial weights is row-standardized \( S_0 = N \)). The Moran’s \( I \) statistic takes value \(-1 \leq I \leq 1 \) (\( I = -1 \) indicates a strong negative spatial autocorrelation, \( I = 0 \) no spatial autocorrelation, and \( I = 1 \) a strong positive spatial autocorrelation).

\[^6\]The k-median algorithm is a variation of k-means algorithm where instead of calculating the mean for each cluster to determine its centroid, it is use its median. The use of median should minimize the impact of possible outliers. See Leisch, 2006 for more details on k-median algorithm.

\[^7\]In the identification of clubs we have imposed that their number is equal to three on the base of the visual inspection of Figure 3.
displayed in Figure 2, that is C1 corresponds to regions belonging to former Eastern Bloc countries, C2 to regions belonging to PIGS countries, and C3 to regions belonging to other EU countries.

However, the standard Moran scatter plot in Figure 3 does not provide any information on the dynamics of these three spatial clubs. To fill this gap, we estimate the joint dynamics of (relative) GDP per worker \( y \) and its spatially lagged \( W_y \) over the period 1991-2008 in the Moran space, which we label *Local Directional Moran Scatter Plot* (LDMS) (see Fiaschi et al., 2014).

![Image of Moran scatter plot](image)

Figure 3: Moran scatter plot for 1991 with the indication of three spatial clubs. The centres of three clubs of regions in 1991 are identified by *k-median* algorithm, and they are indicated by three yellow circles.

### II.A. Estimation of a Local Directional Moran Scatterplot

Consider a sample of \( N \) economies observed for \( T \) periods; economy \( j \) is characterized by its level of relative (to the sample average) income in each point in time \( y_{jt} \), and by the average income of its neighbours \( W_y_{jt} \), where \( W \) is the \( j \)-the row of the spatial weight matrix expressing which economies are neighbours.

---

\(^8\)We report just the geographical distribution in the last year 2008. Similar geographical pattern is found in 1991.
of $j$ ($j = 1, \ldots, N$ and $t = 1, \ldots, T$), and $y_t$ is the vector of relative income of all economies.

We assume that the spatial dynamics of economy $j$ at period $t$, i.e. the dynamics of economy $j$ in the space $(y, Wy)$, only depends on $(y_{jt}, Wy_{jt})$, i.e. $y_{jt}$ follows a time invariant and Markovian stochastic process.

The spatial dynamics of the sample in the Moran space can be therefore represented by a random vector field (RVF). In particular, given a subset $L$ of the possible realization of $(y, Wy)$ (i.e. a lattice in the Moran space), a RVF is represented by a random variable $\Delta z_i$, where $\Delta z_i \equiv (\Delta y_i, \Delta Wy_i) \equiv (y_{it+t} - y_{it}, Wy_{it+t} - Wy_{it})$, indicating the spatial dynamics (i.e. the dynamics from period $t$ to period $t + \tau$ represented by a movement vector) at $z_i \equiv (y_i, Wy_i) \in L$.

For each point in the lattice $z_i$, with $i = 1, \ldots, L$, we therefore estimate the distribution of probability $\Pr(\Delta z_i | z_i)$ on the $N (T - \tau)$ observed movement vectors $\Delta z_{obs}$. In particular, $\Pr(\Delta z_{obs} | z_i)$ measures the probability that the dynamics at $z_i$ follows $\Delta z_{jt}$; this suggests that $\Pr(\Delta z_{obs} | z_i)$ should decrease as function of the distance between $z_i$ and $z_{jt}$.

Following this intuition Fig. 4 depicts a point of the lattice $z_i$ and four observed movement vectors, which origin at different distance from $z_i$. Function $\omega(z_i, z_{jt}^{obs})$ measures for each observed movement vector its probability to affect the movement at $z_i$; these probabilities decline with distance from $z_i$ (i.e.
\( \omega(z_i, z_{OBS}^{OB}) < \omega(z_i, z_{OB}^{OBS}) < \omega(z_i, z_{OB}^{OBS}) \), and very far observed movement vectors should have zero probability \( (\omega(z_i, z_{OBS}^{OB}) = 0) \). Blue vector is the expected movement from \( z_i \), \( \mu_{\Delta r z_i} \), calculated on the base of the distribution of probabilities on the observed movement vectors.

A convenient way to calculate these probabilities is to use a kernel function to measure the distance between \( z_i \) and \( z_{OBS}^{OB} \). In particular:

\[
\omega(z_i, z_{OBS}^{OB}) = \frac{K \left( \frac{(z_i - z_{OBS}^{OB})^T S^{-1}(z_i - z_{OBS}^{OB})}{h^2} \right) \text{det}(S)^{-\frac{1}{2}}} {\sum_{t=1}^{T-\tau} \sum_{j=1}^{N} K \left( \frac{(z_i - z_{OBS}^{OB})^T S^{-1}(z_i - z_{OBS}^{OB})}{h^2} \right) \text{det}(S)^{-\frac{1}{2}}} \]

is assumed to be an estimate of the probability that at \( z_i \) spatial dynamics follows observed movement vectors \( \Delta r z_{j,t} \), where \( K(\cdot) \) is the kernel function, \( h \) is the smoothing parameter and \( S \) is the sample covariance matrix of \( z_{OBS}^{OB} \). The kernel function \( K(\cdot) \) is generally a smooth positive function which peaks at 0 and decreases monotonically as the distance between the observation \( z_{j,t} \) and the point of interest \( z_i \) increases (see Silverman, 1986 for technical details). The smoothing parameter \( h \) controls the width of the kernel function.\(^9\) In the estimation we use a multivariate Epanechnikov kernel (see Silverman, 1986, pp. 76-78), i.e.:

\[
K(u^T S^{-1}u) = \begin{cases} 
\frac{2}{\pi} (1 - u^T S^{-1}u) & \text{if } u^T S^{-1}u < 1 \\
0 & \text{if } u^T S^{-1}u \geq 1 
\end{cases} \]

where \( u \equiv (z_i - z_{OBS}^{OB}) / h \). Multivariate Epanechnikov kernel is particularly adapted to our scope because it assigns zero probability to observed movement vectors very far from \( z_i \).\(^{10}\) The exact quantification of “very far” is provided by bandwidth \( h \), i.e. higher bandwidth means higher number of observed movement vectors entering in the calculation of the movement at \( z_i \).

Given Eq. (2) for each point in the lattice \( z_i \) we estimate the \( \tau \)-period ahead expected movement \( \mu_{\Delta r z_i} = E[\Delta r z_i|z_i] \) using a local mean estimator, firstly proposed by Nadaraya, 1964 and Watson, 1964, where the observations are weighted by the probabilities derived from the kernel function, i.e.:\(^{11}\)

\[
\hat{\mu}_{\Delta r z_i} = \sum_{t=1}^{T-\tau} \sum_{j=1}^{N} \omega(z_i, z_{OBS}^{OB}) \Delta r z_{j,t}^{OBS} = \text{Pr}(\Delta r z_{j,t}^{OBS}) \Delta r z_{j,t}^{OBS}. \]

The estimation of Eq. (4) strongly depends on the choice of \( \tau \). This choice is the result of a trade-off: from one hand, a too short \( \tau \) can increase the noise in the estimation due to the possible presence of business-cycle fluctuations; on

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\(^9\)In all the estimation we use the optimal normal bandwidth; for a discuss on the choice of bandwidth see Silverman, 1986.

\(^{10}\)Other possible kernels, as the Gaussian, does not allow such possibility.

\(^{11}\)See Bowman and Azzalini, 1997 for details.
the other hand, a too long $\tau$ could contrast with the local characteristics of the estimate, increasing the probability that observed movement vectors very far from \( z_i \) affects the estimate of $\mu_{\Delta z_i}$.\(^{12}\)

In the estimation we set $\tau = 15$ years.\(^{13}\)

Figure (5) reports the estimated expected value of the 15-year ahead directions corresponding to a significance level of 5%.\(^{14}\) The three spatial clubs present in 1991 are still there in 2008, but club C2 (the one of PIGS regions) is now well below the sample average, while club C1 (of former Eastern Bloc) moved toward 1 (i.e. sample average) along the bisector. The overall impression is that clubs C1 and C2 are converging, while the club C3 seems fairly stable as (relative) position. The core-periphery pattern observed in 2008 is therefore expected to persist over time, as describe in Figures (6) and (7) which show the geographical representation of the three clusters in 1991 and 2008. Comparing the two pictures we find that C1 is populated by the same regions on the other hand the dynamics of C2 and C3 becomes more clear.

Figure (5) points out that the assignment of a region to different spatial regimes according to the position of the region in the Moran scatter plot in the initial year can be severely biased. For example, it is common to consider regions above 1 both in term of $y$ and $Wy$ as belonging to a high spatial regime, while the ones below both thresholds to a low spatial regime (see, e.g., Ertur et al., 2006). But, according our results, regions just above $y > 1$ and $Wy > 1$ are expected to converge to club C2 of low/medium GDP per worker and not to club C3 of high GDP per worker.

A final question is the contribution of SS versus cross-region heterogeneity to the determination of spatial clubs.\(^{15}\) To answer to this question we elaborate a simple theoretical framework in the next section.

---

\(^{12}\)For samples with a very short time span a further limit to the choice of a long $\tau$ is the relatively strong loss of observations.

\(^{13}\)Therefore, our sample consists of 8 transitions for each of 254 regions.

\(^{14}\)In order to formally establish the significance of the estimated directions, a bootstrap procedure is used (see Fiaschi et al., 2014) with 500 replications.

\(^{15}\)Anselin, 2001 discusses how SS can derive from (possible unobservable) regions characteristics.
Figure 5: Moran scatter plot for 2008, the three spatial clubs, and the estimated joint dynamics for the period 1991-2008 of (relative) GDP per worker and its spatial lagged value (represented by the red arrows). The centres of three clubs of regions in 2008 are identified by \textit{k-median} algorithm, and they are indicated by three yellow circles.
III. A Simple Model of Spatial Clubs

In this section we present a simple model of spatial clubs that allows to disentangle SS from the cross-region heterogeneity in individual characteristics.

III.A. The Model

Assume that total GDP of region $i$ at period $t$, $Y_i$, is given by (see Mankiw et al., 1992):\(^{16}\)

$$Y_i = \exp(c_i + \lambda W_i \log y) K_i^\alpha H_i^\beta [L_i \exp(gt)]^{1-\alpha-\beta}, \quad (5)$$

where $\exp(c_i + \lambda W_i \log y)$ measures the level of technological progress (i.e. TFP) of region $i$ as the result of an unobserved individual effect $c_i$, and $SS W_i \log y$, where $\log y$ is the vector of the log of GDP per worker normalized by technological progress $\exp(gt)$ ($y$ is also called GDP per worker in efficient units), i.e. $y_i \equiv Y_i / (L_i \exp(gt))$; $L_i$ the total employment of region $i$; $K_i$ the stock of physical capital; $H_i$ the stock of human capital (HC); and, finally, $g$ the standard exogenous and time-invariant growth rate of labour-augmenting technological progress. Parameters $\alpha, \beta \in (0, 1)$ measure the elasticity of output to physical and human capital respectively, while $\lambda \in (0, 1)$ the elasticity of output of region $i$ to output of other regions. Higher $\lambda$ therefore means higher technological spillovers.

\(^{16}\)We omit time index if this is not source of confusion.
From Eq. (5) $y_i$ is given by:

$$y_i = \exp (c_i + \lambda W_i \log y) k_i^\alpha h_i^\beta,$$

(6)

where $k_i \equiv K_i / (L_i \exp(gt))$ and $h_i \equiv H_i / (L_i \exp(gt))$ are the physical and HC per worker in efficient units respectively.

Under the hypothesis of competitive markets, physical capital is paid to its marginal productivity, i.e.:

$$r_i = \frac{\partial y_i}{\partial k_i} = \alpha \exp \left( c_i + \lambda W_i \log y \right) \frac{\beta}{\alpha} \frac{k_i^{\alpha-1}}{y_i^{\alpha}},$$

(7)

where $r_i$ is the real rate of return of physical capital. If each region is assumed to be small (i.e. small-open economy hypothesis holds) with respect to world economy, and the allocation of physical capital across different regions is efficient in equilibrium, then $r_i$ should be equal to $\bar{r}$, where $\bar{r}$ is the exogenous real rate of return prevailing at world level assumed constant over time.

Along the transition to equilibrium frictions in the capital allocation, as well as the presence of (idiosyncratic) shocks, could induce a temporary depart of $r_i$ from $\bar{r}$. To take into account this possibility we assume that $r_i$ follows:

$$\log r_{it} = (1 - \phi) \log r_{it-\tau} + \phi \log \bar{r} + \eta_{it},$$

$$\eta_{it} = \theta W_i \eta_{it} + \nu_{it},$$

(8)

where $\phi \in (0, 1)$ measures the frictions in the capital allocation (i.e. for $\phi = 1$ frictions are absent), $\tau$ the time-lag in the reallocation of capital (the speed of reallocation), while $\eta_{it}$ is the error term which capture possible disturbances in the level of interest rate due to: a) the proximity (i.e. $\theta W_i \eta_{it}$, the spatial spillover in the error term $^{17}$) and, b) possible idiosyncratic shocks (i.e $\nu_{it}$ the i.i.d shock).

$\phi \in (0, 1)$ ensures that $r_{it}$ monotonically converges to $\bar{r}$.

Eqq. (7) and (8) leads to the following dynamics for the log of GDP per worker measured in efficient unit $\log y_{it}$:

$$\log y_{it} = \left( \frac{\phi \alpha}{1 - \alpha} \right) \log \alpha - \left( \frac{\phi \alpha}{1 - \alpha} \right) \log \bar{r} + \left( \frac{\phi}{1 - \alpha} \right) c_i + \left( \frac{\beta}{1 - \alpha} \right) \log h_{it} +$$

$$- \left[ \frac{(1 - \phi) \beta}{1 - \alpha} \right] \log h_{it-\tau} + (1 - \phi) \log y_{it-\tau} + \left( \frac{\lambda}{1 - \alpha} \right) W_i \log y_{t} +$$

$$- \left[ \frac{(1 - \phi) \lambda}{1 - \alpha} \right] W_i \log y_{t-\tau} - \left( \frac{\alpha}{1 - \alpha} \right) \theta W_i \eta_{it} - \left( \frac{\alpha}{1 - \alpha} \right) \nu_{it},$$

(9)

where $c_i$ is assumed to be constant over time.

Eq. (9) makes clear that the observed heterogeneity of GDP per worker of regions is accounted by SS (measured by $\lambda$), and by the cross-region heterogeneity in unobservable characteristics $c_i$.

$^{17}$W is the spatial matrix in the error term, see App. A, for more details.
Finally, from Eq. (9) the equilibrium level of the (log of) GDP per worker in efficient units $y^E$, given by:

$$\log y^E = \left[ I - \left( \frac{\lambda}{1 - \alpha} \right) W \right]^{-1} \left[ \left( \frac{\alpha}{1 - \alpha} \right) \log \alpha - \left( \frac{\alpha}{1 - \alpha} \right) \log \bar{r} + \left( \frac{1}{1 - \alpha} \right) c + \left( \frac{\beta}{\alpha} \right) \log h^E \right],$$

where $c$ is the vector of unobserved time-invariant individual effects and $h^E$ the vector of indexes of HC of workforce of all regions in equilibrium.

Spatial clubs in the long run can be therefore the result of a particular spatial matrix $W$ (e.g. many regions are interconnected among them and others no, i.e. the exploitation of SS is spatially determined), and of a cross-regions heterogeneity with a strong spatial characterization (e.g. neighbouring regions share the same output composition and some sectors are relatively more productive than others).

IV. The Estimation of the Model

Directly inspired by Eq. (9) we estimate the following (unconstrained) model with spatial effects also in the error term:

$$\log y_{it} = \beta_0 + \tilde{c}_i + \beta_1 \log h_{it} + \beta_2 \log h_{it-\tau} + \beta_3 \log y_{it-\tau} + \beta_4 W_i \log y_t + \beta_5 W_i \log y_{t-\tau} + u_{it},$$

$$u_{it} = \rho W_i u_t + \epsilon_{it},$$

where $\tilde{c}_i$ is the fixed effect (FE) of region $i$, $\beta$'s different parameters to be estimated, and $\epsilon_{it}$ the error term.

The natural estimation method for Model (11) is a Spatial Autoregressive model with Spatial Autoregressive disturbance, i.e. SARAR model.\(^{18}\)

We consider as proxy of the HC the share of active population with tertiary education.\(^{19}\) Moreover, we use a lag $\tau = 15$ in order to limit the possible bias in the estimate caused by serial correlation in $u$ (i.e. endogeneity).\(^{20}\)

Finally, in the estimate we do not impose any restriction on parameters deriving from Eq. (9).\(^{21}\)

Table 1 shows that all estimated parameters are highly statistically significant, and with the correct sign. The estimated coefficient for HC is highly statistically significant but very low if compared to Mankiw et al., 1992’s estimates of $\alpha$.\(^{21}\)

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\(^{18}\)Model (11) is estimate via maximum likelihood, with \textit{spml} function in R.

\(^{19}\)Data on tertiary education from 1995 to 2008 directly come from the Eurostat website. Backward extrapolation with non parametric regression (GAM) estimation has been used to complete the dataset for the period 1991-1994. We obtain small negative values in 1991 for two regions DK05 and FI13. Negative values are justified by the decreasing distribution in the initial years. We replace them with zero.

\(^{20}\)Otherwise, if Cov ($u_{it}$, $u_{it-1}$) $\neq$ 0 and $\tau = 1$, then Cov ($\log y_{it-1}$, $u_{it}$) $\neq$ 0, i.e. endogeneity becomes a concern for the estimate.

\(^{21}\)In particular, that $\beta_5 = -\beta_3 \times \beta_4$ (compare Eq. (9) with Eq. (11)).
Table 1: The estimate of Model (11). Significance level: *p<0.1; **p<0.05; ***p<0.01.

| Coefficients                                      | Estimate | Std.Err. | t-value | Pr(>|z|) |
|---------------------------------------------------|----------|----------|---------|---------|
| **HC**                                            |          |          |         |         |
| $\log h_{it}$                                     | 0.099124 | 0.017587 | 5.6360  | 1.74e-08*** |
| **Time lagged HC**                                |          |          |         |         |
| $\log h_{it-\tau}$                               | -0.015740| 0.004259 | -3.6957 | 0.0002193*** |
| **Time lagged GDP per worker**                    |          |          |         |         |
| $\log y_{it-\tau}$                               | 0.025185 | 0.011038 | 2.2816  | 0.0225149** |
| **Time and spatially lagged GDP per worker**      |          |          |         |         |
| $W \log y_{t-\tau}$                              | -0.049074| 0.019134 | -2.5648 | 0.0103244** |
| **Spatially lagged GDP per worker**               |          |          |         |         |
| $W \log y$                                       | 0.860181 | 0.026078 | 32.9854 | <2.2e-16*** |
| **Spatially lagged error**                        |          |          |         |         |
| $W u$                                             | -0.348068| 0.122043 | -2.8520 | 0.0043445*** |

Observations: 762  
$AIC_c$: -595639.2

and $\beta$ of about 0.33 (from which an expected value of coefficient of 0.5). A possible explanation of this low coefficient is that the share of active population with tertiary education is not proportional to the stock of HC, but instead it has a strongly concave relationship. The low value of the estimated coefficient of time lagged of GDP per worker indicates that 15 years should be a sufficient time for an almost full convergence in the return on capital across regions. The estimated coefficient of the spatially lagged variable points to a presence of SS. We refer to the next section for a their more precise quantitative evaluation. Finally, the estimated coefficient for the time and spatially lagged variable is negative as expected. However, the restriction implied in the empirical Model (1) $\beta_4 = -\beta_3 \times \beta_5$ derived from Eq. (9), is not satisfied. A possible explanation can be traced to the assumption of Cobb-Douglas production function in the theoretical model of Eq.(5).

V. Spatial Spillover versus Cross Region Heterogeneity

One of the research questions of the paper is to disentangle the role of spatial spillover versus cross region heterogeneity on the formation of the three spatial clubs. In our analysis spatial spillovers are capture by the spatially lagged GDP per worker and its autoregressive specification while, cross region heterogeneity by the HC variable and by the FE. In particular, FE accounts for any characteristics of regions constant over time which are not directly ascribe to physical and human capital accumulation, i.e, capture the unobserved heterogeneity at regional level. Therefore, they could represent a measure of the quality of institutions or social capital generally proposed in the literature. To detect the role played by the
two effects, the counterfactual distributions of the GDP per worker is presented. The counterfactual distributions in Figure 8 show what the GDP per worker distribution would be in absence of specific regional effects (FE and HC) or spatial effects (SS).

The comparison between the observed distribution in 2008 (black solid line) and the hypothetical distribution in 2008 in absence of SS in Figure 8 indicates that distributional impact of spatial spillover SS is very important both in terms of dispersion (10 points in terms of Gini index) and polarization (no polarization in the counterfactual distribution) (compare blue with black lines is Figure 8). In particular, the Gini index decreases to 0.13, and the distribution becomes unimodal and more concentrate around zero. Different conclusion holds looking at the counterfactual distribution with no HC, where their contribution to explain the distribution of GDP per worker is negligible both on dispersion and polarization. On the contrary, the estimated fixed effects FE explain a significant share of total dispersion (4 points basis out of 23 of Gini index), and a large share of polarization (BIPOL with no FE is equal to 0.46 versus 0.78 of the actual distribution, see Figure 8).

<table>
<thead>
<tr>
<th></th>
<th>Observed 2008</th>
<th>No SS 2008</th>
<th>No FE 2008</th>
<th>No HC 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gini</td>
<td>0.23</td>
<td>0.13</td>
<td>0.19</td>
<td>0.22</td>
</tr>
<tr>
<td>BIPOL</td>
<td>0.78</td>
<td>NA</td>
<td>0.46</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Figure 8: Observed versus counterfactual distributions of GDP per worker in 2008 with no SS (spatial spillovers), no FE (fixed effects) and no heterogeneity in HC (human capital).

Figures 9 and 10 show the distribution of FE and GDP per worker in 2008 at regional level. FE map has e geographical patter very similar to GDP per worker.
The correlation between the estimated fixed effects and GDP per worker in 2008 is about 0.55 but some differences emerge among which the most important is the less pronounced core-periphery pattern of FE (compare Figures 9 and 10). This intuition is confirmed by the Moran’s statistic.

Table 2 reports the values of the Moran’s I statistic for GDP per worker in 1991, 2008 and FE. In particular, Moran’s I calculated on FE becomes no significant reflecting the absence of spatial dependence, while the Moran’s I calculated on the series of per worker GDP in the 2008 is positive, statistically significant and no different from those in 1991 as expected.

Finally, to complete the analysis, the scatter plot and the non parametric estimation between FE and relative GDP per worker in 2008 is presented in Figure 11. Figure 11 gives a clear representation of the analysis, confirming the higher and positive impact of FE to explain the distribution of GDP per worker.
in the last year, and consequently on the formation of spatial clubs.\footnote{The non-parametric specification is expressed as: \[ GDP_{pw2008} = f(FE_i) + \zeta_i, \] where $GDP_{pw2008}$ is the level of the GDP per worker in 2008, $FE$ the fixed effects estimated from Model 11, and $\zeta_i$ is the error component. The estimated model could explain about 60\% of the total variance, as showed by the $R^2 = 0.61$.}

VI. Concluding Remarks

We identify spatial clubs in European regions by a new methodology which can circumvent the drawback of the standard approach based on simple Moran scatter plot (see, e.g., Ertur et al., 2006). By the estimate of a simple model we conclude that spatial spillovers are present across European regions, and their contribution to the emergence of spatial clubs is high as well as the individual
regional (unobserved) characteristics. Heterogeneity in human capital seems to play a marginal role for the distribution of GDP per worker.

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**References**


A Spatial Weight Matrices

The Spatial Matrix $W$ in the dependent variable $y$

The spatial matrix $W$ is a $(N \times N)$ matrix with zeros on its main diagonal. The off-diagonal elements, $w_{ij}$ reflect the spatial dependence i.e. the spatial spillover SS of unit $j$ on unit $i$.

In the rest of paper we consider a row-standardized $W$ based on the centroid distances between each pair of spatial units $i$ and $j$, denoted by $d_{ij}$. In particular, the spatial matrix $W$ in the dependent variable $y$ is defined in term of the inverse of the square of the great circle distance between centroids of regions (i.e. $1/d_{ij}^2$) with a distance cut-off equal to the first quartile ($Q1=403$ miles).

The element $w_{ij}$ of $W$ is therefore given by:

$$
    w_{ij} = \frac{w_{ij}^*}{\sum_j w_{ij}^*},
$$

$$
    w_{ij}^* = \begin{cases} 
        d_{ij}^{-2} & \text{if } i \neq j \text{ and } d_{ij} \leq d_{Q1}; \\
        0 & \text{otherwise}. 
    \end{cases} 
$$

The Spatial Matrix $W^\eta$ in the error term $u$

In the same way $W^\eta$ is a $(N \times N)$ matrix which describe the spatial dependence in the error term. $W^\eta$ is define in term of the inverse of the square of the great circle distance between centroids of regions with a distance cut-off equal to the second quartile ($Q2=671$ miles), which imply a relatively more sparse spatial matrix respect to $W$. The different specification of $W^\eta$ allows us to take into account the dynamics of the process specified in Eq. (??), i.e the changes in $y_i$ and $W_i y$ after $\tau = 15$ periods.

The element $w_{ij}^\eta$ of $W^\eta$ is therefore given by:

$$
    w_{ij}^\eta = \frac{w_{ij}^{\eta*}}{\sum_j w_{ij}^{\eta*}},
$$

$$
    w_{ij}^{\eta*} = \begin{cases} 
        d_{ij}^{-2} & \text{if } i \neq j \text{ and } d_{ij} \leq d_{Q2}; \\
        0 & \text{otherwise}. 
    \end{cases} 
$$
### B Descriptive Statistics

**Table 3: Descriptive Statistics**

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<th>$W y_t = W GDP_{pwRel}$</th>
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**Table 4: Correlation Matrix**

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Table 5: List of EU regions in the sample.