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EU STRUCTURAL FUNDS AND GDP PER CAPITA: SPATIAL VAR EVIDENCE FOR THE EUROPEAN REGIONS

by Sergio Destefanis* and Valter Di Giacinto**

Abstract

This paper focuses on the impact of EU structural funds (SFs) on the GDP per capita of 183 European NUTS2 regions from 1990 to 2016. To allow for the endogeneity of funds allocation to regions, we estimate a bivariate structural panel VAR model, controlling for unobserved heterogeneity through a broad array of deterministic variables. Our main identifying restriction is rooted in the widely documented long lags affecting the implementation of the EU's Cohesion Policy. Through a spatial VAR specification, we also estimate spillovers from local SF expenditure on other areas. We find significant multipliers measuring the local response of GDP to an exogenous shock in local SF expenditure, with a long-run value settling at 2.6. Spillovers for GDP from an exogenous shock to SFs are also positive and significant, but much smaller (about one fifth of within-region responses). When partitioning our sample according to features suggested by the literature (stage of development, EU funding regimes, size), we find that within-region multipliers are higher in lagging regions, especially in recipient countries of the Cohesion Fund, and in regions with a larger population. Spillovers are also heterogeneous across different groups of regions, turning out to be negative in regions in countries that are not recipients of the Cohesion Fund. All this evidence is validated in qualitative terms by robustness checks on model specification and the choice of spatial weights.

JEL Classification: C33, E62, H50.
Keywords: Cohesion Policy, Spatial structural VAR model, Fiscal multipliers, Spillovers, EU NUTS-2 regions.

Contents

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1. Introduction[1]

In the European Union there are still today profound cross-country and cross-regional economic disparities, which led to the creation and expansion of the European Structural and Investment Funds (henceforward the SFs). These funds are the European Union's primary tool to support regional development. For the new programming period (2021-2027), an amount of €330.2 billion has been allocated in Europe for this policy, almost one third (30.7%) of the total budget of the European Union (€1,074.3 billion, net of Next Generation EU).[2] Under the label of SFs, we consider in this paper the European Regional Development Fund (ERDF), created with the specific aim of reducing regional imbalances in the European Union, and the Cohesion Fund (CF), supporting transport and environment projects in countries where the gross national income per inhabitant is less than 90% of the EU average. To assess the impact of SFs on GDP per capita, we estimate a structural VAR model for a panel of 183 NUTS-2 level regions from twelve European countries throughout the 1990–2016 period. Considering the huge wave of public investments undertaken within the Next Generation EU and germane programmes, the evidence from this study has wide policy implications.

There is a large literature on the effectiveness of SFs in achieving their respective goals, which we summarise in Section 2. However, probably because of its data requirements, to the best of our knowledge vector autoregressive (VAR) analysis has never been applied to the study of the SFs' effectiveness across European regions. As is well known, the simple regression of a macroeconomic outcome variable, such as GDP per capita, on the amount of funds spent in any area is not likely to yield an unbiased assessment of that policy's effects. The main potential sources of bias rest in the existence of reverse causation between the outcome variable and the policy tool and of unobserved confounding factors. By estimating a dynamic structural simultaneous equations model in a panel data environment, we can effectively address these issues and provide some novel and credible estimates of the causal effects of the EU cohesion policy on regional economies in member countries.

The problem of reverse causation between the outcome variable and the policy tool is addressed by estimating a simultaneous equations model, namely a structural VAR model. In the baseline specification, a two-variable VAR system is considered, including an equation for GDP per capita and an equation for SFs (the policy tool). The second equation, in the VAR literature, is usually referred to as the policy reaction function, and it decomposes the overall variation in the policy instrument into two orthogonal components: the endogenous policy response to evolutions in local economic conditions and the exogenous policy shocks.[3] Hence, in our baseline bivariate model, local macroeconomic tendencies are simply captured by GDP dynamics. In addition, throughout our analysis, the concern that unobserved heterogeneity may affect the size and significance of the multipliers is addressed by including in the model a rich menu of deterministic controls, detailed in the following sections.

To achieve identification of the structural shocks in the VAR model, following a largely prevailing approach in the literature, we impose the restriction that the policy tool reacts with at least a one period lag to unforeseen shocks to local macroeconomic conditions. This identification hypothesis is particularly appealing in our regional setup. Indeed, subnational bodies are likely to be targeted by fiscal policies that are relatively unresponsive to their idiosyncratic conditions, facilitating the identification of fiscal shocks.[4]

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[1] We thank two anonymous referees, Luca Agnello, Fabrizio Balassone, Roberto Basile, Domenico De Palo, Francesco Zezza and participants at the Bank of Italy seminar and PRIN 2017 "A New Assessment of Cohesion Policies' Effectiveness: Macro and Micro Approaches" meeting for their useful comments. The views expressed in this paper are those of the authors and do not necessarily reflect those of the Bank of Italy and the University of Salerno.

[2] https://www.consilium.europa.eu/it/policies/the-eu-budget/long-term-eu-budget-2021-2027/

[3] In a robustness check, we extend the model by including in it a third variable: gross fixed capital formation.

[4] A thorough analysis of the literature based on the application of time series techniques to subnational data, focusing on US studies, is provided in Chodorow-Reich (2019). Destefanis et al. (2022) also describe the relatively few studies of this kind carried out on non-US data.

Our panel VAR analysis is made possible by a new EU dataset, the 'Historic EU payments' provided by the EU Commission (see https://cohesiondata.ec.europa.eu/Other/Historic-EU-payments-regionalised-and-modelled/tc55-7ysv). This is a source of relatively long and consistent time series about SFs. However, using a spatial VAR imposes some constraints on the sample choice. In particular, the regions in the sample must have time series of reasonable length. This means that we are forced to consider only a subset of the EU NUTS-2[5] regions, excluding those belonging to countries of more recent accession, and to restrict the analysis to the sum of the ERDF and the CF, as other aggregates (for instance the European Social Fund) are only available for fewer years.[6]

The results from the VAR analysis are reported mainly in terms of dynamic multipliers. In the baseline model, we find a significant response of GDP to SF expenditure, with a long-run multiplier settling at 2.6. This figure is in line with comparable values from the literature, including the multipliers yielded for EU regions by the multi-regional dynamic stochastic general equilibrium (DSGE) model of Crucitti et al. (2021).

In assessing fiscal policy effects, a wide literature has stressed the importance of properly addressing the issue of spatial spillovers. Policy decisions in specific areas may, in fact, induce spatial externalities in other areas when the areas are jointly connected via trade linkages or other types of market and non-market mechanisms. A complete evaluation of the policy outcomes thus requires an assessment of both the within-region and the between-regions policy effects. In this paper, we deal with this issue by specifying a panel VAR model including spatial interaction terms between regions. We find positive and significant spillovers for GDP following an SF shock. However, the multipliers related to these between-region effects are much smaller than the within-region responses (about one fifth).

The literature also suggests that the effectiveness of fiscal policy across different regions may be heterogeneous along various dimensions. In this paper, we address this issue by partitioning our sample into regional groups chosen according to a set of relevant structural features (stage of development, EU funding regimes, size, etc.) and estimating specific dynamic policy multipliers for each group. We find that within-region multipliers are higher in lagging regions, especially if located in countries supported by the CF, and in regions with larger populations. Positive between-region multipliers are higher for regions located in countries supported by the CF. Some evidence of negative spillovers, although not always statistically significant, is found for regions belonging to countries not supported by the CF. As explained in detail in Section 5, this evidence is consistent, at least for the within-region multipliers, with previous findings from the literature on fiscal multipliers and SFs' effectiveness. These results from our analysis have a clear policy relevance. A downsizing of the EU cohesion policy could have, in the current economic situation, dire consequences for the level of economic activity, especially in the less-developed regions of the EU.

The rest of this paper has the following structure. Section 2 is dedicated to a short survey of the relevant literature, while the data and empirical approach are detailed in Sections 3 and 4, respectively. Section 5 presents the main findings of the analysis, and some robustness checks are provided in Section 6. Section 7 concludes.

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[5] The NUTS (Nomenclature of territorial units for statistics) classification is a hierarchical system for dividing up the economic territory of the EU and the UK for the purpose of the collection, development and harmonisation of European regional statistics, socio-economic analyses of the regions and framing of EU regional policies. NUTS-2 are middle-sized geographic entities according to the standard EU classification. For example, in Germany this level corresponds to the governmental regions known as *Regierungsbezirke* and in Italy to the nineteen administrative *Regioni* and the two *Province autonome*.

[6] This is a relatively innocuous limitation. The ERDF is widely acknowledged to be the mainstay of European cohesion policy and, together with the CF, makes up over 60% of the UE expenditure in this field.

2. The literature

Although EU cohesion policy addresses a variety of economic and social objectives, the primary aim of SFs (European Commission, 2000, p. 155) is to increase the productive capacity of the benefitting regions. In this paper, we focus on the SFs' aggregate effects on the GDP per capita of a given area. Even considering only studies concerned with NUTS-2 or NUTS-3 regions across several EU countries on this restricted topic, one can find substantial literature and it is fairly heterogeneous in terms of estimation methods.

Initially, the literature mostly focused on estimating regressions à la Barro augmented by SFs, in order to test various hypotheses about growth and convergence among regions (Cappelen et al., 2003; Rodriguez Pose and Fratesi, 2004; Beugelsdijk and Eijffinger, 2005; Esposti and Bussoletti, 2008; Rodriguez-Pose and Novak, 2013). Then attention turned to various kinds of panel models (Fratesi and Perucca, 2014, 2019; Rodríguez-Pose and Garcilazo, 2015; Percoco, 2017; Di Caro and Fratesi, 2021) or to spatial models, which will be considered below in greater detail. The past decade has seen the appearance of papers explicitly based on a treatment effect framework. Examples of this kind of analysis, based on the creation of a control group (for instance, receiving no funding), and mostly couched within a cross-sectional regression discontinuity design, include Becker et al. (2010, 2012, 2013, 2018), Pellegrini et al. (2013), Giua (2017), and Crescenzi and Giua (2020). The literature on the effectiveness of European regional policy also includes macroeconomic simulation models (Hermin, Quest, RHOMOLO; also see the surveys by Tondl, 2004; Lopez Rodriguez and Faiña, 2014). These models have a richer structure than the other econometric analyses but rely on many more (often untested) hypotheses about specification (variables included, key parameters, dynamic structure, functional form, etc.). To the best of our knowledge, there are no studies that apply VAR analysis to the study of the impact of SFs on GDP per capita across European regions (a Bayesian VAR analysis is applied by Destefanis et al., 2022 on Italian data).

A feature that emerges across all these strands of the literature is that most studies not finding a significant SFs effect consider EU regions as an aggregate sample. More significant effects are found on samples split across institutional divides (e.g. Objective 1 regions) or some structural characteristics. Indeed, the literature emphasises the relevance of a series of conditioning factors in affecting the significance of SFs: industrial structure (Cappelen et al., 2003; Becker et al., 2013; Percoco, 2017); axes (types) of expenditure (Rodriguez-Pose and Fratesi, 2004); endowment of various types of capital, including human capital (Becker et al., 2013; Fratesi and Perucca, 2014; Di Caro and Fratesi, 2021); and quality of local governance (Beugelsdijk and Eijffinger, 2005; Becker et al., 2013; Rodríguez-Pose and Garcilazo, 2015; Di Caro and Fratesi, 2021). This heterogeneity is reminiscent of the situation existing for fiscal policy multipliers. Faggian and Biagi (2003), as well as Destefanis et al. (2022), find that multipliers across Italian regions are associated positively with the size of the regional economy and labour slack, and negatively with trade openness and the strength of automatic stabilisers in a given region. These are all factors quoted by Mineshima et al. (2014) among the country-specific characteristics that affect the size of the fiscal multiplier in developed countries. At this juncture it should also be pointed out that studies based on the calibration of theoretical macroeconomic models (Baxter and King, 1993; Leeper et al., 2010; Cwik and Wieland, 2011; Coenen et al., 2012) indicate the marginal productivity of public capital as the key factor in driving a permanent long-run effect of public expenditure on GDP.

The spatial analyses of the GDP impact of SFs deserve, as stated above, a further look. While theoretical models consistently predict strong and positive spillovers of fiscal shocks across countries and regions, the evidence about the sign and magnitude of these spillovers remains mixed (Alcidi et al., 2015). In the field of European regional policy, Crucitti et al. (2021) apply a multi-regional DSGE model (based on the RHOMOLO model) to a sample of 267 NUTS-2 regions. They find that EU cohesion policy had a positive and significant impact on GDP, particularly in the poorest regions of the EU. Additionally, for some of the member states, spatial spillovers even constitute the main source of benefits from SFs.[7] Such unambiguous results cannot be retrieved from more data-driven studies. The beta-convergence models à la Barro estimated in Dall'Erba and Le Gallo (2008) and Le Gallo et al. (2011) find evidence of a direct impact of (total) SFs only locally (for British, Greek, and southern Italian regions) and no evidence of spillovers. In the spatial panel models from Mohl and Hagen (2010), Bouayad Agha et al. (2011), and Fiaschi et al. (2018), there is evidence of a direct effect of Objective 1 SF payments (which does not show up for other indicators of EU cohesion policy) as well as significant and positive regional spillovers (interestingly, Fiaschi et al. [2018] consider measures of both geographical and technological proximity). On the other hand, Antunes et al. (2020), estimating a Durbin panel model on a sample of 96 EU regions excluding Italy, Austria, and all the Eastern European member states, find no impact from SFs, either directly or through spillover effects. Finally, Römish (2020) breaks down world input–output tables to regional input–output tables and finds that spillovers from EU cohesion policy are positive and sizeable. Spillovers, particularly from less-developed regions to other regions, may even exceed 40% of the initial EU funding.

This body of spatially oriented studies highlights once more the lack of a VAR-based analysis of the effectiveness of SFs. Furthermore, also within this literature, the most significant effects of SFs are found for restricted subsamples of regions or for particular types of expenditures. The relevance of sample heterogeneity calls, once more, for careful treatment of the factors potentially conditioning the strength of policy effects. This requires exploiting to its fullest extent the information available in panel data to control for unobserved heterogeneity, as well as exploring the influence of various sample cuts on the size and significance of fiscal multipliers.

In this paper, we aim to contribute to the literature in the following ways:

(i) Analysing the impact of SFs on the GDP per capita of the EU NUTS-2 regions through a structural VAR model. As already pointed out above, we know of no studies that evaluate the impact of SFs across European regions through a VAR analysis. This model allows for an effective treatment of the simultaneity and reverse causation issues potentially marring much of the existing literature. The impact of SFs is measured mainly in terms of dynamic multipliers.

(ii) Extending the model, through a spatial VAR specification, to gauge the direction and strength of dynamic spillover effects of SFs across EU regions. Using a properly specified and identified structural spatial VAR model at the regional level, we can provide novel empirical evidence on the size, magnitude, and possible heterogeneity of the spatial spillover effects on economic activity induced by the regional cohesion policy in the EU. [8]

(iii) Assessing whether the multipliers of SF expenditure are affected by regional characteristics singled out by the relevant literature. We provide novel evidence on the relevance of these structural features for policy effectiveness, controlling for a rich menu of deterministic controls. The latter comprise region-specific deterministic time trends controlling for unobserved region-specific factors that are either constant or evolve smoothly over time, year fixed effects controlling for unobservable shocks that are common across regions, and country-specific fixed effects interacted with year fixed effects controlling for country-specific macroeconomic factors varying across time at relatively high frequencies (national cycle, etc.).

3. The data

Our empirical analysis is based on annual data for 183 NUTS-2 level regions from twelve European countries (for details, see Table A1 in the Appendix) throughout the 1990–2016 period. Table A2 provides some useful descriptive statistics (mean, standard deviation, 10th percentile, and

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[7] Similar results are reached in cross-country DSGE setup by Pfeifer et al. (2021), who quantify, for each EU member state, the effects of the expenditures set forth in the Next Generation EU programme. According to them, the EU-wide GDP effects of Next Generation EU are about one third larger when explicitly accounting for cross-country spillovers.

[8] Note that in the presence of spillovers, the country-level (or EU-level) fiscal multiplier will be higher (or lower if spillovers are negative) than the average within-region multiplier. We do not pursue this comparison in detail here. See Chodorow-Reich (2019) for further details about this issue.

90th percentile) for all variables. GDP, gross fixed capital formation (to be used at a later stage of the analysis), and SFs are all deflated using the GDP purchasing parity index sourced from EUROSTAT (base year = 2005). It should be noted that our dataset potentially includes over 260 NUTS-2 regions. In the Introduction section, we already expounded on the criteria for choosing the regions included in our sample. There must be no remote territories (far-off islands, French overseas territories, Ceuta and Melilla), and the regions in the sample must have time series since at least 1990. This effectively limits the sample to 183 regions from Belgium, Denmark, Ireland, France, Germany, Greece, Italy, Luxembourg, Netherlands, Portugal, Spain, and the UK. Due to its relatively small size, Luxembourg was treated as a NUTS-2 level region in our dataset.

We rely on EU-based data throughout our empirical analysis. GDP, gross fixed capital formation, and population are taken from the EUROSTAT regional database. SFs are taken from the 'Historic EU payments' provided by the EU Commission (see https://cohesiondata.ec.europa.eu/Other/Historic-EU-payments-regionalised-and-modelled/tc55-7ysv).

It is widely acknowledged that funds from the EU are paid out to the regions with a lag of approximately one year with respect to the regions' actual spending decisions. This time pattern between the payments to the member states and the dates on which expenditures take place on the ground is also noted in the 'Historic EU payments' provided by the EU Commission. Accordingly, this dataset provides a measure of the 'expenditures taking place on the ground', the modelled expenditures, which are the SF indicators that we use in our empirical analysis.

As in Bouayad Agha et al. (2011) and in Rodriguez-Pose and Garcilazo (2015), we divide SFs by population. This means that our policy variable is the sum of ERDF and CF per capita. Dealing with per capita variables (GDP and gross fixed capital formation are also divided by population) has some advantages for the computation of multipliers. Indeed, the common procedure of relying on logarithmically transformed variables can lead to biases in the estimation of fiscal multipliers (Gordon and Krenn, 2010; Ramey and Zubairy, 2018).

4. The baseline spatial VAR model

4.1 Model definition

In this section, we detail our baseline model specification, including an equation for GDP per capita and an equation for the policy instrument (SFs). We assume that data are collected over a set of N regions, belonging to $C < N$ countries, for T consecutive time periods. To highlight the main identifying restriction underlying our structural VAR model specification and allow for a direct comparison with the related literature, we start from the following bivariate panel VAR specification:

$$\mathbf{B}_0 z_{it} = \mu_i + \delta_i t + \lambda_{c(i)t} + \mathbf{B}_1 z_{it-1} + \cdots + \mathbf{B}_p z_{it-p} + \varepsilon_{it} \quad (1)$$

where $z_{it} = [f_{it}, y_{it}]'$, f_{it} and y_{it} denote the amount of per capita SF expenditure and per capita GDP, respectively, observed in year t in region i of country c, and where $\varepsilon_{it} = [\varepsilon_{it}^f, \varepsilon_{it}^y]'$ is a vector of white-noise structural errors, with a variance–covariance matrix equal to:

$$\Sigma_{ii} = E(\varepsilon_{it}\varepsilon_{it}') = \begin{bmatrix} \omega_i^f & 0 \\ 0 & \omega_i^y \end{bmatrix}, \Sigma_{ij} = E(\varepsilon_{it}\varepsilon_{jt}') = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix} \text{ for } i \neq j, \ \ i,j = 1,2,\ldots N.$$

Finally, the $\mu_i = [\mu_i^f, \mu_i^y]'$ coefficients are region-specific fixed effects, allowing for time invariant differences between regions in structural features such as human capital endowment and the quality of local institutions, $\delta_i = [\delta_i^f, \delta_i^y]'$ are region-specific deterministic trends, and $\lambda_{c(i)t} =$

$[\lambda^{f}_{c(i)t}, \lambda^{y}_{c(i)t}]$ are country-specific fixed effects interacted with year fixed effects, capturing the influence of macroeconomic factors common across the regions of the same country that vary across time at relatively high frequencies (national cycle, etc.).

The unrestricted VAR coefficient matrixes in (1) have the following expression:

$$\mathbf{B}_h = \begin{bmatrix} \beta^h_{ff} & \beta^h_{fy} \\ \beta^h_{yf} & \beta^h_{yy} \end{bmatrix} \quad (h=1,2,\ldots,p). \tag{2}$$

As is well known, restrictions must be placed on the simultaneous coefficient matrix $\mathbf{B}_0$ to obtain the identification of the structural parameters in the VAR model specified in (1). While several alternative approaches have been proposed in the literature for this purpose (see Caldara and Kamps, 2008, for a taxonomy), the recursiveness hypothesis represents the assumption most often enforced. Under this hypothesis, it is assumed that while all the remaining macroeconomic variables included in the VAR system are allowed to react immediately to government spending shocks, government spending does not react on impact to other shocks in the system. Given the delays inherent in the legislative system, this is also considered a tenable assumption on annual data (see, e.g., Pereira and Roca Sagales, 1999; Kamps, 2005; Di Giacinto et al., 2010; Pereira and de Fatima Pinho, 2011; Deleidi et al., 2020, Destefanis et al., 2022). Indeed, the short-term inertia of public expenditure may be even more pronounced in the case of SFs, where the design and implementation of policy measures are subject to strict bureaucratic rules at the local, national, and supranational levels.

Under the recursiveness hypothesis, the $\mathbf{B}_0$ matrix in the VAR model takes the following lower triangular form:

$$\mathbf{B}_0 = \begin{bmatrix} 1 & 0 \\ \beta^0_{yf} & 1 \end{bmatrix} \tag{3}$$

imposing that, conditional on past system dynamics, the current evolution of SF expenditure is not affected by current shocks to per capita GDP.[9]

In the bivariate VAR specification outlined above, exogenous shocks to regional SF expenditure are identified by conditioning only on past GDP and SF expenditure dynamics. We are confident that this information set, although apparently limited, may suffice to provide a credible identification of exogenous shocks to regional SF expenditure, essentially because GDP can proxy for a wide range of macroeconomic disturbances.[10] Nonetheless, we subsequently check the robustness of this hypothesis by estimating a three-variable VAR model, including investment in fixed capital. Investment, while of course already entering GDP, may provide a signal to local policy makers that goes beyond the current state of the economy, capturing more forward-looking behaviour, possibly related to the level of uncertainty about economic prospects faced locally by economic agents.

While the standard panel VAR model specification may provide a useful tool to identify and estimate the local impact of SF expenditure on regional GDP per capita, it also has a strong limitation given that it treats individual regions as mutually unrelated units. This hypothesis clearly represents an unreasonable assumption, considering that regional economies may be expected to interact with each other via trade, labour and financial markets, and possibly along other dimensions too.

Neglecting regional interactions has two important consequences. On the one hand, it may lead to biased estimates of model parameters in the presence of simultaneous interactions between

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[9] This is equivalent to applying a Choleski decomposition to the variance–covariance matrix of a VAR in unrestricted reduced form and then re-parameterising the model.

[10] A similar specification is quite common in the fiscal panel VAR literature. See, for example, Auerbach et al. (2020), Deleidi et al. (2021), and Destefanis et al. (2022).

regions. On the other hand, it does not allow for the evaluation of spatial spillover effects resulting from local policy implementation, which are to be expected considering the strong linkages that usually exist between regions, especially those that are geographically close.

To overcome this limitation, spatial VAR (SpVAR) model specifications have been proposed in the literature for identifying and estimating dynamic spatial spillover effects between connected areas (Di Giacinto, 2003, 2006, 2010; Beenstock and Felsenstein, 2007; Marquez et al., 2015; Ramajo et al., 2017). As usual in spatial econometrics, a set of spatial weights matrices whose coefficients are set a priori based on the spatial structure of the regional sample (i.e. the closeness of each region to any of the remaining regions) is employed in order to achieve a parsimonious model parameterisation that also allows for a straightforward way to obtain structural parameter identification.

To introduce the SpVAR model specification, it is useful to rewrite the model by stacking the cross-sectional observations of the endogenous variables for each time period, setting:

$$\begin{aligned}
\mathbf{z}_t &= [f_{1t}, f_{2t},, \dots, f_{Nt}, y_{1t}, y_{2t},, \dots, y_{Nt}]' \\
\boldsymbol{\varepsilon}_t &= \left[\varepsilon_{1t}^{f}, \varepsilon_{2t}^{f}, \dots, \varepsilon_{Nt}^{f}, \varepsilon_{1t}^{y}, \varepsilon_{2t}^{y}, \dots, \varepsilon_{Nt}^{y}\right]' \\
\boldsymbol{\mu} &= \left[\mu_1^f, \mu_2^f, \dots, \mu_N^f, \mu_1^y, \mu_2^y, \dots, \mu_N^y\right]' \\
\boldsymbol{\delta} &= \left[\delta_1^f, \delta_2^f, \dots, \delta_N^f, \delta_1^y, \delta_2^y, \dots, \delta_N^y\right]' \\
\boldsymbol{\lambda}_t &= \left[\lambda_{c(1)t}^{f}, \lambda_{c(f)t}^{f}, \dots, \lambda_{c(N)t}^{f}, \lambda_{c(1)t}^{y}, \lambda_{c(2)t}^{y}, \dots, \lambda_{c(N)t}^{y}\right]'.
\end{aligned}$$

With the above notation, the SpVAR model expression can be stated as:

$$\mathbf{C}_0\mathbf{z}_t = \boldsymbol{\mu} + \boldsymbol{\delta}t + \boldsymbol{\lambda}_t + \mathbf{C}_1\mathbf{z}_{t-1} + \dots + \mathbf{C}_p\mathbf{z}_{t-p} + \boldsymbol{\varepsilon}_t \tag{4}$$

Where the 2*N* x 2*N* coefficient matrices $\mathbf{C}_h$, $(h = 0,1,.., p)$, which are functions of the spatial weight matrices, have the following block structure:

$$\mathbf{C}_0 = \begin{bmatrix} \mathbf{A}_{ff}^{(0)} & \mathbf{0} \\ \mathbf{A}_{yf}^{(0)} & \mathbf{A}_{yy}^{(0)} \end{bmatrix} \tag{5}$$

$$\mathbf{C}_h = \begin{bmatrix} \mathbf{A}_{ff}^{(h)} & \mathbf{A}_{fy}^{(h)} \\ \mathbf{A}_{yf}^{(h)} & \mathbf{A}_{yy}^{(h)} \end{bmatrix} \tag{6}$$

with individual *N* x *N* blocks given by:

$$\mathbf{A}_{rr}^{(0)} = \mathbf{I}_N - \sum_{m=1}^{q} \phi_{rr,0m}\, \mathbf{W}^{(m)} \qquad r \in [f, y] \tag{7}$$

$$\mathbf{A}_{yf}^{(0)} = \beta_{yf}^{0}\, \mathbf{I}_N - \sum_{m=1}^{q} \phi_{yf,0m}\, \mathbf{W}^{(m)} \tag{8}$$

$$\mathbf{A}_{rs}^{(h)} = \beta_{rs}^{h}\, \mathbf{I}_N - \sum_{m=1}^{q} \phi_{rs,hm} \mathbf{W}^{(m)} \qquad h = 1, \dots, p;\;\; r, s \in [f, y]. \tag{9}$$

and where $\mathbf{W}^{(m)}$ denotes the *m*-th order spatial weights matrix. As usual in model specifications allowing for spatial lags of higher order, the first-order matrix $\mathbf{W}^{(1)}$ is associated to its nearest spatial neighbours - that is, regions that are directly connected with each other - while higher-order matrices consider indirect linkages between regions (e.g. two regions that are not directly connected to each other but which are both connected to a third region are assumed to be connected at spatial lag order = 2). As the spatial lag order increases, the distance between areas on the graph whose arcs represent direct linkages similarly increases (see Anselin and Smirnov, 1996, for a comprehensive treatment of the definition and computation of higher-order spatial lag operators).

By allowing for higher-order spatial lags to be introduced when needed, the SpVAR specification considered here ensures a great degree of flexibility in empirical applications, as it does not impose strong restrictions on the spatial range of regional interactions, letting the data mostly 'speak for themselves' in this respect. Our SpVAR specification can thus accommodate a wide range of possible spatial interaction patterns, ranging from externalities that rapidly cut-off with distance to spillovers that are possibly highly persistent in space.

Endogenous spatial interaction effects are modelled through the $\phi_{\cdot,\cdot}$ coefficients in equations (7)–(9). When the latter are all set equal to zero, the spatial VAR model can be immediately seen to coincide with the structural panel VAR model given by expression (1).

The triangular structure of the $\mathbf{B}_0$ matrix in the identified panel VAR model maps into the block triangular structure of the $\mathbf{C}_0$ matrix in our structural SpVAR model specification. In this case, identification is achieved by combining the lagged response of funds expenditure to macroeconomic shocks with geographical restrictions on the scope of spatial interactions between regions. Di Giacinto (2010) discusses in detail the identification of spatial VAR models specified as in equation (4) and provides an order condition for structural parameter identification.

In the specification detailed above, spatial homogeneity is assumed in the SpVAR model by assuming that VAR coefficients take the same value on all the regions in the sample. However spatial heterogeneity can be introduced in a straightforward way by letting the coefficients vary across the individual regions or between groups of regions, as initially proposed in Di Giacinto (2006). In Section 2, we saw that the literature emphasises the relevance of some structural characteristics (regional size, labour slack, and stage of development) in influencing the size and significance of SF multipliers. Accordingly, in the subsequent empirical analysis (see Section 5), the potential existence of group-heterogeneity will be assessed by adopting some sample partitions suggested by the relevant literature.

4.2 The empirical SpVAR model specification

As a preliminary step to model specification, we winsorised our time series to limit the effect of anomalous values on the VAR estimation. More precisely, we replaced the values below the p-th and above the P-th percentile of the distribution with the closest percentile.[11] Compared to simply dropping the observations in the tails of the distribution from the sample, this procedure has the advantage of avoiding the introduction of missing values in our regional time series.

The first step in VAR model specification requires the assessment of the degree of integration of the time series and of the possible existence of cointegration. In the literature, several different tests have been proposed to verify the null hypothesis of the presence of unit roots in a panel data setting. Considering that we expect our regional panel data to be denoted by strong cross-sectional dependence, because of the influence of common shocks and interregional spillovers, we utilised the Pesaran (2007) CADF test, which is explicitly designed to cope with dependence between the individual time series in the panel. We ran the test both with and without the inclusion of individual deterministic time trends, and the results, displayed in Table 1, show that in no case could the null hypothesis that the series are $I(1)$ be rejected. Having assessed the presence of unit roots, we tested the hypothesis that the GDP per capita and SFs per capita series are cointegrated. In this case too, several alternative test statistics have been proposed in the literature. We relied on the ADF version of the Kao and Pedroni tests, as these tests have been proved to have higher power in panel with a short time dimension (T < 100; see Pedroni, 2004). As in the standard augmented Dickey–Fuller test, the null hypothesis of no cointegration is rejected if a large and significant negative value of the t statistic is observed. The Kao's test fails to reject the null at the standard 5% level. The Pedroni tests

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[11] We set $p = 1$ and $P = 99$ for the GDP per capita series and $p = 5$ and $P = 95$ for the more volatile SFs per capita series.

are significant but take positive values, thus providing strong evidence against the hypothesis that GDP and SFs are cointegrated. Based on this evidence, we took first differences of the data and estimated the following SpVAR specification:

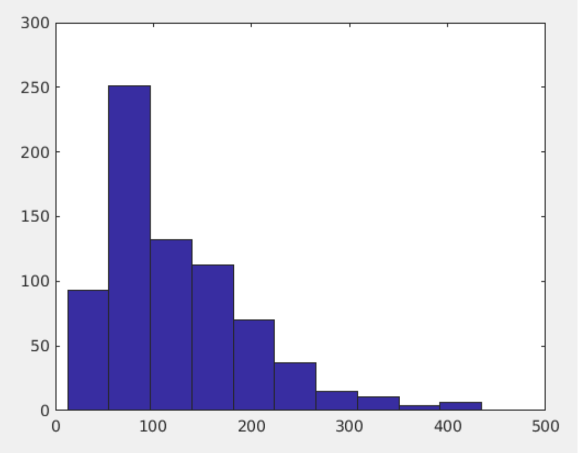
$$\mathbf{C}_0 \Delta \mathbf{z}_t = \boldsymbol{\delta} + \Delta \boldsymbol{\lambda}_t + \mathbf{C}_1 \Delta \mathbf{z}_{t-1} + \cdots + \mathbf{C}_p \Delta \mathbf{z}_{t-p} + \mathbf{u}_t \tag{10}$$

with $\mathbf{u}_t = \left[u_{1t}^f, u_{2t}^f, \ldots, u_{Nt}^f, u_{1t}^y, u_{2t}^y, \ldots, u_{Nt}^y\right]'$

A second step in the empirical specification of the SpVAR regards the choice of the first-order spatial weights matrix, from which higher-order matrices can be derived by applying the proper algorithm. First-order neighbours are usually identified based on the existence of a common border or, alternatively, by relying on the distance between the centroids of the individual areas. Distance-based approaches include the *k*-nearest neighbour method and the distance-bands method. The *k*-nearest neighbour criterion does not impose a maximum distance between areas and thus appears to be well suited to the geography of our panel of European regions, which involves rather heterogeneous units according to size and relative location on the map. Compared to distance-bands methods, it has the advantage of avoiding by construction that any of the regions is treated as being isolated - that is, with no neighbours.

Setting $k = 4$ yields a distribution of distances between first-order spatial neighbours in our regional panel with a median value of about 100 km and a 95th percentile equal to about 400 km (see Figure 1). Overall, the method thus seems to succeed in identifying regions that are reasonably close to each other in space.

Figure 1. The sample distribution of geodetic distances between the centroids of first-order spatial neighbouring regions



Distance in kilometres

As anticipated above, any longer-distance interactions between regions can be dealt with in our SpVAR specification by utilising higher-order spatial weights matrices, setting a spatial lag order $q > 1$. The temporal and spatial lag orders of the SpVAR model do not have to be imposed a priori but can be selected according to the available sample evidence. Information criteria such as Akaike's AIC, Schwarz's BIC, and Hannan and Quinn's criterion provide a standard reference for this purpose in time series VAR modelling (see, e.g., Lütkepohl, 2007, and the references therein) and can be extended in a straightforward manner to the SpVAR model specification.

Considering that our panel data contain observations at the annual frequency, setting a maximum temporal lag order of $p = 3$ appears to be appropriate. The maximum spatial lag order was then set to $q = 2$, and the performance of the individual SpVAR specifications was compared. According to both the Akaike and the Schwarz information criteria, the best performing model specification was obtained by setting $p = 2$ and $q = 1$. Hence, we end up with a SpVAR (2,1) as our chosen empirical model specification.

The model parameters were estimated by the full information maximum likelihood (FIML, see Di Giacinto, 2010) method. Table 2 details the estimation results separately for the two equations of the SpVAR system. In seven cases out of a total of eleven, the ϕ coefficients gauging the strength of spatial interactions between regions are statistically significant. Moreover, the likelihood ratio test of the restriction that all the spatial interaction coefficients are equal to zero strongly rejects the null hypothesis for both equations. Hence, spatial linkages cannot be neglected. Fitting to the data, a simple panel VAR model, as specified in equation (1), would lose significant information and possibly incur omitted variable biases.

4.3 Impulse responses and dynamic spatial multipliers

The above detailed SpVAR model specification allows for a straightforward computation of the impulse response functions, measuring the impact, at the h time horizon, of a structural shock to any of the system variables on each endogenous variable.

The coefficients of the impulse response function of the VAR system can be computed, as usual, from the Wold, or MA(∞), representation of the process. The latter can be derived from the reduced form expression of the structural SpVAR, which in the present case reads as:

$$\Delta\mathbf{z}_t = \tilde{\boldsymbol{\xi}}_t + \tilde{\mathbf{C}}_1\Delta\mathbf{z}_{t-1} + \cdots + \tilde{\mathbf{C}}_p\Delta\mathbf{z}_{t-p} + \tilde{\mathbf{u}}_t \qquad (11)$$

where $\tilde{\boldsymbol{\xi}}_t = \mathbf{C}_0^{-1}(\boldsymbol{\delta} + \Delta\boldsymbol{\lambda}_t)$, $\tilde{\mathbf{C}}_h = \mathbf{C}_0^{-1}\mathbf{C}_h$, $h = 1,2,\dots,p$, and $\tilde{\mathbf{u}}_t = \mathbf{C}_0^{-1}\mathbf{u}_t$. The corresponding Wold representation has the following expression:

$$\Delta\mathbf{z}_t = \sum_{h=1}^{\infty}\tilde{\boldsymbol{\Psi}}_h(\tilde{\boldsymbol{\xi}}_{t-h} + \tilde{\mathbf{u}}_{t-h}) \qquad (12)$$

where the MA coefficients matrices $\tilde{\boldsymbol{\Psi}}_i$ are yielded by the recursion $\tilde{\boldsymbol{\Psi}}_i = \sum_{h=1}^{i}\tilde{\boldsymbol{\Psi}}_{i-k}\,\tilde{\mathbf{C}}_h$. By setting $\boldsymbol{\Psi}_i = \tilde{\boldsymbol{\Psi}}_i\mathbf{C}_0^{-1}$ and $\boldsymbol{\xi}_t = \boldsymbol{\delta} + \Delta\boldsymbol{\lambda}_t$, the Wold representation can finally be expressed as a function of the vector of structural errors $\mathbf{u}_t$:

$$\Delta\mathbf{z}_t = \sum_{h=1}^{\infty}\boldsymbol{\Psi}_h(\boldsymbol{\xi}_{t-h} + \mathbf{u}_{t-h}) \qquad (13)$$

Each $\boldsymbol{\Psi}_h$ matrix, in the case under analysis, is a $2N$ x $2N$ block matrix with the following structure composed of four N x N blocks:

$$\boldsymbol{\Psi}_h = \begin{bmatrix} \boldsymbol{\Psi}_{ff}^{(h)} & \boldsymbol{\Psi}_{fy}^{(h)} \\ \boldsymbol{\Psi}_{yf}^{(h)} & \boldsymbol{\Psi}_{yy}^{(h)} \end{bmatrix} \qquad (14)$$

where the generic (i,j) elements of the individual blocks on the RHS of (13) are given by:

$$\psi_{ff}^{(h)}(i,j) = \frac{\partial\Delta f_{it+h}}{\partial u_{jt}^{f}} \qquad (15)$$

$$\psi_{fy}^{(h)}(i,j) = \frac{\partial\Delta f_{it+h}}{\partial u_{jt}^{y}} \qquad (16)$$

$$\psi_{yf}^{(h)}(i,j) = \frac{\partial\Delta y_{it+h}}{\partial u_{jt}^{f}} \qquad (17)$$

$$\psi_{yy}^{(h)}(i,j) = \frac{\partial\Delta y_{it+h}}{\partial u_{jt}^{y}}, (i,j) = 1,2,\dots N \qquad (18)$$

and measure the response of any of the two endogenous variables observed at location i at time $t+h$ to a unit structural shock imparted to SF or GDP at location j and time t, where $i, j = 1,2, \dots, N$.

As usual in spatial autoregressive models, due to the workings of the so-called spatial multiplier, the SpVAR model incorporates global spillover effects, in the sense that a shock occurring in any one region spreads, through the neighbouring regions, to all the remaining regions (see, e.g., Anselin, 2003).

When the spatial homogeneity of the process is assumed, the individual entries of each block of the $\boldsymbol{\Psi}_h$ matrix can be averaged across regions and across neighbours of each region without loss of information, yielding the Space-Time Impulse Response (STIR) function. The latter, proposed in Di Giacinto (2006, 2010), summarises the individual bilateral space-time impulse responses, expressing them as functions of the time horizon h and of the spatial lag order m. Outward and inward definitions of the STIR are proposed in Di Giacinto (2010). The outward-STIR measures the average response of a shock imparted in a given region on its neighbouring regions. Symmetrically, the inward-STIR measures the average response recorded for a given region to a shock simultaneously imparted to all its neighbouring regions. The two definitions tend to coincide under the spatial homogeneity of the underlying process but may differ when model coefficients vary across regions. In all the ensuing computations, since we consider model specifications with coefficients assumed either to be same for all regions or to show only limited variation, we will refer to the outward-STIR definition, whose expression reads as:

$$\eta_{rs}(h,m) = N^{-1} \sum_{i=1}^{N} \sum_{j=1}^{N} w_{ij}^{(m)} \psi_{rs}^{(h)}(i,j) \;\;,\;\; r,s \in [f,y] \tag{19}$$

where $w_{ij}^{(m)}$ denotes the generic element of the *m*-th order spatial weights matrix, $\mathbf{W}^{(m)}$, assumed to be row normalised ($\sum_{j=1}^{N} w_{ij}^{(m)} = 1,\; i = 1,2, \dots, N$).

In the Appendix, we present the plots for the estimated STIR functions, while in the text we focus on the multipliers of EU funds expenditure. Since both SF and GDP are measured in euros per inhabitant at constant PPP values, the impulse response coefficients measure the changes in euro p.c. of the endogenous variables in response to a unit euro p.c. structural shock to SF of GDP p.c. in each region. Following the approach of Gordon and Krenn (2010) and Ramey and Zubairy (2018), we normalise all variables (in this case by population) to compute unbiased multipliers. As the SpVAR model is estimated on differenced data, the impact of the structural shocks on the levels of the two endogenous variables is retrieved through the cumulated responses to a unit shock. The individual, region-specific, cumulative multipliers at time horizon *h* have the following expression, proposed by Ramey and Zubairy (2018) and recently implemented in a VAR environment by Destefanis et al. (2022):

$$M_{yf}^{(h)}(i,j) = \frac{\sum_{r=0}^{h} \psi_{yf}^{(r)}(i,j)}{\sum_{r=0}^{h} \psi_{ff}^{(r)}(j,j)} \tag{20}$$

Where the numerator gives a discrete approximation of the integral of the impulse response function of GDP in region *I* to SF expenditure in region j, and the denominator is a discrete approximation of the integral of the impulse response function (IRF) of the SF expenditure aggregate in region j.

In analogy with the procedure that summarises bilateral regional impulse responses in the STIR, as outlined above, by averaging over the *N* regions and over the set of neighbours of each region, for a given spatial lag order, we get the following formula for the space-time multipliers, expressed as a function of the time horizon *h* and of the spatial lag order *m*:

$$\mu_{yf}(h,m) = N^{-1} \sum_{i=1}^{N} \sum_{j=1}^{N} w_{ij}^{(m)} M_{yf}^{(h)}(i,j) \tag{21}$$

Our results concerning the dynamic multipliers measuring the response of regional GDP to an exogenous shock to the local SF expenditure are reported in row (1) of Table 3.[12] Their values imply that every euro spent in SFs translates into 1.3 euros of GDP on impact, into 2.9 euros the following year, and into 2.6 euros after 10 years and at longer time horizons. These figures are in line with the considerations made in a recent survey about the macroeconomic impact of infrastructure investment by Ercolani, according to which: 'The available evidence, with rare exceptions, suggests output multipliers well above unity in the medium-to-long run' (Ercolani, 2021, p. 5). They also fall within the 1.3–2.8 range of the values surveyed by Busetti et al. (2019, table 2) from various DSGE models, including the Bank of Italy multi-country DSGE model. Within the large field of sub-national estimates for the US, our long-run multiplier is comparable (within the range of a 95% confidence interval) with the value of 1.8 that Chodorow-Reich (2019) derives from the literature, or with the state-level GDP multiplier of 1.7 from Auerbach et al. (2020).[13] The US literature also highlights very high multipliers, ranging from 3 to 7, reported by Leduc and Wilson (2013) for state-level investments in transport infrastructure. As for the less abundant empirical evidence outside the US, Pereira and Roca-Sagales (1999) calculate, for Spain, a long-term accumulated marginal product of output with respect to public capital in the areas of transportation and communications approximately equal to 4.4. Acconcia et al. (2014) find a long-run fiscal multiplier of 1.9 on NUTS-3 data from Southern Italy, while the NUTS-2 long-run estimates for the same area from Destefanis et al. (2022) yield a 1.5 GDP-weighted mean multiplier on total SFs (which include, beside the ERDF, the European Social Fund and a set of agriculture- and fishery-related funds). Finally, the simulations conducted for the whole set of EU regions by Crucitti et al. (2021), utilising the RHOMOLO model, provide a long-run GDP-weighted mean NUTS-2 multiplier of 3.1 at a forecast horizon of 30 years (this value increases at longer horizons due to long-lasting persistence of positive supply-side effects). We draw three general considerations from this perusal of econometric findings. First, our multiplier values, although quite high, are not at the top end of the field either of the US or of the non-US findings. Furthermore, it appears that particularly high multipliers are associated with expenditures on transport and communication infrastructure. We will come back to these figures in Section 5, when commenting on the evidence obtained across several sample partitions. Finally, fiscal multipliers have usually been found to be much larger in recessions than in expansions (see, e.g., Auerbach and Gorodnichenko, 2012). It is possible that we capture an average multiplier that is high due to the several slumps experienced by EU countries since the early 1990s.[14]

The spillover effects for GDP from an exogenous shock to SFs, reported in row (1) of Table 4, are positive and statistically significant at all temporal horizons. At spatial lag = 1, the impact multiplier on the more closely located regions is equal to about 0.2, while in the long term the multiplier increases to slightly below 0.5. [15] Hence, a euro spent in SFs in a given region translates into 0.5 euros of the nearest neighbours' GDP in the long term. While these estimates are considerably smaller (about one fifth) compared to the responses observed within the region where the SF expenditure takes place, they are nonetheless positive and sizeable. They are in the range of the

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[12] The results in Table 3, as well as in the following tables, measure the average effects of a shock occurring in the *i*-th region on the region itself and on the neighbouring regions (outward-STIR definition). In all these tables, standard errors were estimated by the bootstrap method (100 replications of the sample were utilised for this purpose).

[13] Auerbach et al. (2020) also find strong positive spillovers across locations and industries, although geographic spillovers vanish above 50 miles of distance.

[14] We are grateful to an anonymous referee for raising this point. Unfortunately, the shortness of available time series for the EU NUTS-2 does not allow any attempt at estimating asymmetric multipliers. For instance, the study by Auerbach and Gorodnichenko (2012) is based on a time series of 244 observations.

[15] To save on space, we do not present or comment on spillover effects on second-order spatial neighbours, which are always of very limited size.

predictions of the regional input–output model of Römish (2020) and the multi-regional DSGE models (Crucitti et al., forthcoming; Pfeiffer et al., 2021), yielding evidence that is consistent with the predictions of theoretical models (Alcidi et al., 2015).

5. The group-heterogeneous SpVAR specification

The empirical findings detailed in Section 4 are only entirely informative under the hypothesis of the spatial homogeneity of the underlying stochastic processes. When this assumption is violated, the estimation results will reflect a mixture of the actual, possibly highly differentiated, conditions across the individual regions. As outlined in the literature review provided in Section 2, the issue of spatial heterogeneity in the effects of the EU cohesion policy has been addressed in several previous studies.

In particular, fiscal multipliers have been related to territorial differences in features such as regional size, the stage of development, and funding regime (areas belonging to the former Objective 1, now Convergence Objective, or located in a country that benefits from the CF). To gather evidence on the relative importance of the above outlined factors in influencing the size and possibly the sign of the local effects of the EU cohesion policy, we have enriched our baseline SpVAR specifications, estimating different dynamic spatial multipliers for separate groups of regions in the panel. More precisely, group heterogeneity was considered by partitioning the sample according to the following criteria:

- Regions belonging to the former Objective 1, now Convergence Objective, vs. other regions.
- Regions located in a country benefitting from the CF vs. other regions.
- Regions with a larger population size vs. regions with a smaller population size (the 1990 median population being taken as the dividing point).

Separating regions belonging to the former Objective 1, now Convergence Objective, from the other regions essentially means focusing on regions that have a relatively low GDP per capita (less than 75% of the EU average) and a relatively low rate of employment (concerning this and the following points, see the descriptive statistics given in Table A2). The latter implies a relatively higher labour slack, while Faggian and Biagi (2003) maintain that a lower GDP per capita is associated with a higher propensity to consume. Both factors are conducive to fiscal multipliers being higher, all other things being equal. The literature on SFs also suggests that the support to business and competitiveness provided by the ERDF yields more boost to output in relatively disadvantaged regions, although this effect does not apply with the same strength in all countries (Pellegrini et al., 2013; Fratesi and Perucca, 2019; Bachtrögler et al., 2020). Countries benefitting from the CF also have relatively low GDP per capita and low rates of employment, with the implications for the fiscal multiplier that have been pointed out above. These countries, at least at the outset of the estimation period, were also likely to be characterised by a higher marginal productivity of public capital. Accordingly, the theoretically based DSGE model of Crucitti et al. (2021) predicts that EU cohesion policy has a particularly positive and significant impact on GDP in the poorest regions of the EU. Furthermore, the evidence from Pereira and Roca-Sagales (1999) and Leduc and Wilson (2013) is consistent with expenditures in transportation and communication, such as those supported by the CF, to yield particularly high values for fiscal multipliers. Finally, regions with a larger population size usually have a wider and more complete economy than smaller size regions. Other things being equal, this should make larger regions able to retain within their own area a higher share of fund expenditure, increasing the within-area effects.

To deal with this sample partitioning, we introduce the following model parameterisation. Considering a partition of the set of the region indexes $R = \{1, 2, \ldots, N\}$ into $M < N$ subsets and letting $g(i)$, $I = 1,2,\ldots N$ denote the function that associates to each region the corresponding group index, the group-heterogeneous SpVAR model specification is obtained by imposing the following structure on the matrices of the model coefficients:

$$\mathbf{A}_{rr}^{(0)} = \mathbf{I}_N - \sum_{m=1}^{q} \boldsymbol{\phi}_{rr,0m} \mathbf{W}^{(m)} \tag{22}$$

with $\boldsymbol{\phi}_{rr,0m} = diag([\phi_{rr,0m}^{g(1)}, \phi_{rr,0m}^{g(2)}, \dots, \phi_{rr,0m}^{g(N)}]), \;\; r \in [f, y]$

$$\mathbf{A}_{yf}^{(0)} = \boldsymbol{\beta}_{yf}^{0} \mathbf{I}_N - \sum_{m=1}^{q} \boldsymbol{\phi}_{yf,0m} \mathbf{W}^{(m)} \tag{23}$$

with $\boldsymbol{\beta}_{yf,0m} = diag([\beta_{yf,0m}^{g(1)}, \beta_{yf,0m}^{g(2)}, \dots, \beta_{yf,0m}^{g(N)}])$ and $\boldsymbol{\phi}_{yf,0m} = diag([\phi_{yf,0m}^{g(1)}, \phi_{yf,0m}^{g(2)}, \dots, \phi_{yf,0m}^{g(N)}])$

$$\mathbf{A}_{rs}^{(h)} = \beta_{rs}^{h} \mathbf{I}_N - \sum_{m=1}^{q} \boldsymbol{\phi}_{rs,hm} \mathbf{W}^{(m)} \tag{24}$$

with $\boldsymbol{\beta}_{rs,hm} = diag([\beta_{rs,hm}^{g(1)}, \beta_{rs,hm}^{g(2)}, \dots, \beta_{rs,hm}^{g(N)}])$ and $\boldsymbol{\phi}_{rs,hm} = diag([\phi_{rs,hm}^{g(1)}, \phi_{rs,hm}^{g(2)}, \dots, \phi_{rs,hm}^{g(N)}])$, $h = 1, \dots, p; \;\; r, s \in [f, y]$.

According to this specification, the values of the model coefficients are allowed to vary between different groups of regions, while being forced to remain constant for regions belonging to the same group. Based on the Wold representation of the SpVAR model, the following expression for the group-specific outward-STIR function can be immediately derived:

$$\eta_{rs}^{l}(h, m) = N_{G_l}^{-1} \sum_{i \in G_l} \sum_{j=1}^{N} w_{ij}^{(m)} \psi_{rs}^{(h)}(i, j) \,, \;\; r, s \in [f, y] \tag{25}$$

where G_l is the set of the indices associated with the regions belonging to the l-th group, and N_{G_l} is the number of regions in the G_l group ($l = 1,2,\dots,M$).

Tables 3 and 4 report the GDP space-time multipliers of SF expenditure obtained for the above-mentioned sample groupings. We first group together all the lagging regions (i.e. the regions belonging to the Convergence group—the former Objective 1 regions—plus the regions located in countries supported by the CF) and compare them with the remaining regions. Within-region dynamic multipliers are positive for both groups but are only significant for the lagging regions (see row (2) in Table 3). The multiplier of the lagging regions more than doubles two years after the shock, at about 3.2, and stabilises at a value slightly below 2.9. Spatial spillover effects are weak and not significant for both groups (see row (2) in Table 4). They are positive for the lagging regions and negative for the remaining regions.

To sort out which of the two factors - belonging to the Convergence or to the CF countries' group of regions - is more relevant in driving the size of the dynamic multipliers, we re-estimated the model, partitioning the sample in three subsets: CF countries' regions, Convergence regions not included in CF countries, and other regions. Table 3 (row (3)) provides evidence of sizeable within-region effects of SFs both in the CF countries' and the Convergence regions, but the long-run multiplier is much higher and more significant for the first group compared to the second (3.6 vs. 1.6). As expected, when splitting the sample of lagging regions in two different groups, the efficiency of the estimates decreases (as witnessed by the larger standard errors of row (3) vis-à-vis those of row (2)).[16] No significant GDP multipliers emerge in the other regions. Spillover effects from Table 4 are positive and significant for the CF countries' regions (the long-run multiplier is equal to 0.6). Negative, but not significant, estimates are obtained for the two remaining groups of regions.

As a final partition, we split regions according to the size of the resident population. Two separate groups are created, separating regions with population below and above the sample median.

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[16] Unit standard error (68%) confidence bands were first adopted in Sims and Zha (1999) and then customarily utilised in the VAR literature.

Table 3 (row (4)) shows that for both groups the long-run multiplier is positive and significant, although a larger value is obtained, as expected, for regions with a larger population (3.7 vs. 2.2). Table 4 shows spillover effects of equal positive sign and similar size for the two regional groups. Consequently, the ratio of the between-region to the within-region multiplier is much higher for the smaller regions, which are expected to be less able to retain within their own boundaries the policy effects.

Summing up, the above results validate the existence of important heterogeneity in the responses of regional GDP per capita to an exogenous SF shock. In accordance with the arguments made at the outset of this section, within-region multipliers are higher, as expected, in regions with a larger population and lower GDP per capita. These regions are likely to have more unemployed resources and a higher propensity to consume. Neoclassical growth theory also suggests that the marginal returns from investment in both public and private capital are higher in these regions. These different multiplier values are also consistent with the role expected from support to business and competitiveness in relatively disadvantaged regions (Pellegrini et al., 2013; Fratesi and Perucca, 2019; Bachtrögler et al., 2020) and from expenditures in transportation and communication (Pereira and Roca-Sagales, 1999; Leduc and Wilson, 2013). The latter expenditures are likely to be considerably higher in regions belonging to CF countries.

Spillover effects are significant and positive for regions belonging to CF countries and for both larger and smaller regions. Spillovers are negative (albeit not significant) in regions not belonging to CF countries. This evidence suggests that expenditures in transportation and communication, supported by the CF, might play a key role in the determination of positive spatial spillovers. On the other hand, one can surmise that subsidies to business and competitiveness, which are the mainstay of SFs outside the CF countries, may entail negative externalities (crowding-out effects) on neighbouring regions over and above the positive spillovers predicted by theoretical models.

6. Robustness checks

6.1 Extended VAR model specification

In this section, we extend the SpVAR specification, gauging the sensitivity of the identification of local structural shocks to SFs to the range of variables included in the VAR system. At the same time, the extended model specification allows us to present some additional results on the dynamic responses of gross fixed capital formation (for short, investment) to an SF shock. A three-variable model is considered for this purpose, by adding investment per capita to the baseline model (this variable was winsorised, using the 1st and 99th percentiles as threshold values). A block-recursive system is also assumed for this model, the main identifying hypothesis remaining the delayed response of SF to shocks affecting both GDP and investment. GDP, as the most endogenous variable, is ordered last in the system; investment, a variable widely believed to lead GDP, is ordered second; and SF is ordered first. Note that, as our main aim is to identify SF shocks, the only crucial assumption is that SFs do not react to current GDP and investment shocks, which, in a regional setup, seems appropriate for annual data. The same lag orders (two in time and one in space) were assumed as in the baseline specification and the model was subsequently estimated by the FIML method.

The GDP and investment within-region multipliers are reported in Table 5. The overall pattern of the full-sample GDP multiplier (row 1)) is very close to one obtained under the baseline SpVAR specification, with an insignificantly larger long-run multiplier (2.9 vs. 2.6). The impact response of investment to SF is positive but rather small. The dynamic response peaks two years after the shock and then sets back slightly, stabilising after about five years at its highly significant long-run level (slightly below 1.0). This dynamic pattern rules out the hypothesis that an SF shock simply induces an intertemporal substitution of capital outlays, with an initial increase of the expenditure, matched by a corresponding decrease in subsequent years.

The full-sample GDP between-region multipliers, reported in row (1) of Table 6, indicate the existence of positive and significant spillovers very similar to those evidenced in Table 4. Significant positive spillovers also show up for investment.

As already done for the baseline model, we checked for the heterogeneity of dynamic multipliers across different groups of regions.

When splitting the sample in lagging and remaining regions, the GDP within-region multipliers of lagging regions (see row (2) of Table 5) follow a dynamic pattern like their counterpart of Table 3 but reach a higher long-value (3.2 vs. 2.9). They are not significant in the remaining regions. The investment multipliers replicate the results of row (1). The GDP between-region multipliers, reported in row (2) of Table 6, are similar to those from Table 4. However, they are now marginally significant in the lagging regions. Positive and marginally significant spillovers also show up for the investment multipliers, with lower values in the lagging regions.

The results regarding the three-group classification in CF countries' regions, Convergence regions not in CF countries, and oher regions are given in row (3) of Tables 5 and 6. The GDP within-region multipliers are close to those found in Table 3, with a higher long-run GDP multiplier for CF regions. However, they fall short of significance in Convergence regions not in CF countries. The long-run multiplier of investment is also not significant (and low) in these regions. On the other hand, a positive and significant long-run multiplier is estimated for investment in the CF countries' regions and in the (more advanced) remaining regions. The latter show higher long-run values (above 1.4). In Table 6, the GDP spillovers are positive and significant in the CF countries' regions and negative (but not significant) otherwise. Significant positive spillover effects on investment are found, on the other hand, only for the more advanced regions.

When regions are split in larger and smaller ones, the results are very similar to those in Table 3 for within-region GDP multipliers (in the long run, 3.9 for the larger regions vs. 2.5 for the smaller regions, see row (4) in Table 5). The within-region investment multipliers are mostly the same, close to 1, across the two region groups (see, again, row (4)). Table 6 indicates that spillovers are positive and significant for both GDP and investment. Results are very close across the two regional groups, with investment spillovers weaker than those on GDP (as in row (1)).

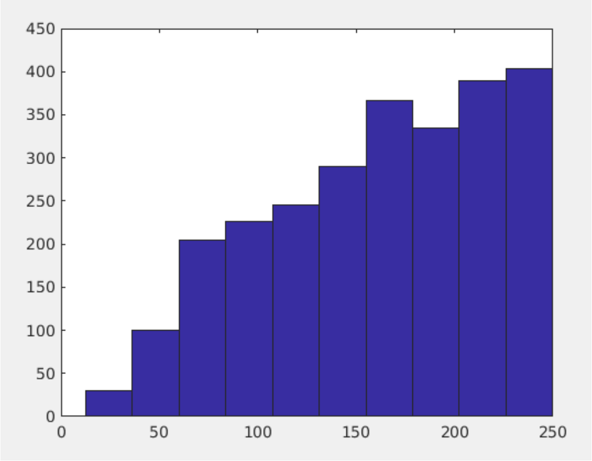
Summing up, the evidence from the three-variable model for GDP multipliers is qualitatively similar to that from the baseline two-variable model. It follows that the considerations made from the economic standpoint at the end of Section 5 apply in this case, too.

6.2 Alternative spatial weighting scheme

In spatial econometrics modelling, estimation results are always conditional on the hypothesis made about the spatial weights matrix connecting the spatial units in the sample. In our SpVAR model, we pursue a flexible approach by allowing for higher-order spatial lags to enter the spatial weights matrix. Nonetheless, to provide a further robustness check, we report here the results obtained when the baseline SpVAR is estimated utilising a different spatial weighting scheme.

A common alternative to the K-nearest neighbour approach implemented in Section 4 is the distance-band approach. In this case, instead of fixing the number of neighbours, the latter are identified as the regions located within a given maximum geographical distance with respect to each given location. For our sample, we choose to fix the distance threshold at 250 km, to allow most of the regions to possess at least one neighbouring region in this range.

Figure 2. The sample distribution of geodetic distances between the centroids of first-order spatial neighbouring regions according to the distance band method (threshold=250 km)



Distance in kilometres

The distribution of distances between first-order spatial neighbours in our regional panel is left-skewed, with a median value of about 168 km and most observations in the distance range close to the threshold. Compared to the four-nearest neighbours' method, the distance-band method with the 250-km threshold identifies, as first-order spatial neighbours, regions that are separated by a larger distance (see Figure 2). Moreover, a much larger number of regions are classified as first-order neighbours, the mean and median values of directly connected regions being equal to 14.2 and 11, respectively. More than two thirds of the first-order neighbours according to the distance-band method would be classified as higher-order spatial connections according to the 4-nearest neighbours' method.

Tables 7 and 8 show the results respectively for the within-region and spillover effects (at spatial lag = 1) for the two-variable SpVAR model utilising distance-band spatial weights. The within-region multipliers from Table 7 are close to the baseline multipliers from Table 3. On the other hand, some interesting differences emerge from Table 8. Positive spillovers are, in general, much less significant. This is consistent with the evidence from Auerbach et al. (2020), who find positive and significant spillovers only below 50 miles of distance. On the other hand, the negative spillovers already found in Table 4 are now much more significant. These negative spillovers emerge, in particular, outside the CF countries' regions (see row (3) of Table 8). Accordingly, these results are consistent with the hypothesis that the crowding-out effects supposedly associated with support to business and competitiveness (the mainstay of SFs outside the CF countries) predominate over positive externalities at broader spatial ranges.

7. Concluding remarks

In this paper, we estimate the impact of SFs on the GDP per capita of a panel of 183 NUTS-2 level regions from twelve European countries, throughout the 1990–2016 period. At a time when the COVID pandemic has prompted an unprecedented wave of public expenditure across Europe, this analysis acquires a particular policy relevance. We innovate on the literature by analysing the effectiveness of EU cohesion policy through a VAR structural spatial model. The implementation of a dynamic structural simultaneous equations approach allows us to address the likely existence of reverse causation between the outcome and policy variables. Moreover, we deal with unobserved confounding factors by including a rich menu of deterministic controls in the model (region-specific deterministic time trends, year fixed effects, and country-specific fixed effects interacted with year fixed effects). Since we report the policy effects in terms of dynamic multipliers, our evidence also relates to the recent literature on the subnational analysis of fiscal multipliers. Both this literature and the literature on the EU cohesion policy stress the role of heterogeneity in the effectiveness of policy. Subsequently, we consider several partitions of our sample, selected according to some structural features of the regions (stage of development, EU funding regimes, size, etc.) deemed relevant. We attach particular importance to stage of development and EU funding regimes (CF countries, Objective 1—more recently Convergence—regions), as this type of partition is grounded in economic theory (also relating to various growth models) and in the results of a multi-regional DSGE model (Crucitti et al., 2021).

Our baseline specification is a two-variable VAR system, including an equation for GDP per capita and an equation for SFs (also divided by total population). As a wide literature stresses the importance of spatial spillovers in the measurement of fiscal impulses, we estimate both within-region and between-region multipliers. The latter are based on spatial linkages identified through the K-nearest neighbours' approach. As for robustness checks, we first extend the VAR system by including, beside GDP and SFs, gross fixed capital formation. Secondly, we adopt the distance-band approach as an alternative weighting scheme for the spatial interaction terms.

Our main evidence, largely validated in qualitative terms by the robustness checks, can be summed up as follows. The dynamic multipliers measuring the local response of GDP to an exogenous shock in local SF expenditure are positive, sizeable, and significant, both in the short and long term. The values obtained (with a long-term value settling at 2.6 after ten years) are in line with the values predicted on average for the EU regions by the multi-regional dynamic general equilibrium model of Crucitti et al. (2021) and are compatible with the findings of the literature on local multipliers, available especially for the US. Spillover effects for GDP from an exogenous shock to SFs are also positive and statistically significant at all time horizons. These effects are about one fifth of the within-region multipliers. Nonetheless, they are positive and sizeable, in line with the predictions of the reference multi-regional DSGE model.

The results for the partitioned samples unveil important group-related differences in the responses of regional GDP per capita to an exogenous SF shock. In accordance with a priori expectations, within-region multipliers are higher in regions with a larger population and in lagging regions. Indeed, these regions are likely to have more unemployed resources and a higher propensity to consume. In CF countries, they are also likely to benefit particularly from SF expenditures geared towards infrastructure in transport and communication, as well as by higher marginal returns from investment. Spatial spillovers are considerably heterogenous across different groups of regions, turning out to be negative in regions not belonging to CF countries. In these regions, support to business and competitiveness, which are the mainstay of SFs outside the CF countries, could have negative externalities for the neighbouring regions, overwhelming the positive spillover effects predicted by theoretical models. This may explain why the empirical literature, working with different regions' samples, finds diversified results about the existence of spatial spillovers.

It is appropriate to note at this stage some limits of the analysis. The VAR setup imposes severe constraints to further exploration of the heterogeneity of multipliers for groups of countries or periods. For instance, application of the spatial VAR models to single countries is not likely to provide reliable evidence, due to the influence of sample size on the efficiency of the estimates (a problem that emerged in the analysis for the Convergence regions not belonging to CF countries). Furthermore, the size of our sample over time (27 years) prevents the assessment of structural breaks (e.g. before and after the Great Recession) in the relationships under scrutiny.

At any rate, our evidence indicates that a downsizing of the EU cohesion policy could have severe consequences for the level of economic activity, especially in the less developed regions of the EU. Indeed, in the more advanced regions, where within-region multipliers are low and not significant, the CF and the ERDF are less relevant policy tools. They both acquire high relevance in the regions of CF countries, where multipliers are more significant. Matters are less clear in the Convergence regions not belonging to CF countries. In this case, we get relatively low (but still above unity) and imprecisely estimated multipliers. Due to the relatively small number of regions in this subsample, further research on this matter is likely to be useful.

More generally, future work could focus on two (not mutually exclusive) points. First, we intend to assess the role of a set of structural factors that are best considered jointly (capital endowment, quality of institutions, and industrial structure) on the size and significance of the dynamic multipliers. To do so, it may prove necessary to construct region-specific measures of the multipliers and relate them to a given set of potential determinants through some form of multivariate regression. Given the length of the time series available for each region, this is likely to require the extension of the Bayesian VAR framework utilised in Destefanis et al. (2022) to cover the case of interregional spillovers. Secondly, an interesting and relatively easy extension of the research framework here proposed relates to the split of GDP per capita into its two components: GDP per employee (a rough measure of productivity) and rate of employment. In this manner, it will be possible to shed light on the influence of SFs on these two very important policy outcomes, which sometimes may turn out to be substitute, rather than complementary, goals.

References

Acconcia A., Corsetti G., Simonelli S. (2014). Mafia and public spending: Evidence on the fiscal multiplier from a quasi-experiment. *American Economic Review*, 104(7), 2185-2209.

Alcidi, C., Määttänen, N., Thirion, G. (2015). Cross-Country Spillover Effects and Fiscal Policy Coordination in EMU, FIRSTRUN - Fiscal Rules and Strategies under Externalities and Uncertainties, Horizon 2020 Framework Programme of the European Union.

Anselin L., Smirnov O. (1996). Efficient Algorithms for Constructing Proper Higher Order Spatial Lag Operators. *Journal of Regional Science* 36(1), 67-89.

Anselin L. (2003). Spatial Externalities, Spatial Multipliers and Spatial Econometrics, *International Regional Science Review*, 26(2), 153-166.

Antunes M., Viegas M., Varum C., Pinho C., 2020. The Impact of Structural Funds on Regional Growth: A Panel Data Spatial Analysis, *Intereconomics*, 5, 312–319.

Auerbach A.J., Gorodnichenko Y. (2012). Fiscal Multipliers in Recession and Expansion, NBER Chapters, in: Fiscal Policy after the Financial Crisis, 63-98, National Bureau of Economic Research, Inc.

Auerbach, A.J., Gorodnichenko, Y., Murphy, D. (2020). Local Fiscal Multipliers and Fiscal Spillovers in the USA. *IMF Economic Review*, 68(1), 195-229.

Bachtrögler, J., Fratesi, U., Perucca, G., 2020. The influence of the local context on the implementation and impact of EU cohesion policy. *Regional Studies*, 54(1), 21-34.

Baxter, M., King, R. (1993). Fiscal policy in general equilibrium. *American Economic Review*, 83(3), 315-33.

Becker S. O., Egger P. H., Von Ehrlich M. (2010). Going NUTS: The effect of EU Structural Funds on regional performance, *Journal of Public Economics*, n. 94(9-10), 578-590.

Becker S.O., Egger P.H., Von Ehrlich M. (2012). Too Much of a Good Thing? On the growth effects of the EU's regional policy, *European Economic Review*, 56(4), 648-668.

Becker S.O., Egger P.H., Von Ehrlich M. (2013). Absorptive capacity and the growth and investment effects of regional transfers: a regression discontinuity design with heterogeneous treatment effects, *American Economic Journal: Economic Policy*, 5(4), 29-77.

Becker S.O., Egger P.H., Von Ehrlich M. (2018). Effects of EU Regional Policy: 1989-2013, *Regional Science and Urban Economics*, 69(C), 143-152.

Beenstock, M., Felsenstein D. (2007), Spatial Vector Autoregressions, *Spatial Economic Analysis*, 2(2), 167-196.

Beugelsdijk M., Eijffinger S.C.W. (2005), The Effectiveness of Structural Policy in the European Union: An Empirical Analysis for the EU-15 in 1995-2001, *Journal of Common Market Studies*, 43(1), 37-51.

Bouayad Agha S., Turpin N., Vedrine L. (2011), Fostering the development of European regions: a spatial dynamic panel data analysis of the impact of cohesion policy. *Regional Studies*, 47(9), 1-21.

Busetti F., Giorgiantonio C., Ivaldi G., Mocetti S., Notarpietro A., Tommasino P. (2019). Capitale e investimenti pubblici in Italia: effetti macroeconomici, misurazione e debolezze regolamentari, Banca d'Italia, Questioni di economia e finanza (Occasional Papers), N. 520.

Caldara, D., Kamps, C. (2008). What are the effects of fiscal policy shocks? A VAR-based comparative analysis, No 877, Working Paper Series, European Central Bank.

Cappelen A., Castellacci F., Fagerberg J., Verspagen B. (2003). The Impact of EU Regional Support on Growth and Convergence in the European Union, *Journal of Common Market Studies*, 41(4), 621-644.

Chodorow-Reich, G. (2019). Geographic cross-sectional fiscal spending multipliers: What have we learned? *American Economic Journal: Economic Policy*, 11(2), 1-34.

Coenen, G., Straub, R., Trabandt, M. (2012). Fiscal policy and the great recession in the euro area. *American Economic Review*, 102(3), 71-76.

Crescenzi R., Giua M. (2020). One or many Cohesion Policies of the European Union? On the differential economic impacts of Cohesion Policy across member states, Regional Studies 54(1), 10-20.

Crucitti, F., Lazarou, N.J., Monfort, P., and Salotti, S. (2021). Where does the EU cohesion policy produce its benefits? A model analysis of the international spillovers generated by the policy. *Economic Systems*, forthcoming.

Cwik, T., Wieland, V. (2011). Keynesian government spending multipliers and spillovers in the euro area. *Economic Policy*, 26(67), 493-549.

Dall'erba S., Le Gallo J. (2008). Regional convergence and the impact of European structural funds over 1989-1999: A spatial econometric analysis, Papers in Regional Science, 87(2), 219-244.

Deleidi, M., Iafrate, F., Levrero, E.S. (2020). Public investment fiscal multipliers: An empirical assessment for European countries, *Structural Change and Economic Dynamics*, 52(C), 354-365.

Deleidi, M., Romaniello, D., Tosi, F. (2021). Quantifying fiscal multipliers in Italy: A Panel SVAR analysis using regional data, *Papers in Regional Science*, 100(5), 1158-1177.

Destefanis S., Di Serio M., Fragetta M., 2022. Regional multipliers across the Italian regions, *Journal of Regional Science*, 62(4), 1179-1205.

Di Caro P., Fratesi U. (2021). One policy, different effects: Estimating the region-specific impacts of EU cohesion policy, *Journal of Regional Science*, 62(1), 307-330.

Di Giacinto, V. (2003). Differential Regional Effects of Monetary Policy: A Geographical SVAR Approach, *International Regional Science Review*, 26(3), 313-341.

Di Giacinto, V. (2006). A generalized Space-Time ARMA Model, with an Application to Regional Unemployment Analysis in Italy, *International Regional Science Review*, 29(2), 159-198.

Di Giacinto, V. (2010). On Vector Autoregressive Modeling in Space and Time, *Journal of Geographical Systems*, 12(1), 125-154.

Di Giacinto, V., Micucci, G., Montanaro, P. (2010). Dynamic Macroeconomic Effects of Public Capital: Evidence from Regional Italian Data, *Giornale degli Economisti e Annali di Economia*, Nuova Serie, 69(1), 29-66.

Ercolani, V. (2021). The macroeconomic impact of infrastructure investment: a review of channels, Banca d'Italia, Questioni di economia e finanza (Occasional Papers), N. 613.

Esposti R., Bussoletti S. (2008). The Impact of Objective 1 Funds on Regional Growth Convergence in the EU A panel-data approach, *Regional Studies*, 42(2), 159-173.

Faggian, A., Biagi, B. (2003). Measuring Regional Multipliers: A Comparison between Two Different Methodologies for the Case Of The Italian Regions. *Scienze Regionali: Italian Journal of Regional Science*, 1(2), 33-51.

Fiaschi D., Lavezzi A.M., Parenti A. (2018) Does EU cohesion policy work? Theory and evidence. *Journal of Regional Science*, 58, 386-423.

Fratesi U., Perucca G. (2014). Territorial Capital and the Effectiveness of Cohesion Policies: An Assessment for CEE Regions, *Investigaciones Regionales*, 29, 165-191.

Fratesi U., Perucca G. (2019). EU regional development policy and territorial capital: A systemic approach. *Papers in Regional Science*, 98(1), 265-281.

Giua M. (2017). Spatial Discontinuity for The Impact Assessment of the EU Regional Policy: The Case of Italian Objective 1 Regions, *Journal of Regional Science*, 57(1), 109-131.

Gordon R., Krenn R. (2010). The End of the Great Depression 1939-41: Policy Contributions and Fiscal Multipliers. NBER Working Papers No. 16380.

Kamps, C. (2005). The Dynamic Effects of Public Capital: VAR Evidence for 22 OECD Countries, *International Tax and Public Finance*, 12, 533-58.

Leduc, S., Wilson D. (2013). Roads to Prosperity or Bridges to Nowhere? Theory and Evidence on the Impact of Public Infrastructure Investment. In NBER Macroeconomics Annual 2012, Vol. 27, D. Acemoglu, J. Parker, and M. Woodford (eds), 89-142. Chicago: University of Chicago Press.

Leeper, E. M., Walker, T. B., Yang, S. C. S. (2010). Government investment and fiscal stimulus. *Journal of Monetary Economics*, 57(8), 1000-1012.

Le Gallo J., Dall'erba S., Guillan R. (2011). The Local versus Global Dilemma of the Effects of Structural Funds, Growth and Change, 42(4), 466-490.

LeSage, J.P. (1999). The Theory and Practice of Spatial Econometrics, mimeo, available at http://www.spatial-econometrics.com.

Lopez Rodriguez J., Faiña A., 2014, Rhomolo and other methodologies to assess the European Cohesion Policy, *Investigaciones Regionales*, 29, 5-13.

Lütkepohl, H. (2007). New Introduction to Multiple Time Series Analysis. Berlin: Springer-Verlag.

Mineshima, A., Poplawski-Ribeiro, M., Weber, A. (2015). Size of Fiscal Multipliers. In *Post-crisis Fiscal Policy* (315-372). MIT Press.

Mohl P., Hagen T. (2010). Do EU structural funds promote regional growth? New evidence from various panel data approaches. Regional Science and Urban Economics 40(2010) 353-365.

Márquez, M.A., Ramajo, J., Hewings, G.J.D. (2015). Regional growth and spatial spillovers: Evidence from an SpVAR for the Spanish regions, *Papers in Regional Science*, 94(S1), 1-18.

Pedroni, P. (2004). Panel Cointegration: Asymptotic and Finite Sample Properties of Pooled Time Series Tests with an Application to the PPP Hypothesis. *Econometric Theory*, 20(3), 597-625.

Pellegrini, G., Busillo, F., Muccigrosso, T., Tarola, O., Terribile, F. (2013). Measuring the Impact of the European Regional Policy on Economic Growth: a Regression Discontinuity Design Approach, *Papers in Regional Science*, 92(1), 217-233.

Percoco M., 2017, Impact of European Cohesion Policy on regional growth: does local economic structure matter?, Regional Studies, 51(6), 833-843.

Pereira, A., de Fatima Pinho, M. (2011). Public Investment, Economic Performance and Budgetary Consolidation: Var Evidence for the First 12 Euro Countries, *Journal of Economic Development*, 36(1), 1-20.

Pereira, A.M., Roca-Sagalés O. (1999). Public capital formation and regional development in Spain, *Review of Development Economics*, 3(3), 281-294.

Pesaran, M.H. (2007). A simple panel unit root test in the presence of cross-section dependence, Journal of applied Econometrics, 22(2), 265-312.

Pfeiffer Ph., Varga J., in ‘t Veld J., 2021, Quantifying Spillovers of Next Generation EU Investment, European Economy DP 144 | July, European Commission Directorate-General for Economic and Financial Affairs.

Ramajo, J., Márquez, M.A., Hewings, G.J.D. (2017). Spatiotemporal Analysis of Regional Systems: A Multiregional Spatial Vector Autoregressive Model for Spain, *International Regional Science Review*, 40(1), 75-96.

Ramey V. A., Zubairy S. (2018). Government spending multipliers in good times and in bad: Evidence from US historical data. *Journal of Political Economy*, 126(2), 850-901.

Rodriguez-Pose A., Fratesi U. (2004). Between Development and Social Policies: The Impact of European Structural Funds in Objective 1 Regions, *Regional Studies*, 38(1), 97-113.

Rodriguez-Pose A., Novak K. (2013). Learning processes and economic returns in European Cohesion policy, *Investigaciones Regionales*, 25, 7-26

Rodríguez-Pose, A., Garcilazo, E. (2015). Quality of government and the returns of investment: Examining the impact of cohesion expenditure in European regions. *Regional Studies*, 49(8), 1274- 1290.

Römisch, R. (2020). Estimating Demand Spillovers of EU Cohesion Policy Using European Regional Input-Output Tables, wiiw Working Papers 184, The Vienna Institute for International Economic Studies.

Sims C. A., Zha T. (1999). Error Bands for Impulse Response Functions. *Econometrica*, 67(5), 1113-1155.

Tondl G. (2004). EU Regional Policy, in Van der Hoek M.P. (a cura di), *Handbook of Public Administration and Public Policy in the European Union*, Taylor & Francis, New York. 810-844

Tables

Table 1. Panel unit roots and cointegration test results (*p*-values in brackets)

Variables	Unit roots		Cointegration		
	Pesaran CADF t-bar (1)		Kao ADF t (2)	Pedroni group ADF t (2)	
	(no trend included)	(deterministic trends included)	(no trend included)	(no trend included)	(deterministic trends included)
GDP p.c.	-1.838 (0.137)	-2.210 (0.945)			
SF p.c.	-1.677 (0.875)	-2.076 (1.000)			
GDP p.c.– SF p.c.			-1.464 (0.072)	5.752 (0.000)	5.856 (0.000)

NB: The Newey-West long-run variance estimator is employed, assuming a Bartlett window. Individual ADF lag orders are selected according to BIC (max lag=2). – (2) The Newey-West long-run variance estimator is employed, assuming a Bartlett window. Individual ADF lag orders are set equal to 2.

Table 2. Baseline SpVAR (2, 1) model: estimation results (*p-values in brackets*)

Explanatory variables	Lag orders		Model coefficient (2)	SF expenditure p.c. equation	Model coefficient (2)	GDP p.c. equation
	Time	Space				
SF exp. p.c.	0	0		–	β_{yf}^{0}	1.196 (0.000)***
	0	1	$\phi_{ff,01}$	0.284 (0.000)***'	$\phi_{yf,01}$	0.454 (0.484)
	1	0	β_{ff}^{1}	-0.282 (0.000)***'	β_{yf}^{1}	1.098 (0.001)***
	1	1	$\phi_{ff,11}$	0.041 (0.017)**	$\phi_{yf,11}$	1.149 (0.080)*
	2	0	β_{ff}^{2}	-0.198 (0.000)***'	β_{yf}^{2}	0.359 (0.283)
	2	1	$\phi_{ff,21}$	0.090 (0.000)***'	$\phi_{yf,21}$	-0.438 (0.500)
GDP p.c.	0	0		–		
	0	1		–	$\phi_{yy,01}$	0.094 (0.000)***
	1	0	β_{fy}^{1}	0.000 (0.173)	β_{yf}^{1}	-0.041 (0.006)***
	1	1	$\phi_{fy,11}$	0.000 (0.171)	$\phi_{yy,11}$	0.047 (0.026)**
	2	0	β_{fy}^{2}	-0.000 (0.246)	β_{yf}^{2}	-0.028 (0.060)*
	2	1	$\phi_{fy,21}$	-0.001 (0.020)**	$\phi_{yy,21}$	0.009 (0.660)
Observations				4.209		4.209
Pseudo R-squared				0.067		0.146
LR test of the joint significance of spatial effects:						
$H_0: \phi_{ff,01} = \phi_{ff,11} = \phi_{ff,21} = \phi_{fy,11} = \phi_{fy,21} = 0$				$\chi^2(5)$ =28.797 (0.000)		
$H_0: \phi_{yf,01} = \phi_{yf,11} = \phi_{yf,21} = \phi_{yy,01} = \phi_{yy,11} = \phi_{yy,21} = 0$						$\chi^2(6)$ =18.462 (0.005)

NB: All specifications include a full set of regional dummies and separate time dummies for the regions of any single country (apart from Luxembourg, that is pooled together with the regions of Netherlands, as in this case the national sample includes only one area). Different error variances are allowed for each region. – (2) See equations (6-8). ***, ** and * denote significance at the 1, 5 and 10 percent level, respectively.

Table 3. Cumulative GDP multipliers at spatial lag=0 (within region) from the baseline SpVAR specification. Full-sample and group-heterogeneous results (*standard errors in brackets*)

Regional partition	Time horizon							
	0	1	2	3	4	5	10	20
(1)								
Full sample	1.244**	2.870**	3.038**	2.487**	2.584**	2.656**	2.620**	2.621**
	(0.344)	(0.735)	(0.511)	(0.577)	(0.553)	(0.561)	(0.559)	(0.559)
(2)								
Lagging regions	1.188**	2.753**	3.255**	2.787**	2.808**	2.878**	2.860**	2.861**
	(0.310)	(0.664)	(0.969)	(0.703)	(0.675)	(0.723)	(0.712)	(0.712)
Remaining regions	0.344	0.344	0.349	0.509	0.547	0.550	0.541	0.542
	(1.308)	(2.425)	(3.187)	(1.937)	(2.050)	(2.272)	(2.154)	(2.158)
(3)								
CF countries' regions	1.488**	3.025**	3.918**	3.579**	3.533**	3.610**	3.605**	3.605**
	(0.392)	(0.726)	(1.107)	(0.897)	(0.847)	(0.892)	(0.886)	(0.886)
Convergence regions not in CF countries	0.510	2.075*	1.796	1.448*	1.619*	1.654*	1.616*	1.617*
	(0.671)	1.627)	(2.200)	(1.408)	(1.417)	(1.582)	(1.513)	(1.516)
Further regions	0.343	1.281	0.335	0.509	0.527	0.541	0.530	0.531
	(1.309)	(2.436)	(3.188)	(1.944)	(2.060)	(2.279)	(2.162)	(2.166)
(4)								
Regions with larger population size	1.571**	4.053**	4.211**	3.443**	3.605**	3.700**	3.647**	3.648**
	(0.498)	(0.866)	(1.167)	(0.787)	(0.790)	(0.863)	(0.834)	(0.834)
Regions with smaller population size	1.130**	2.241**	2.839**	2.140**	2.146**	2.296**	2.243**	2.244**
	(0.471)	(0.819)	(1.290)	(0.749)	(0.713)	(0.835)	(0.790)	(0.791)

NB: * and ** denote significance according to 68% and 90% confidence intervals, respectively.

Table 4. Cumulative GDP multipliers at spatial lag=1 (spillovers) from the baseline SpVAR specifications. Full-sample and group-heterogeneous results (*standard errors in brackets*)

Regional partition	Time horizon							
	0	1	2	3	4	5	10	20
(1)								
Full sample	0.208**	0.704**	0.507**	0.462**	0.509**	0.502**	0.499**	0.499**
	(0.138)	(0.264)	(0.191)	(0.213)	(0.204)	(0.207)	(0.207)	(0.207)
(2)								
Lagging regions	0.078	0.411**	0.286	0.259	0.260	0.263	0.264	0.264
	(0.133)	(0.244)	(0.403)	(0.287)	(0.265)	(0.287)	(0.284)	(0.284)
Remaining regions	-0.089	0.190	-0.889	-0.398	-0.360	-0.446	-0.422	-0.423
	(0.300)	(0.596)	(0.938)	(0.548)	(0.566)	(0.633)	(0.603)	(0.604)
(3)								
CF countries' regions	0.223**	0.539**	0.670*	0.604**	0.592**	0.599**	0.598**	0.598**
	(0.138)	(0.284)	(0.482)	(0.406)	(0.374)	(0.393)	(0.392)	(0.392)
Convergence regions not in CF countries	-0.239	0.032	-0.589	-0.324	-0.315	-0.350	-0.340	-0.341
	(0.247)	(0.472)	(0.735)	(0.430)	(0.439)	(0.494)	(0.472)	(0.473)
Further regions	-0.144	0.113	-1.004	-0.485	-0.459	-0.544	-0.519	-0.520
	(0.299)	(0.608)	(0.950)	(0.555)	(0.574)	(0.642)	(0.612)	(0.613)
(4)								
Regions with larger population size	0.331**	1.057**	0.842**	0.734**	0.793**	0.796**	0.788**	0.788**
	(0.143)	(0.295)	(0.378)	(0.269)	(0.270)	(0.290)	(0.282)	(0.283)
Regions with smaller population size	0.298**	0.937**	0.869**	0.660**	0.728**	0.756**	0.735**	0.736**
	(0.133)	(0.263)	(0.381)	(0.253)	(0.244)	(0.272)	(0.263)	(0.263)

NB: * and ** denote significance according to 68% and 90% confidence intervals, respectively.

Table 5. Cumulative GDP and fixed capital investment multipliers at spatial lag=0 (within region) from the three-equation SpVAR specification. Full-sample and group-heterogeneous results (*standard errors in brackets*)

Regional partition	Time horizon							
	0	1	2	3	4	5	10	20
(1)								
Full sample								
GDP response	1.237**	3.152**	3.485**	2.769**	2.877**	2.974**	2.929**	2.929**
	(0.298)	(0.711)	(0.477)	(0.544)	(0.520)	(0.527)	(0.525)	(0.525)
Investment response	0.257**	1.105**	1.195**	0.860**	0.934**	0.975**	0.951**	0.952**
	(0.198)	(0.395)	(0.239)	(0.297)	(0.270)	(0.280)	(0.277)	(0.277)
(2)								
Lagging regions								
GDP response	1.172**	2.954**	3.735**	3.153**	3.148**	3.238**	3.220**	3.220**
	(0.477)	(1.105)	(1.382)	(0.692)	(0.834)	(0.954)	(0.863)	(0.866)
Investment response	0.156	0.797**	0.987**	0.796**	0.803**	0.828**	0.821**	0.821**
	(0.234)	(0.383)	(0.572)	(0.390)	(0.364)	(0.404)	(0.394)	(0.395)
Remaining regions								
GDP response	0.310	1.487	0.652	0.638	0.692	0.732	0.708	0.708
	(1.157)	(2.381)	(3.221)	(1.941)	(2.031)	(2.278)	(2.157)	(2.161)
Investment response	0.415*	1.780**	2.006**	1.183**	1.380**	1.525**	1.435**	1.437**
	(0.365)	(0.753)	(1.104)	(0.814)	(0.787)	(0.841)	(0.828)	(0.828)
(3)								
CF countries' regions								
GDP response	1.581**	3.343**	4.690**	4.261**	4.164**	4.257**	4.251**	4.251**
	(0.363)	(0.711)	(1.067)	(0.905)	(0.860)	(0.885)	(0.882)	(0.882)
Investment response	0.322*	0.822**	1.087**	1.008**	1.012**	1.027**	1.020**	1.020**
	(0.282)	(0.488)	(0.739)	(0.560)	(0.516)	(0.557)	(0.551)	(0.551)
Convergence regions not in CF countries								
GDP response	0.438	1.962**	1.670	1.339	1.508*	1.555	1.509	1.511
	(0.801)	(0.570)	(2.254)	(1.463)	(1.481)	(1.634)	(1.570)	(1.572)
Investment response	-0.006	0.817	0.775	0.570	0.602	0.654	0.629	0.630
	(0.396)	(0.819)	(1.137)	(0.690)	(0.709)	(0.800)	(0.755)	(0.757)
Further regions								
GDP response	0.310	1.4842	0.6323	0.6326	0.6648	0.7158	0.690	0.691
	(1.154)	(2.399)	(3.153)	(1.880)	(2.014)	(2.257)	(2.127)	(2.132)
Investment response	0.417	1.788**	2.000**	1.193**	1.383**	1.527**	1.439**	1.441**
	(0.463)	(0.917)	(1.201)	(0.596)	(0.708)	(0.813)	(0.733)	(0.736)
(4)								
Regions with larger population size								
GDP response	1.509**	4.182**	4.710**	3.697**	3.846**	3.992**	3.923**	3.924**
	(0.445)	(0.813)	(1.187)	(0.795)	(0.783)	(0.860)	(0.832)	(0.833)
Investment response	-0.046	1.125**	1.087**	0.743**	0.845**	0.879**	0.854**	0.854**
	(0.239)	(0.462)	(0.616)	(0.369)	(0.388)	(0.431)	(0.408)	(0.409)
Regions with smaller population size								
GDP response	1.161**	2.555**	3.220**	2.362**	2.388**	2.570**	2.503**	2.505**
	(0.527)	(0.985)	(1.264)	(0.805)	(0.825)	(0.909)	(0.868)	(0.869)
Investment response	0.568**	0.881**	1.526**	1.043**	0.960**	1.106**	1.067**	1.068**
	(0.319)	(0.478)	(0.815)	(0.404)	(0.400)	(0.499)	(0.450)	(0.452)

NB: * and ** denote significance according to 68% and 90% confidence intervals, respectively.

Table 6. Cumulative GDP and fixed capital investment multipliers at spatial lag=1 (spillovers) from the three-equation SpVAR specification. Full-sample and group-heterogeneous results (*standard errors in brackets*)

Regional partition	Time horizon							
	0	1	2	3	4	5	10	20
(1)								
Full sample								
GDP response	0.188**	0.707**	0.451**	0.415**	0.476**	0.463**	0.460**	0.460**
	(0.122)	(0.260)	(0.181)	(0.202)	(0.194)	(0.197)	(0.196)	(0.196)
Investment response	-0.066	0.290**	0.248**	0.144*	0.186**	0.192**	0.184**	0.184**
	(0.074)	(0.134)	(0.086)	(0.102)	(0.094)	(0.097)	(0.096)	(0.096)
(2)								
Lagging regions								
GDP response	0.047	0.401**	0.274*	0.239*	0.236*	0.235*	0.238*	0.238*
	(0.136)	(0.228)	(0.314)	(0.175)	(0.192)	(0.213)	(0.198)	(0.199)
Investment response	-0.076*	0.155*	0.195*	0.139*	0.141*	0.143*	0.143*	0.143*
	(0.069)	(0.132)	(0.193)	(0.135)	(0.130)	(0.140)	(0.137)	(0.137)
Remaining regions								
GDP response	-0.051	0.207	-0.995*	-0.464	-0.400	-0.503	-0.477	-0.478
	(0.317)	(0.571)	(0.889)	(0.526)	(0.541)	(0.604)	(0.577)	(0.578)
Investment response	0.103	0.697**	0.402*	0.308*	0.415*	0.399*	0.389*	0.389*
	(0.141)	(0.292)	(0.390)	(0.285)	(0.279)	(0.297)	(0.292)	(0.292)
(3)								
CF countries’ regions								
GDP response	0.144**	0.508**	0.701**	0.614**	0.583**	0.583**	0.578**	0.578**
	(0.147)	(0.307)	(0.479)	(0.389)	(0.367)	(0.383)	(0.379)	(0.379)
Investment response	-0.117*	-0.014	0.092	0.113	0.106	0.101	0.099	0.099
	(0.092)	(0.178)	(0.278)	(0.211)	(0.197)	(0.209)	(0.206)	(0.206)
Convergence regions not in CF countries								
GDP response	-0.208	-0.072	-0.859*	-0.485	-0.467	-0.520	-0.508	-0.508
	(0.252)	(0.534)	(0.762)	(0.506)	(0.508)	(0.551)	(0.536)	(0.536)
Investment response	-0.014	0.367**	0.122	0.127	0.167	0.162	0.157	0.157
	(0.113)	(0.216)	(0.274)	(0.182)	(0.185)	(0.197)	(0.191)	(0.192)
Further regions								
GDP response	-0.208	-0.072	-0.859	-0.485	-0.467	-0.520	-0.508	-0.508
	(0.292)	(0.654)	(0.931)	(0.559)	(0.600)	(0.659)	(0.628)	(0.629)
Investment response	0.104	0.700**	0.375*	0.304**	0.406**	0.387**	0.380**	0.380**
	(0.142)	(0.264)	(0.327)	(0.179)	(0.211)	(0.229)	(0.212)	(0.213)
(4)								
Regions with larger population size								
GDP response	0.298**	1.073**	0.835**	0.712**	0.787**	0.788**	0.778**	0.778**
	(0.126)	(0.243)	(0.338)	(0.234)	(0.229)	(0.248)	(0.242)	(0.242)
Investment response	-0.060	0.413**	0.448**	0.259**	0.299**	0.328**	0.312**	0.312**
	(0.078)	(0.156)	(0.204)	(0.122)	(0.129)	(0.143)	(0.135)	(0.135)
Regions with smaller population size								
GDP response	0.264**	0.910**	0.816**	0.602**	0.677**	0.707**	0.684**	0.685**
	(0.118)	(0.227)	(0.334)	(0.220)	(0.210)	(0.233)	(0.226)	(0.226)
Investment response	-0.046	0.377**	0.526**	0.262**	0.285**	0.343**	0.318**	0.319**
	(0.079)	(0.150)	(0.217)	(0.116)	(0.123)	(0.143)	(0.132)	(0.132)

NB: * and ** denote significance according to 68% and 90% confidence intervals, respectively.

Table 7. Cumulative GDP multipliers at spatial lag=0 (within region) from SpVAR specification with distance-band spatial weights matrix. Full-sample and group-heterogeneous results (*standard errors in brackets*)

Regional partition	Time horizon							
	0	1	2	3	4	5	10	20
(1)								
Full sample	1.166**	2.679**	2.803**	2.271**	2.396**	2.455**	2.418**	2.419**
	(0.347)	(0.752)	(0.508)	(0.583)	(0.555)	(0.565)	(0.562)	(0.562)
(2)								
Lagging regions	1.170**	2.583**	2.997**	2.522**	2.569**	2.636**	2.612**	2.612**
	(0.320)	(0.644)	(0.923)	(0.923)	(0.669)	(0.640)	(0.675)	(0.675)
Remaining regions	0.535	1.599	1.496	1.175	1.275	1.309	1.283	1.283
	(1.255)	(2.417)	(3.347)	(1.981)	(2.091)	(2.343)	(2.216)	(2.220)
(3)								
CF countries' regions	1.417**	2.869**	3.678**	3.356**	3.334**	3.415**	3.407**	3.407**
	(0.421)	(0.717)	(1.041)	(0.866)	(0.808)	(0.850)	(0.848)	(0.848)
Convergence regions not in CF countries	0.487	1.505	0.753	0.728	1.098	1.019	0.971	0.973
	(0.702)	(1.551)	(2.160)	(1.318)	(1.374)	(1.545)	(1.460)	(1.462)
Further regions	0.530	1.595	1.475	1.164	1.254	1.293	1.266	1.267
	(1.225)	(2.369)	(2.958)	(1.841)	(1.983)	(2.166)	(2.063)	(2.066)
(4)								
Regions with larger population size	1.542**	3.802**	3.791**	3.252**	3.418**	3.449**	3.420**	3.421**
	(0.423)	(0.948)	(1.147)	(0.776)	(0.821)	(0.870)	(0.845)	(0.845)
Regions with smaller population size	1.092**	2.025**	2.715**	2.029**	2.004**	2.160**	2.111**	2.112**
	(0.433)	(0.839)	(1.427)	(0.808)	(0.742)	(0.899)	(0.846)	(0.847)

NB: * and ** denote significance according to 68% and 90% confidence intervals, respectively.

Table 8. Cumulative GDP multipliers at spatial lag=1 (spillovers) from SpVAR specification with distance-band spatial weights matrix. Full-sample and group-heterogeneous results (*standard errors in brackets*)

Regional partition	Time horizon							
	0	1	2	3	4	5	10	20
(1)								
Full sample	0.066	0.244*	0.111	0.102	0.132	0.125	0.124	0.124
	(0.097)	(0.178)	(0.132)	(0.146)	(0.141)	(0.143)	(0.142)	(0.142)
(2)								
Lagging regions	0.050	0.248	0.070	0.068	0.091	0.083	0.083	0.083
	(0.135)	(0.266)	(0.401)	(0.291)	(0.264)	(0.288)	(0.285)	(0.285)
Other regions	-0.178	-0.255	-1.075**	-0.621**	-0.578**	-0.678**	-0.649**	-0.649**
	(0.208)	(0.403)	(0.509)	(0.318)	(0.350)	(0.377)	(0.359)	(0.359)
(3)								
CF countries' regions	0.146	0.297*	0.333	0.332	0.345	0.353	0.353	0.353
	(0.168)	(0.285)	(0.464)	(0.390)	(0.360)	(0.382)	(0.382)	(0.381)
Convergence regions not in CF countries	-0.300	-0.294	-1.192*	-0.790*	-0.647*	-0.742*	-0.750*	-0.749*
	(0.313)	(0.684)	(0.885)	(0.507)	(0.532)	(0.629)	(0.587)	(0.583)
Further regions	-0.198	-0.281	-1.133**	-0.660**	-0.616**	-0.719**	-0.688**	-0.689**
	(0.177)	(0.403)	(0.498)	(0.298)	(0.325)	(0.356)	(0.338)	(0.338)
(4)								
Regions with larger population size	0.065	0.289	0.128	0.136	0.160	0.151	0.151	0.151
	(0.082)	(0.171)	(0.233)	(0.155)	(0.158)	(0.171)	(0.166)	(0.166)
Regions with smaller population size	0.071	0.263	0.130	0.114	0.153	0.147	0.143	0.143
	(0.083)	(0.161)	(0.259)	(0.160)	(0.150)	(0.1749	(0.166)	(0.167)

NB: * and ** denote significance according to 68% and 90% confidence intervals, respectively.

Appendix

Table A1: The NUTS-2 level regions included in the sample

Country	Code	Name	Lagging regions	CF countries' regions	Convergence regions not in CF countries
Belgium	BE10	Région de Bruxelles	NO	NO	NO
	BE21	Prov. Antwerpen	NO	NO	NO
	BE22	Prov. Limburg (BE)	NO	NO	NO
	BE23	Prov. Oost	NO	NO	NO
	BE24	Prov. Vlaams	NO	NO	NO
	BE25	Prov. West	NO	NO	NO
	BE31	Prov. Brabant wallon	NO	NO	NO
	BE32	Prov. Hainaut	YES	NO	YES
	BE33	Prov. Liège	NO	NO	NO
	BE34	Prov. Luxembourg (BE)	NO	NO	NO
	BE35	Prov. Namur	NO	NO	NO
Germany	DE11	Stuttgart	NO	NO	NO
	DE12	Karlsruhe	NO	NO	NO
	DE13	Freiburg	NO	NO	NO
	DE14	Tübingen	NO	NO	NO
	DE21	Oberbayern	NO	NO	NO
	DE22	Niederbayern	NO	NO	NO
	DE23	Oberpfalz	NO	NO	NO
	DE24	Oberfranken	NO	NO	NO
	DE25	Mittelfranken	NO	NO	NO
	DE26	Unterfranken	NO	NO	NO
	DE27	Schwaben	NO	NO	NO
	DE30	Berlin	YES	NO	YES
	DE40	Brandenburg	YES	NO	YES
	DE50	Bremen	NO	NO	NO
	DE60	Hamburg	NO	NO	NO
	DE71	Darmstadt	NO	NO	NO
	DE72	Gießen	NO	NO	NO
	DE73	Kassel	NO	NO	NO
	DE80	Mecklenburg	YES	NO	YES
	DE91	Braunschweig	NO	NO	NO
	DE92	Hannover	NO	NO	NO
	DE93	Lüneburg	NO	NO	NO
	DE94	Weser	NO	NO	NO
	DEA1	Düsseldorf	NO	NO	NO
	DEA2	Köln	NO	NO	NO
	DEA3	Münster	NO	NO	NO
	DEA4	Detmold	NO	NO	NO
	DEA5	Arnsberg	NO	NO	NO
	DEB1	Koblenz	NO	NO	NO
	DEB2	Trier	NO	NO	NO
	DEB3	Rheinhessen	NO	NO	NO
	DEC0	Saarland	NO	NO	NO
	DED2	Dresden	YES	NO	YES
	DED4	Chemnitz	YES	NO	YES
	DED5	Leipzig	YES	NO	YES
	DEE0	Sachsen	YES	NO	YES
	DEF0	Schleswig-Holstein	NO	NO	NO
	DEG0	Thüringen	YES	NO	YES
Denmark	DK01	Hovedstaden	NO	NO	NO
	DK02	Sjælland	NO	NO	NO
	DK03	Syddanmark	NO	NO	NO
	DK04	Midtjylland	NO	NO	NO
	DK05	Nordjylland	NO	NO	NO
Greece	EL30	Attiki	YES	YES	NO
	EL41	Voreio Aigaio	YES	YES	NO
	EL42	Notio Aigaio	YES	YES	NO
	EL43	Kriti	YES	YES	NO
	EL51	Anatoliki Makedonia, Thraki	YES	YES	NO

	EL52	Kentriki Makedonia	YES	YES	NO
	EL53	Dytiki Makedonia	YES	YES	NO
	EL54	Ipeiros	YES	YES	NO
	EL61	Thessalia	YES	YES	NO
	EL62	Ionia Nisia	YES	YES	NO
	EL63	Dytiki Ellada	YES	YES	NO
	EL64	Sterea Ellada	YES	YES	NO
	EL65	Peloponnisos	YES	YES	NO
Spain	ES11	Galicia	YES	YES	NO
	ES12	Principado de Asturias	YES	YES	NO
	ES13	Cantabria	YES	YES	NO
	ES21	País Vasco	YES	YES	NO
	ES22	Comunidad Foral de Navarra	YES	YES	NO
	ES23	La Rioja	YES	YES	NO
	ES24	Aragón	YES	YES	NO
	ES30	Comunidad de Madrid	YES	YES	NO
	ES41	Castilla y León	YES	YES	NO
	ES42	Castilla	YES	YES	NO
	ES43	Extremadura	YES	YES	NO
	ES51	Cataluña	YES	YES	NO
	ES52	Comunidad Valenciana	YES	YES	NO
	ES53	Illes Balears	YES	YES	NO
	ES61	Andalucía	YES	YES	NO
	ES62	Región de Murcia	YES	YES	NO
France	FR10	Île de France	NO	NO	NO
	FR21	Champagne	NO	NO	NO
	FR22	Picardie (NUTS 2013)	NO	NO	NO
	FR23	Haute	NO	NO	NO
	FR24	Centre (FR) (NUTS 2013)	NO	NO	NO
	FR25	Basse	NO	NO	NO
	FR26	Bourgogne (NUTS 2013)	NO	NO	NO
	FR30	Nord	YES	NO	YES
	FR41	Lorraine (NUTS 2013)	NO	NO	NO
	FR42	Alsace (NUTS 2013)	NO	NO	NO
	FR43	Franche-Comté	NO	NO	NO
	FR51	Pays de la Loire (NUTS 2013)	NO	NO	NO
	FR52	Bretagne (NUTS 2013)	NO	NO	NO
	FR53	Poitou	NO	NO	NO
	FR61	Aquitaine (NUTS 2013)	NO	NO	NO
	FR62	Midi	NO	NO	NO
	FR63	Limousin (NUTS 2013)	NO	NO	NO
	FR71	Rhône	NO	NO	NO
	FR72	Auvergne (NUTS 2013)	NO	NO	NO
	FR81	Languedoc	NO	NO	NO
	FR82	Provence	NO	NO	NO
	FR83	Corse (NUTS 2013)	YES	NO	YES
Eire	IE01	Border, Midland and Western (NUTS 2013)	YES	YES	NO
	IE02	Southern and Eastern (NUTS 2013)	YES	YES	NO
Italy	ITC1	Piemonte	NO	NO	NO
	ITC2	Valle d'Aosta/Vallée d'Aoste	NO	NO	NO
	ITC3	Liguria	NO	NO	NO
	ITC4	Lombardia	NO	NO	NO
	ITF1	Abruzzo	YES	NO	YES
	ITF2	Molise	YES	NO	YES
	ITF3	Campania	YES	NO	YES
	ITF4	Puglia	YES	NO	YES
	ITF5	Basilicata	YES	NO	YES
	ITF6	Calabria	YES	NO	YES
	ITG1	Sicilia	YES	NO	YES
	ITG2	Sardegna	YES	NO	YES
	ITH1	Provincia Autonoma di Bolzano/Bozen	NO	NO	NO
	ITH2	Provincia Autonoma di Trento	NO	NO	NO
	ITH3	Veneto	NO	NO	NO
	ITH4	Friuli Venezia Giulia	NO	NO	NO
	ITH5	Emilia-Romagna	NO	NO	NO
	ITI1	Toscana	NO	NO	NO

	ITI2	Umbria	NO	NO	NO
	ITI3	Marche	NO	NO	NO
	ITI4	Lazio	NO	NO	NO
Luxembourg	LU00	Luxembourg	NO	NO	NO
Netherlands	NL11	Groningen	NO	NO	NO
	NL12	Friesland (NL)	NO	NO	NO
	NL13	Drenthe	NO	NO	NO
	NL21	Overijssel	NO	NO	NO
	NL22	Gelderland	NO	NO	NO
	NL23	Flevoland	YES	NO	YES
	NL31	Utrecht	NO	NO	NO
	NL32	Noord-Holland	NO	NO	NO
	NL33	Zuid	NO	NO	NO
	NL34	Zeeland	NO	NO	NO
	NL41	Noord-Brabant	NO	NO	NO
	NL42	Limburg (NL)	NO	NO	NO
Portugal	PT11	Norte	YES	YES	NO
	PT15	Algarve	YES	YES	NO
	PT16	Centro (PT)	YES	YES	NO
	PT17	Área Metropolitana de Lisboa	YES	YES	NO
	PT18	Alentejo	YES	YES	NO
UK	UKC1	Tees Valley and Durham	NO	NO	NO
	UKC2	Northumberland and Tyne and Wear	NO	NO	NO
	UKD1	Cumbria	NO	NO	NO
	UKD3	Greater Manchester	NO	NO	NO
	UKD4	Lancashire	NO	NO	NO
	UKD6	Cheshire	NO	NO	NO
	UKD7	Merseyside	YES	NO	YES
	UKE1	East Yorkshire and Northern Lincolnshire	NO	NO	NO
	UKE2	North Yorkshire	NO	NO	NO
	UKE3	South Yorkshire	YES	NO	YES
	UKE4	West Yorkshire	NO	NO	NO
	UKF1	Derbyshire and Nottinghamshire	NO	NO	NO
	UKF2	Leicestershire, Rutland and Northamptonshire	NO	NO	NO
	UKF3	Lincolnshire	NO	NO	NO
	UKG1	Herefordshire, Worcestershire and	NO	NO	NO
	UKG2	Shropshire and Staffordshire	NO	NO	NO
	UKG3	West Midlands	NO	NO	NO
	UKH1	East Anglia	NO	NO	NO
	UKH2	Bedfordshire and Hertfordshire	NO	NO	NO
	UKH3	Essex	NO	NO	NO
	UKI1	Inner London	NO	NO	NO
	UKI2	Outer London	NO	NO	NO
	UKJ1	Berkshire, Buckinghamshire and Oxfordshire	NO	NO	NO
	UKJ2	Surrey, East and West Sussex	NO	NO	NO
	UKJ3	Hampshire and Isle of Wight	NO	NO	NO
	UKJ4	Kent	NO	NO	NO
	UKK1	Gloucestershire, Wiltshire and Bristol/Bath	NO	NO	NO
	UKK2	Dorset and Somerset	NO	NO	NO
	UKK3	Cornwall and Isles of Scilly	YES	NO	YES
	UKK4	Devon	NO	NO	NO
	UKL1	West Wales and The Valleys	YES	NO	YES
	UKL2	East Wales	NO	NO	NO
	UKM2	Eastern Scotland (NUTS 2013)	NO	NO	NO
	UKM3	South Western Scotland (NUTS 2013)	NO	NO	NO
	UKM5	North Eastern Scotland	NO	NO	NO
	UKM6	Highlands and Islands	YES	NO	YES
	UKN0	Northern Ireland (UK)	YES	NO	YES

Table A2: The main variables. Summary statistics

Sample statistics (1)	Full sample	EU Objective			Population size	
		Cohesion Fund regions	Other Convergence regions	Further regions	Larger regions	Smaller regions
N. of regions	**183**	**36**	**26**	**121**	**91**	**92**
N. of obs.	**4575**	**900**	**650**	**3025**	**2275**	**2300**
	Population (2)					
Mean	1874.5	1680.2	1928.8	1920.6	2919.1	841.2
Median	1525.9	1002.9	1649.5	1534.4	2430.8	857.9
Stand Dev	1550.1	1691.6	1448.9	1534.9	1583.1	395.4
10th –perc.le	437.6	267.1	332.9	537.7	1645.3	309.5
90th –perc.le	3894.3	3826.2	4042.3	3863.3	4967.4	1380.6
	GDP per capita (3)					
Mean	22735.3	18418.0	17626.1	25056.2	23574.7	21905.0
Median	21463.5	17184.5	17416.0	23511.5	22192.5	20649.0
Stand Dev	8574.2	6388.2	4059.2	8867.9	8975.6	8074.2
10th –perc.le	13946.2	11234.1	12535.0	15892.8	14175.9	13697.0
90th –perc.le	32721.4	27487.3	23003.0	35169.1	34021.2	31275.2
	Structural Fund Expenditure per capita (3)					
Mean	51.4	186.2	67.3	8.4	37.3	65.3
Median	11.2	163.5	60.8	5.5	9.5	12.8
Stand. Dev.	98.4	150.4	49.5	8.9	62.3	122.6
10th –perc.le	0.9	25.8	13.5	0.5	0.7	1.1
90th –perc.le	170.1	379.1	131.5	19.4	120.7	236.6
	Gross Fixed Capital Formation per capita (3)					
Mean	4790.3	4456.9	4095.1	5031.2	4813.5	4767.4
Median	4480.4	4124.9	4014.3	4670.9	4568.5	4378.3
Stand Dev	1884.4	2008.2	1360.5	1889.2	1710.4	2042.1
10th –perc.le	2829.0	2167.5	2497.4	3164.1	2978.8	2650.4
90th –perc.le	7139.9	7257.3	5663.5	7303.2	7024.9	7264.2
	Employment Rate (4)					
Mean	43.75	40.44	38.29	45.84	43.99	43.51
Median	43.41	39.95	38.79	45.52	43.83	43.03
Stand. Dev.	7.96	5.44	7.29	7.86	8.58	7.29
10th –perc.le	34.73	33.91	31.04	37.65	35.11	34.55
90th –perc.le	52.55	48.11	46.37	54.30	52.94	52.13

(1) Statistics computed on the whole sample period. (2) Thousands of inhabitants. (3) Euros at PPP 2005 prices per inhabitant. (4) Ratio of total employment over population, in percentage points.

The Space-Time Impulse Response (STIR) functions

All the figures shown below include approximated 68 and 90 per cent confidence bands (i.e. ± 1 and ± 1.645 standard errors bands, respectively) around the point estimates, relying on the unbiasedness and asymptotic normality of VAR impulse responses (see, e.g., Lütkepohl, 2007). Standard errors were estimated by the bootstrap method (100 replications of the sample were utilised for this purpose). Note that the STIR functions plotted below are based on SpVAR models estimated on differenced data. The multipliers commented in the main text, which relate to the levels of the variables of interest, are computed by cumulating the impulse responses to a unit shock.

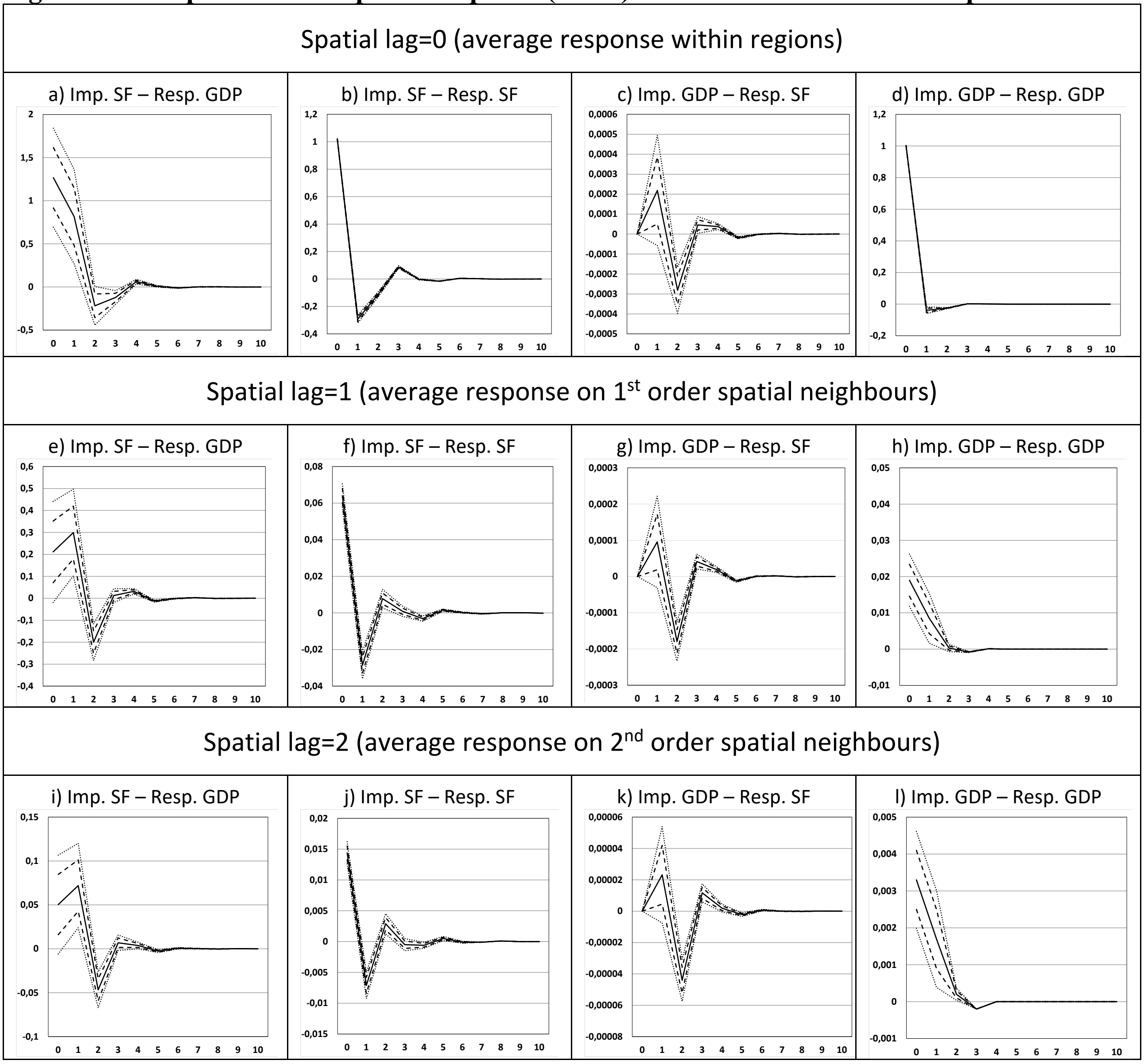
Baseline SpVAR model

In Figure A1, the estimated STIR functions are plotted for the two endogenous variables and the two shocks in the baseline SpVAR model, considering spatial lag orders from zero to two and a time horizon up to ten years ahead. The first row of Figure A1 displays the STIR functions at spatial lag = 0—that is, the response within each region to a shock occurring in the same region. The response of GDP to an exogenous shock to SF expenditure is plotted in panel *a*. The estimated STIR coefficients are positive and sizeable both on impact and one year after the shock. They turn slightly negative at years two and three and then become negligible after five years. The dynamic response of SF expenditure to its own shock, depicted in panel *b*, converges quite rapidly to zero.

Panel *c* of Figure A1 displays the response of SF expenditure to a GDP shock. The response, which is equal to zero on impact by assumption, is positive and mildly significant one year after the shock, then turns negative and converges to zero for lags greater than two. Overall, there is evidence of a non-negligible degree of endogeneity of SF expenditure with respect to past GDP, conditional on past SF dynamics. On the other hand, the dynamic response of GDP to its own shock, plotted in panel *d*, rapidly converges to zero.

Panels *e* to *l* plot the estimated dynamic spatial spillover effects on the nearest neighbouring regions (spatial lag = 1) and on the neighbours of the latter (spatial lag = 2). In particular, the STIR of GDP on nearest neighbours from an exogenous SF shock (see panel *e*) is equal on impact to about 0.2. It raises to 0.3 after one year, becomes negative at lag two, and is not statistically different from zero henceforward. Qualitatively, dynamic responses at spatial lag = 2 (found in panels *i* to *l*) mimic closely those observed at spatial lag = 1 but are about one quarter the size of the latter, thus providing evidence of a quick spatial decay of spatial spillover effects. At spatial lags ≥ 3, the estimated spillover effects become negligible and are not displayed for the sake of brevity.

Figure A1. Space-Time Impulse Response (STIR) functions for the baseline SpVAR model



NB: Dashed and dotted lines respectively represent approximate 68% and 90% confidence bands.

Extended SpVAR model

The estimated space-time impulse responses for the extended SpVAR model are plotted in Figure A2 for a time horizon up to ten years ahead,[17] omitting the responses to the variables' own shock as they are of no direct interest here (the pattern of these responses is analogous to those documented for the baseline model). Panel (a) displays the impulse response of local GDP to a local SF expenditure shock. The overall pattern is very close to one obtained under the baseline SpVAR specification, both qualitatively and quantitatively. The dynamic response of local investment per capita to a local SF per capita shock is displayed in panel (b). This response is positive on impact but rather small, peaks one year after the shock, and then takes slightly negative values. Panels (c) and

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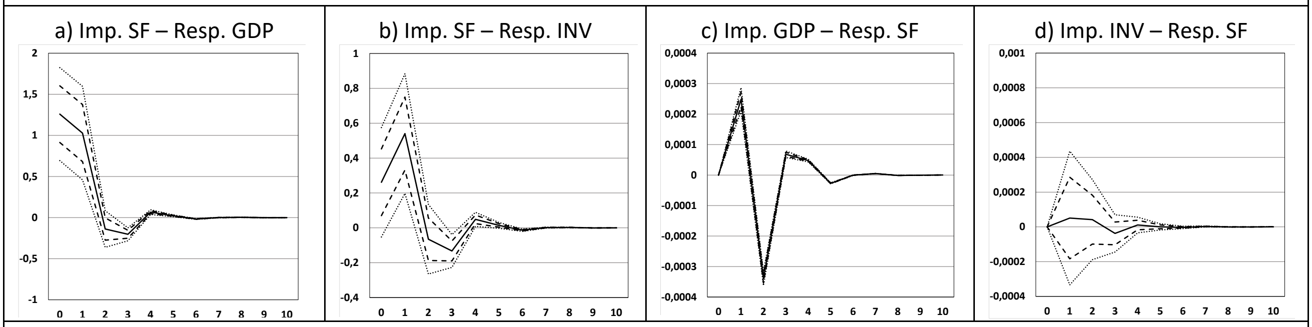
[17] For the sake of brevity, we do not report here the analytical model expression, as it can be derived from the bivariate formulation given in Section 4 and the general SpVAR model expression given in Di Giacinto (2010).

(d) display the response of SF expenditure to GDP and investment shocks. This response is only significant for the GDP shock in the short run.

Panels (e) to (l) depict the spatial spillover effects, as measured by the STIR function. The evidence, at spatial lag = 1, of positive, sizeable, and highly significant spillovers from SF shocks to GDP per capita in neighbouring areas is confirmed. Positive spillover effects are also observed on investment—that is, an exogenous shock to SF expenditure in one region crowds in investment in neighbouring regions. As already seen for the baseline two-equation specification, spatial externalities, although still significant at spatial lag = 2, tail out quite rapidly as the geographical distance between regions increases.

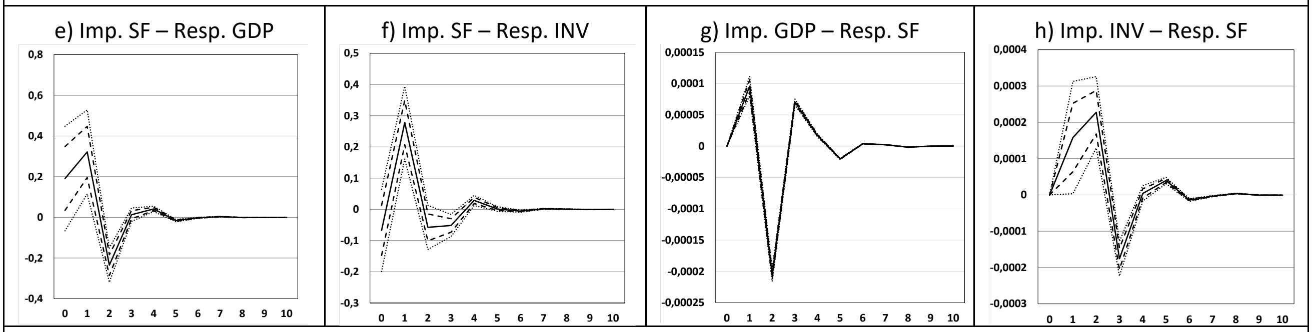
Figure A2. Space-Time Impulse Response (STIR) functions for the extended SpVAR model

Spatial lag=0 (average response within regions)



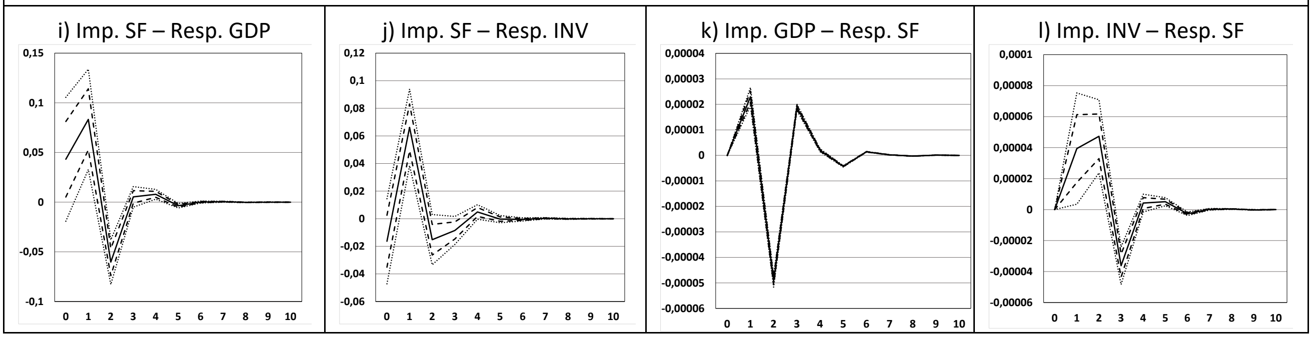
a) Imp. SF – Resp. GDP b) Imp. SF – Resp. INV c) Imp. GDP – Resp. SF d) Imp. INV – Resp. SF

Spatial lag=1 (average response on 1st order spatial neighbours)



e) Imp. SF – Resp. GDP f) Imp. SF – Resp. INV g) Imp. GDP – Resp. SF h) Imp. INV – Resp. SF

Spatial lag=2 (average response on 2nd order spatial neighbours)



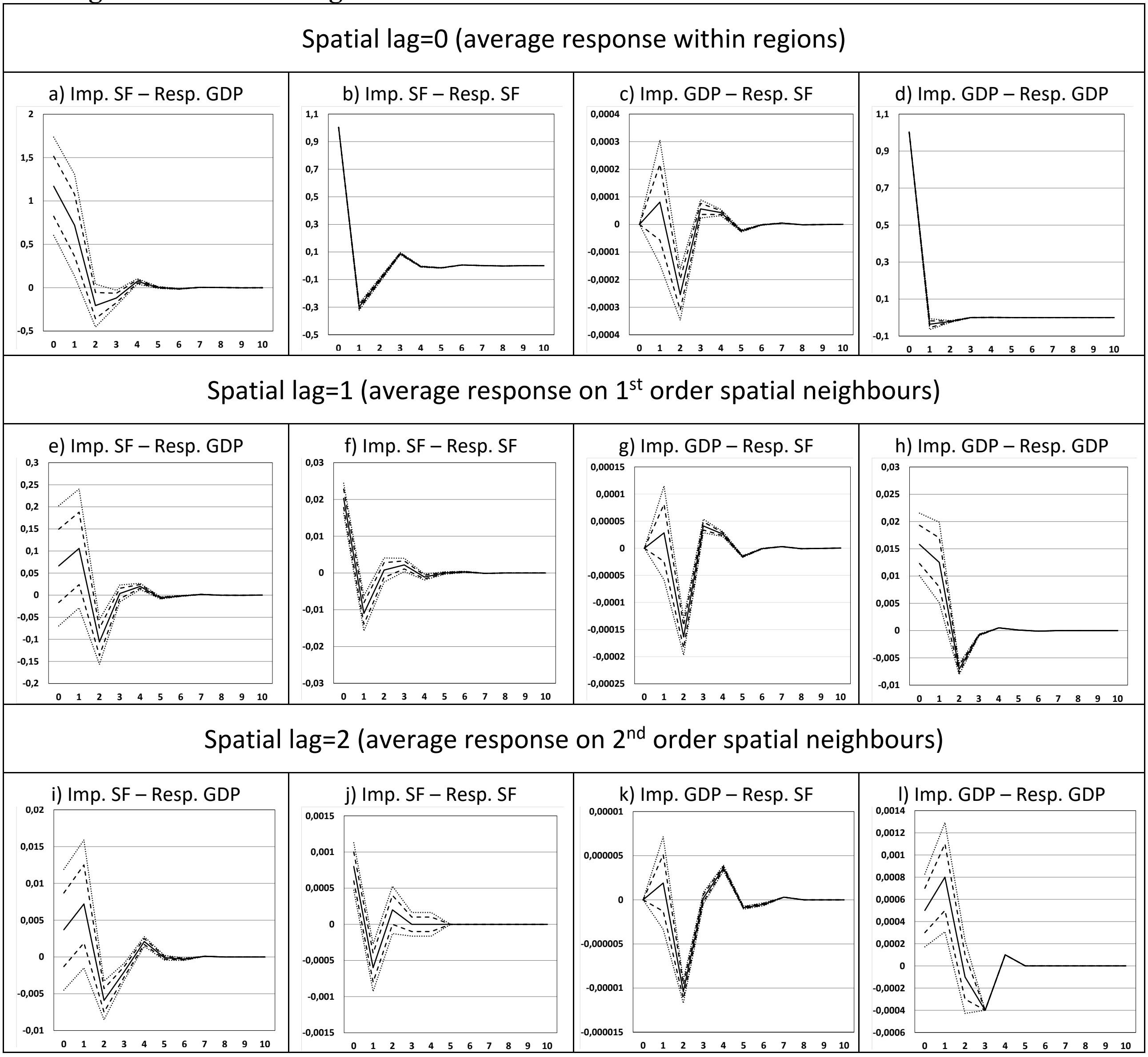
i) Imp. SF – Resp. GDP j) Imp. SF – Resp. INV k) Imp. GDP – Resp. SF l) Imp. INV – Resp. SF

NB: Dashed and dotted lines respectively represent approximate 68% and 90% confidence bands.

Baseline SpVAR model utilising distance-band weights

Estimating the baseline SpVAR utilising the above detailed distance-band approach yields the impulse-responses plotted in Figure A3. At spatial lag = 0 (within-region effects), the results match very closely with the baseline. On the other hand, the spillovers of local shocks to SF on GDP measured on first and second-order neighbours, while qualitatively similar, are smaller in size and only barely significant. This evidence can be easily rationalised considering the rapid distance-decay of spillover effects documented in the baseline results. Indeed, in the distance-band weights specification, the distance between any given region and its first and second-order neighbours is larger, subsequently dampening cross-region effects.

Figure A3. Space-Time Impulse Response (STIR) functions for the baseline SpVAR model utilizing distance-band weights



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Albanese G., G. de Blasio and A. Locatelli, *Does EU regional policy promote local TFP growth? Evidence from the Italian Mezzogiorno,* Papers in Regional Science, v. 100, 2, pp. 327-348, **WP 1253 (December 2019).**

Albertazzi A., A. Nobili and F. M. Signoretti, *The bank lending channel of conventional and unconventional monetary policy,* Journal of Money, Credit and Banking, v. 53, 2-3, pp. 261-299, **WP 1094 (Jan 2017).**

Anzuini A. and L. Rossi, *Fiscal policy in the US: a new measure of uncertainty and its effects on the American economy*, Empirical Economics, v. 61, 6, pp. 2613-2634, **WP 1197 (November 2018).**

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Banerjee R, L. Gambacorta and E. Sette, *The real effects of relationship lending,* Journal of Financial Intermediation, v. 48, Article 100923, **WP 1133 (September 2017).**

Barone G., F. David, G. de Blasio and S. Mocetti, *How do house prices respond to mortgage supply?,* Journal of Economic Geography, v. 21, 1, pp.127-140, **WP 1282 (June 2020).**

Barone G. and S. Mocetti, *Intergenerational mobility in the very long run: Florence 1427-2011,* Review of Economic Studies, v. 88, 4, pp. 1863–1891, **WP 1060 (April 2016).**

Bartocci A., L. Burlon, A. Notarpietro and M. Pisani, *Macroeconomic effects of non-standard monetary policy measures in the Euro Area: the role of corporate bond purchases,* The Manchester School, v. 89, S1, pp. 97-130, **WP 1241 (October 2019).**

Batini N., A. Cantelmo, G. Melina and S. Villa, *How loose, how tight? A measure of monetary and fiscal stance for the euro area,* Oxford Economic Papers, v. 73, 4, pp. 1536-1556, **WP 1295 (September 2020).**

Benetton M. and D. Fantino, *Targeted monetary policy and bank lending behavior,* Journal of Financial Economics, v. 142, 1, pp. 404-429, **WP 1187 (September 2018).**

Busetti F., M. Caivano and D. Delle Monache, *Domestic and global determinants of inflation: evidence from expectile regression,* Oxford Bulletin of Economics and Statistics, v. 83, 4, pp. 982-1001, **WP 1225 (June 2019).**

Busetti F., M. Caivano, D. Delle Monache and C. Pacella, *The time-varying risk of Italian GDP,* Economic Modelling, v. 101, Article 105522, **WP 1288 (July 2020).**

Busetti F., S. Neri, A. Notarpietro and M. Pisani, *Monetary Policy strategies in the new normal: a model-based analysis for the Euro Area,* Journal of Macroeconomics, v. 70, Article 103366, **WP 1308 (December 2020).**

Capolongo A. and C. Pacella, *Forecasting inflation in the Euro Area: countries matter*, Empirical Economics, v. 61, 4, pp. 2477-2499, **WP 1224 (June 2019).**

Carmignani A., G. de Blasio, C. Demma and A. D'Ignazio, *Urbanization and firm access to credit,* Journal of Regional Science, v. 61, 3, pp. 597-622, **WP 1222 (June 2019).**

Corneli F., *Financial integration without financial development,* Atlantic Economic Journal, v. 49, 2, pp. 201-220, **WP 1120 (June 2017).**

Cova P., P. Pagano, A. Notarpietro and M. Pisani, *Secular stagnation, R&D, public investment and monetary policy: a global-model perspective,* Macroeconomic Dynamics, v. 25, 5, pp. 1267-1287, **WP 1156 (December 2017).**

De Philippis M., *Multitask agents and incentives: the case of teaching and research for university professors,* Economic Journal, v. 131, 636, pp. 1643-1681, **WP 1042 (December 2015).**

Del Prete S. and M. L. Stefani, *Women as "Gold Dust": gender diversity in top boards and the performance of Italian banks,* Economic Notes, Monte dei Paschi di Siena, v. 50, 2, e12183, **WP 1014 (June 2015).**

Ferrero G., M. Loberto and M. Miccoli, *The assets' pledgeability channel of unconventional monetary policy,* Economic Inquiry, v. 59, 4, pp. 1547-1568, **WP 1119 (June 2017).**

Fidora M., C. Giordano and M. Schmitz, *Real exchange rate misalignments in the Euro Area,* Open Economies Review, v. 32, 1, pp. 71-107, **WP 1162 (January 2018).**

Gambacorta L., G. Ricotti, S. Sundaresan and Z. Wang, *Tax effects on bank liability structure,* European Economic Review, v. 138, Article 103820, **WP 1101 (February 2017).**

Hertweck M., V. Lewis and S. Villa, *Going the extra mile: effort by workers and job-seekers,* Journal of Money, Credit and Banking, v. 54, 8, pp. 2099-2127, **WP 1277 (June 2020).**

Li F., A. Mercatanti, T. Makinen and A. Silvestrini, *A regression discontinuity design for ordinal running variables: evaluating central bank purchases of corporate bonds,* The Annals of Applied Statistics, v. 15, 1, pp. 304-322, **WP 1213 (March 2019).**

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Nispi Landi V. and A. Schiavone, *The effectiveness of capital controls,* Open Economies Review, v. 32, 1, pp. 183-211, **WP 1200 (November 2018).**

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Pereda Fernandez S., *Copula-based random effects models for clustered data,* Journal of Business & Economic Statistics, v. 39, 2, pp. 575-588, **WP 1092 (January 2017).**

2022

Andini M., M. Boldrini, E. Ciani, G. de Blasio, A. D'Ignazio and A. Paladini, *Machine learning in the service of policy targeting: the case of public credit guarantees,* Journal of Economic Behavior & Organization, v. 198, pp. 434-475, **WP 1206 (February 2019).**

Angelico C., J. Marcucci, M. Miccoli and F. Quarta, *Can we measure inflation expectations using twitter?,* Journal of Econometrics, v. 228, 2, pp. 259-277, **WP 1318 (February 2021).**

Bartocci A., A. Notarpietro and M. Pisani, *Covid-19 shock and fiscal-monetary policy mix in a monetary union,* Economic challenges for Europe after the pandemic, Springer Proceedings in Business and Economics, Berlin-Heidelberg, Springer, **WP 1313 (December 2020).**

Bottero M., C. Minoiu, J. Peydrò, A. Polo, A. Presbitero and E. Sette, *Expansionary yet different: credit supply and real effects of negative interest rate policy,* Journal of Financial Economics, v. 146, 2, pp. 754-778, **WP 1269 (March 2020).**

Bronzini R., A. D'Ignazio and D. Revelli, *Financial structure and bank relationships of Italian multinational firms,* Journal of Multinational Financial Management , v. 66, Article 100762, **WP 1326 (March 2021).**

Cantelmo A., *Rare disasters, the natural interest rate and monetary policy,* Oxford Bulletin of Economics and Statistics, v. 84, 3, pp. 473-496, **WP 1309 (December 2020).**

Carriero A., F. Corsello and M. Marcellino, *The global component of inflation volatility,* Journal of Applied Econometrics, v. 37, 4, pp. 700-721, **WP 1170 (May 2018).**

Ciapanna E. and G. Rovigatti, *The grocery trolley race in times of Covid-19. Evidence from Italy,* Italian Economic Journal / Rivista italiana degli economisti, v. 8, 2, pp. 471-498, **WP 1341 (June 2021).**

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Pericoli M. and M. Taboga, *Nearly exact Bayesian estimation of non-linear no-arbitrage term-structure models,* Journal of Financial Econometrics, v. 20, 5, pp. 807-838, **WP 1189 (September 2018).**

Rossi P. and D. Scalise, *Financial development and growth in European regions,* Journal of Regional Science, v. 62, 2, pp. 389-411, **WP 1246 (November 2019).**

Schivardi F., E. Sette and G. Tabellini, *Credit misallocation during the European financial crisis,* Economic Journal, v. 132, 641, pp. 391-423, **WP 1139 (September 2017).**

Taboga M., *Cross-country differences in the size of venture capital financing rounds: a machine learning approach,* Empirical Economics, v. 62, 3, pp. 991-1012, **WP 1243 (November 2019).**

2023

Aprigliano V., S. Emiliozzi, G. Guaitoli, A. Luciani, J. Marcucci and L. Monteforte, *The power of text-based indicators in forecasting Italian economic activity,* International Journal of Forecasting, v. 39, 2, pp. 791-808, **WP 1321 (March 2021).**

Bartocci A., A. Notarpietro and M. Pisani, *Non-standard monetary policy measures in non-normal times,* International Finance, v. 26, 1, pp. 19-35, **WP 1251 (November 2019).**

Di Addario S., P. Kline, R. Saggio and M. Sølvsten, *It ain't where you're from, it's where you're at: hiring origins, firm heterogeneity, and Wages,* Journal of Econometrics,v. 233, 2, pp. 340-374, **WP 1374 (June 2022).**

Loberto M., *Foreclosures and house prices,* Italian Economic Journal / Rivista italiana degli economisti, , v. 9, 1, pp. 397-424, **WP 1325 (March 2021).**

FORTHCOMING

Ciapanna E, S. Mocetti and A. Notarpietro, *The macroeconomic effects of structural reforms: an empirical and model-based approach,* Economic Policy, **WP 1303 (November 2022).**

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