CONTRIBUTI DI RICERCA CRENOS

EU FUNDS AND TFP GROWTH: HOW THE IMPACT CHANGED OVER TIME AND SPACE

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WORKING PAPERS

2024/12

CENTRO RICERCHE ECONOMICHE NORD SUD
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Title: EU FUNDS AND TFP GROWTH: HOW THE IMPACT CHANGED OVER TIME AND SPACE

Prima Edizione: Luglio 2024
ISBN: 978 88 68515 300

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EU funds and TFP growth: how the impact changed over time and space

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Abstract

This paper investigates the economic impact of European Structural and Investment Funds (ESIF) for 262 EU NUTS2 regions over the period 2000-2019. Differently from previous contributions, we focus on the impact of ESIF on regional Total Factor Productivity (TFP) growth, which allowed us to account for other sources of regional investments. A relevant contribution of this study is the thorough examination of the effect of the four main funds included in ESIF on the productivity of a comprehensive set of EU regions. Results show the prevailing effectiveness of the European Regional Development Fund (ERDF), featuring a great deal of heterogeneity over time and across EU geographic areas. Moreover, by analyzing the role played by the European Agricultural Fund (EAFRD) on the TFP of the agricultural sector, we found that its growth impact crucially depends on the initial level of regional sectoral TFP. Our results contribute to a deeper understanding of ESIF economic impact and suggest policy implications for enhancing their contribution to regional economic development.

Keywords: European Structural and Investment Funds, Regional Development, Spatial Error Model, European Union.
Jel Classification: O47, R11, R58

Acknowledgements. The Authors gratefully acknowledge funding from the EU Horizon Project ESSPIN "Economic Social and Spatial Inequalities in Europe in the Era of Global Mega-Trends" (project n. 101061104). They are grateful to participants in the RSA 2023, AISRe 2023 and SIE 2023 conferences for their valuable comments and suggestions.

1. Introduction

The European Union (EU) has established a comprehensive cohesion program to enhance the integration process among its member countries by fostering economic growth and promoting development in less-developed regions. Central to this policy is a wide set of financial instruments, among which a primary role is played by the European Structural and Investment Funds (ESIF), which target diverse purposes and economic activities. The main objective of these funds is to reduce economic and social disparities among regions in the EU by supporting investments in infrastructure, human capital, innovation and favoring a productive business environment.

The European Regional Development Fund (ERDF) and the European Social Fund (ESF) are the main structural funds in terms of allocated financial resources. The European Agricultural Fund for Rural Development (EAFRD) supports farmers and the rural economy through various measures, like rural development programs and sustainable agriculture promotion. The Cohesion Fund (CF) aims to reduce economic and social disparities in less developed territories by fostering investments in environmental and transport infrastructure. To give an idea of the extraordinary financial effort put in place, consider that ESIF's total amount reached 500 billion euros for the years 2009-2018.

Over the past two decades, a substantial body of research has focused on evaluating the impact of EU funds on regional economic performance (see, among many others, Becker et al. 2010, Rodríguez-Pose and Garcilazo 2015, Dall'Erba and Fang 2017, Gagliardi and Percoco, 2017). Overall, results suggest that structural funds positively influence the growth of regional per capita Gross Domestic Product (GDP), even if their efficacy seems to be highly influenced by regional contextual factors and the considered time span.

The main drawback of the extant literature on the role of EU funds is that it neglects the concurrent impact generated by other channels of investments realized in each region (a notable exception is Fiaschi et al. 2018). This is noteworthy as ESIF accounted for only 1.1% of Europe's total gross fixed capital formation during 2016-2018. Moreover, the share of ESIF in total regional investments varies considerably across EU regions. For instance, it reaches 26% in the Acores while being as low as 0.05% in Île de France. It implies that private investment and public capital accumulation from other sources (national and regional administrations, public enterprises) play a major role, particularly in the more developed regions where the role of private investment is dominant.

A second shortcoming of previous contributions is that they overlook the funds' different objectives, thus failing to detect possible heterogeneous effects. Numerous studies have indeed analyzed cohesion policy's impact considering an aggregated measure of ESIF (among others, Becker et al., 2010; Gagliardi and Percoco, 2017), while others have just focused on ERDF (Di Caro and Fratesi, 2022; Albanese et al., 2021).

The present paper aims to contribute to the current debate on ESIF's impact on regional economic performance, overcoming the two main gaps in the existing literature discussed above.

First, we focus on the impact of EU funds on regional Total Factor Productivity (TFP) growth. TFP levels are computed after estimating a production function in which labor and the stock of capital are included as the main production inputs. This way, we account for all the other sources of investments that contributed to the formation of the capital stock. This approach ensures a more accurate estimate of ESIF's impact.

Second, considering their distinct objectives, we also consider ESIF disaggregated into its four main funds to explore their different effects on regional productivity growth.

We employ data on investment funds made available by the DG Regional and Urban Policy of the European Commission (EC 2017), which provides annualized and regionalized ESIF payment figures. The information supplied by this new dataset allows for a more accurate analysis of the fund's efficacy with respect to previous contributions based on commitment data. Our research focuses on a comprehensive set of 262 NUTS2 EU territories and spans from 2000 to 2019, enabling us to examine different sub-periods. ESIF's impact may have varied over time due to changes in spatial fund allocation and critical macro events, like the 2008 financial crisis. Moreover, we acknowledge and investigate the potential spatial heterogeneity of ESIF's effect, recognizing different economic trends across EU geographic areas. This thorough approach aims to enhance our understanding on how ESIF contributes to regional development in a multifaceted European context.

Our empirical strategy is organized into two stages. As mentioned above, we firstly estimate a production function model with the traditional inputs, labor and capital in order to compute regional TFP levels for 2000-2019. Secondly, we assess the effects of EU funds on the TFP annual average growth rates while controlling for a wide set of contextual variables – namely human capital, technological capital, social capital, and population density – and spatial dependence.

Our results indicate that EU funds' effectiveness is strongly characterized by heterogeneity, as the effects vary across funds, geographical areas and time periods. Once controlling for other sources of investments, we found that ERDF exerts an additional effect on regional TFP, which became substantial in the period 2014-2019. Hence, it has contributed to narrowing the productivity gap among EU macro-areas. This was especially the case for the West-East divide, while Southern regions faced more difficulties in taking advantage of the funding. In general, the other funds did not positively impact regional TFP growth. We thus conducted a targeted analysis to evaluate the impact of the EAFRD on regional agricultural TFP growth. Our findings indicate a generally positive effect of the EAFRD, although its impact varies significantly depending on regional initial agricultural productivity level.

The rest of the paper is organized as follows. Section 2 outlines the literature background and defines our research question. The third section describes regional TFP dynamics and funds distribution among EU territories, while the econometric methodology is outlined in Section 4. Section 5 discusses the main results of the analysis. Section 6 extends the research by focusing on the EAFRD's effect on regional agriculture productivity. The final section summarizes the findings and discusses their broader policy implications.

2. Literature background

ESIF's financial importance has increased over time, capturing scholars' interest. While the topic has been widely discussed in the economic literature, contributions have not yet reached a consensus on ESIF's effect on regional economic performance. Indeed, some early studies have shown contrasting results depending on sample selection and the period considered (among others: Fagerberg and Verspagen, 1996; Cappelen et al., 2003). Heterogeneity in the results is also determined by data characteristics, research design, and regressor selection, as discussed in the meta-analysis by Dall'Erba and Fang (2017).

More recent contributions have highlighted the important role of other regional contextual factors in enhancing the effectiveness of ESIF, providing more insights regarding their heterogeneous impacts. Despite finding less ambiguous results and an overall positive ESIF impact (Rodríguez-Pose and Garcilazo, 2015; Becker et al., 2010; Pellegrini et al., 2013), new studies have indeed shown that this effect is often conditioned by other regional characteristics, such as human capital and the quality of local institutions (Di Caro and Fratesi, 2022; Incaltarau et al., 2020; Becker et al., 2013) and territorial capital (Bachtrögler et al., 2020). Moreover, ESIF's impact varies among economic sectors, being more effective in industry and agriculture and less relevant for services, as highlighted by Coppola et al. (2023) for the Italian context. Consequently, the sectorial composition of regional economies also influences ESIF's efficacy (Percocco, 2017).

As a result, ESIF's economic impact is highly heterogeneous among different geographic areas, as shown by Crescenzi and Giua (2020). They show that the policy has been mainly effective in more developed and mature economies like Germany and the United Kingdom, while its impact has been weaker in the southern regions of Italy, as also discussed by Albanese et al. (2021) and Ciani and de Blasio (2015). Furthermore, the economic effects of ESIF also vary among different types of territory, being particularly effective in rural areas close to principal urban agglomerations (Gagliardi and Percoco, 2017).

Most studies have evaluated ESIF's efficacy by estimating its impact on regional GDP growth, employing regression analyses and policy evaluation methodologies. However, they often overlook other sources of regional investments despite ESIF being only a small portion of regional total capital accumulation. Remarkable exceptions are Fiaschi et al. (2018), who included regional average annual investment rate in their specification, and Albanese et al. (2021), who investigated ESIF's impact on the TFP of southern Italian Local Labor Markets (LLM). Furthermore, previous contributions do not account for potentially different economic impacts of the funds.

Our contribution aims to evaluate ESIF's regional economic impacts by incorporating other sources of investments in the analysis by employing TFP as the dependent variable. Additionally, this study investigates the distinct effects of the four funds, each with different aims and objectives, potentially leading to varying economic impacts. By analyzing them separately, we can better understand their individual effects, as aggregation might obscure differences and weaken the overall estimated impact due to potentially contrasting influences. To further address this, we examine the spatially heterogeneous effects across EU geographic macro areas. Finally, we examine ESIF's impact across four sub-periods (2000-2004, 2004-2008, 2008-2014, and 2014-2019) to assess the impact of major economic events, such as the 2008 financial crisis.

3. Regional TFP and ESIF

3.1 Regional TFP

As highlighted above, most previous contributions on the impact of EU funds have overlooked other sources of investment – both private and public – that have played an important role in shaping regional development. Although sizeable in absolute terms, ESIF constitutes a marginal part when compared to total regional investments. Thus, it is essential to account for other sources of capital accumulation when evaluating the impact of ESIF on regional economic performance. An effective way of doing so is to assess the impact of EU funds on TFP computed at the regional level. As it is well-known, such computation is based on a production function framework, which allows accounting for the accumulation of previous investments from any source. Therefore, this choice allows for a more accurate assessment of the impact of ESIF on regional performance.

Following Marrocu et al. (2022), we compute regional TFP levels using a quasi-growth accounting approach. We first estimate labor and capital elasticities from a Cobb-Douglas production function model, rather than imposing them. Next, we compute the regional TFP levels for the 262 NUTS2 EU regions (2010 version) included in our sample over the period 2000-2019 by applying the growth accounting method using the estimated factors elasticities, assumed invariant over the period under study.[1]

Figure 1.a shows the regional TFP levels in the year 2000 (index, EU=100), while the regional TFP average annual growth rates for the 2000-2019 period are depicted in Figure 1.b. The maps show very different productivity trends among the EU macro-areas. Regions of Central-northern countries show notably high initial TFP levels and exhibit stable, albeit modest, TFP growth rates. In contrast, despite their lower initial TFP levels, regions of new accession countries (Bulgaria, Cyprus, Czech Republic, Croatia, Estonia, Hungary, Lithuania, Latvia, Poland, Romania, Slovenia, Slovakia) display high and sustained growth rates. Initial TFP levels in Southern areas are close to the EU average, even though regions in Italy and Greece have experienced a negative TFP growth. These trends are also reported in Table 1 for three different macro-areas: Central-Northern, Southern, and New EU accessions countries and four sub-periods.[2] The period 2008-2014 stands out as the one characterized by the lowest annual average growth rate for all three macro-areas: during the financial crisis, TFP decreased at a high rate in southern regions, while in new and central-northern territories, the annual average TFP growth rate remained positive. The contrasting trajectories summarized in Table 1 highlight the complex landscape of regional development within the EU, revealing the productivity convergence of new accession countries towards Central-Northern ones juxtaposed with the fall of the Southern regions. Such heterogeneous geographical dynamics across EU macro-areas will be carefully addressed in our econometric analysis.

3.2 European Structural and Investment Funds (ESIF)

ESIF are key EU regional policy instruments that promote economic, social, and territorial cohesion. Although they are supposed to have a direct effect on GDP per capita growth, they can also significantly impact TFP by addressing investment in key economic areas such as physical and digital infrastructure, human capital, new technologies adoption and collaborative networks, as well as providing support to streamline regulatory processes, reduce bureaucratic red tape and improve the ease of doing business. This way, ESIF could lead to a more efficient allocation of resources and favor diversification into higher-value-added sectors, moving regions away from low-productivity industries.

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[1] To estimate the Cobb-Douglas production function, we used data on Gross Value Added, Labour and Gross Fixed Capital formation from EUROSTAT. The estimation results for the Cobb-Douglas production function are reported in Table A2 in Appendix 1, along with the computation of the capital stock series calculation.

[2] The detailed macro-area composition is presented in Table A3.

In our analysis, we employ a novel dataset on ESIF provided by the Directorate-General for Regional and Urban Policy of the European Commission (EC 2017), which provides regional-level annualized expenditure data based on the Commission payments. This marks a significant improvement compared to previous studies that often used commitment data. Using actual payment data is crucial for an accurate assessment, as commitments can substantially differ from executed payments, as highlighted by Fratesi (2016). The dataset focuses on EU payments, excluding national and regional co-financing expenditures.[3]

Figure 2 shows annual per capita ESIF for different EU geographic macro-areas. The diagram reveals that per capita ESIF in both Central-Northern and Southern regions have remained relatively stable throughout the period 2000-2016. In contrast, countries that have recently become EU members show a pronounced and steady increase in per capita ESIF from 2000 to 2014, surpassing the other macro-areas in per capita funding from 2009 onwards. This trend reflects the EU's strategic emphasis on supporting the post-accession development of the new regions. Notably, before 2007, the per capita ESIF for these regions was considerably lower, with Croatia not receiving any funds and Bulgaria and Romania receiving only the CF's financing during the early phase of their EU membership.[4] Figure 3 reports regional per capita ESIF in 2018. ESIF payments are highly concentrated in new EU regions (the highest per capita ESIF amount is in Estonia, with 285 euros) and in Southern Europe, especially in Portugal and Greece. Time and spatial heterogeneity of ESIF allocation were meant to have different policy outcomes depending on the development stage of the receiving regions. Such expectation will be tested in our econometric analysis with respect to TFP dynamics.

ESIF comprises seven funds (see Table 2). However, to simplify the econometric analysis, we focus on the four principal funds (ERDF, EAFRD, ESF, CF), which represent 95% of the total ESIF amount.[5] The eligibility criteria for these funds vary, leading to differences in financial allocation across macro-areas, as displayed in Table 3. The main differences regard the CF, which is directed at Member States with a per capita Gross National Income (GNI) below 90% of the EU-27 average. It is worth noting that for new EU countries, CF constitutes a large share of total ESIF (30%), while it plays a less relevant role in Southern and Central-Northern areas.

4. Econometric modelling

As discussed in the previous sections, the aim of our analysis is to assess the role of ESIF on regional TFP growth, while controlling for a comprehensive set of contextual regional factors that might affect the outcome variable. More specifically, we account for the regional endowments of human capital (HK), technological capital (TK), social capital (SK) and population density (DEN).

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[3] In our empirical framework, the national and regional co-financing expenditures, which vary according to the regional development stage, are already considered in the gross capital formation, used to compute the capital stock for the TFP estimation.

[4] The share of funding received by each country for different subperiods is shown in Table A3.

[5] Moreover, the remaining three funds - the European Maritime and Fisheries Fund (EMFF), the Fund for European Aid to Most Deprived (FEAD) and the Youth Employment Initiative (YEI) - have only been introduced in the programming period 2014-2020.

All factors are supposed to exert a positive effect on productivity as higher levels of human capital and technological capital enhance the absorptive and innovative capabilities of firms, while social capital contributes to reducing transaction costs by increasing the level of trust (Dettori et al., 2012). Population density allows us to control for possible agglomeration externalities, which may favor specializations in specific sectors (Marrocu et al., 2013).

Human capital is included in the models as the percentage of people between 25 and 64 years old with a tertiary education level (ISCED 5-6). Technological capital is measured in terms of per capita R&D expenditure; this variable, an input in the knowledge production process, is preferred to the patents output variable because is more adequate to account for a wider set of firms' innovative efforts, including those that did not result in codified knowledge. Social capital is proxied by the percentage of people over 15 years of age who have worked in a volunteer organization in the last year.[6] See Table A1 in the Appendix for a detailed description of the data and Table 4 for a comparison with respect to EU average values across macro-areas and time. We also included two territorial dummies (New and South) to account for regions located in the New Accession countries or in the Southern ones, and the initial level of TFP to account for convergence dynamics.

Our analysis is carried out for the whole period 2000-2019 and for four sub-periods to assess possible impact heterogeneity over time and to better evaluate the consequences of macroeconomic events like the 2008 and 2011 financial crises, as well as the entrance of new EU members in 2004 and their increasing ESIF flows since 2007. Finally, we assess how the funds' effects change across the three European geographical macro-areas.

When we consider the whole period, we specified a panel TFP growth model as follows:

$$\Delta TFP_{i,t-\tau} = \beta_0 + \beta_1 ESIF_{i\tau} + \beta_2 HK_{i\tau} + \beta_3 TK_{i\tau} + \beta_4 SK_{i\tau} + \beta_5 DEN_{i\tau} + \beta_6 New_i + \beta_7 South_i + \beta_8 TFP_{i\tau} + \delta_t + \upsilon_{i\tau} \quad (1)$$

where the dependent variable ($\Delta TFP_{i,t-\tau}$) is the regional annual TFP average growth rate for 262 NUTS 2 territorial units over four subperiods, with *t*=2004, 2008, 2012, 2016 and t=2000, 2004, 2008, 2012. The time windows considered are expected to smooth out potential short-term business cycle variations. All right-hand side variables are log-transformed and included at their initial period values (t).

Our variable of interest, ESIF, is included in the analysis in per capita terms, both aggregated and disaggregated into the four main funds – ERDF, EAFRD, ESF, CF – as we expect a differentiated effect on TFP growth. More specifically, we expect a positive effect, especially for the first two funds, as they are more directly meant to sustain productive activities, whereas the latter two might be more effective in enhancing broader social initiatives.

A relevant issue when analyzing regional data is the existence of possible spatial dependence. To perform spatial dependence tests, we considered the inverse distance matrix. Given the extant large evidence that spillovers are bounded in space (see, among many others,

[6] We also consider including a proxy for Institutional Quality as it also supposed to enhance productivity by increasing the general level of trust and ensuring an efficient functioning of the government and administrative bodies. However, it turned out to be highly correlated (0.61) with social capital making multicollinearity an issue in the estimation process.

Dall'Erba and Le Gallo, 2008), we set a cut-off point at 600 kilometers.[7] Following Kelejian and Prucha (2010), the proximity matrix is maximum-eigenvalue normalized; such a normalization, while avoiding imposing strong restrictions, allows us to preserve symmetry and the importance of absolute, rather than relative, distance.

Following Elhorst (2014), we consider as a starting point the flexible Spatial Lag of X (SLX) model to test for spatial dependence in the form of local spillovers. However, the coefficients of the spatially lagged variables turned out to be not significant. We then proceed by estimating the more general Spatial Durbin model (SDM), which entails both local and global spillovers. It is worth recalling that SDM nests the SLX, the spatial autoregressive (SAR) and the spatial error (SEM) more parsimonious models. Having already ruled out the SLX specification, we then tested whether the SDM could be simplified to one of the other two specifications. The tests pointed to the SEM specification as the most adequate one:[8]

$$\Delta TFP_{i,t-\tau} = \beta_0 + \beta_1 ESIF_{i\tau} + \beta_2 HK_{i\tau} + \beta_3 TK_{i\tau} + \beta_4 SK_{i\tau} + \beta_5 DEN_{i\tau} + \beta_6 New_i + \beta_7 South_i + \beta_8 TFP_{i\tau} + \delta_t + \upsilon_{i\tau} \quad (2)$$

with $\upsilon_{i\tau} = \lambda W \upsilon_{i\tau} + \varepsilon_{i\tau}$

Moreover, the choice of the SEM specification was confirmed by the robust Lagrange multiplier tests (Anselin et al., 1996) carried out on the residuals ($\upsilon_{i\tau}$) of model (1). Thus, the subsequent econometric analysis is based on the estimation of spatial error models.

5. Estimation results: the impact of ESIF on TFP growth

5.1 Entire period analysis

Main results are reported in Table 5 for both panel and sub-period models. In this section, we focus on the panel model estimation carried out for the entire period 2000-2019.

When ESIF are considered as an aggregate single fund (column 1), the effect is significant, but unexpectedly it exhibits a negative coefficient. All contextual variables have the expected positive and significant coefficients.[9] It is worth noting that the coefficient of the dummy for the New accession countries' regions is positive and highly significant, whereas the South dummy exhibits a negative coefficient, comparable in magnitude and significance to the New dummy one. This indicates that we are effectively controlling for the territorial

[7] The distance of 600 km approximately corresponds to the first quartile of the overall distance distribution for the 262 regions considered in our study. Although this choice could be considered discretionary, it guarantees that each region is connected at least with another one, as in Dall'Erba and Le Gallo (2008).

[8] The SDM specification is as follows: $Y = \rho WY + X\beta + WX\theta + \varepsilon$, where *Y* is the outcome variable *Y*, *X* a set of covariates and *W* is the normalized spatial matrix as described in the main text. Given that the null hypothesis H_0: $\theta + \rho\beta = 0$ was not rejected for most of the explanatory variables included in our model, we select the SEM specification. All results are available from the authors upon request.

[9] For robustness, we have also estimated models in which R&D was replaced by the stock of patent applications presented at the European Patent Office (EPO) and social capital by institutional quality. The main results for the variables of interest remained unchanged. We have also included a measure for production specialization on knowledge-intensive services, but it did not show a significant impact on productivity growth.

differences in TFP growth discussed in Section 3. When we consider the four main ESIF (column 2), a different and more engaging picture emerges: the ERDF fund has a positive coefficient, whereas both the ESF and CF have a negative one; the EAFRD does not seem to affect total TFP growth.

The estimated ERDF coefficient implies a not negligible effect on the level of TFP in the long-run: a 10% increase in ERDF investments entails an increase in total productivity of around 0.4% every four years. This result indicates that the ERDF is effective at promoting regional productivity growth through its focus on infrastructure development, support for small and medium-sized enterprises, and investment in innovation and technology, which directly impact the productivity and competitiveness of regions.

As for the EAFRD, ESF and CF investments, it is important to remark that they may have different and specific goals, such as social inclusion in the case of ESF and improving the agricultural sector's competitiveness in the case of EAFRD. These objectives are not meant to directly increase production efficiency. On the contrary, given that in the period analyzed, two severe financial crises – the subprime one (2008) and the sovereign debt one (2011) – hit the economic system worldwide with particularly disruptive effects at the local level, the ESF and CF funds have been used to support employment and build resilience, especially in lagging-behind regions. This might have had adverse effects on efficiency. Unfortunately, given that the Covid-19 pandemic occurred when some European regions were still recovering from the previous crises, it will take some time before detecting possible positive effects of ESF and CF on TFP growth.

5.2 Impact heterogeneity over time

As outlined in paragraph 3.2, new EU regions have received substantial financing from ESIF after 2007. Hence, examining each sub-period separately is essential to explore potential time heterogeneity in the program's economic impact.

In columns (3)-(6) of Table 5 we report the empirical results for each sub-period considering the main four EU funds.[10] The estimated coefficient for ERDF is positive (0.0015) and significant for 2000-2004, while it is non-significant for the two following periods and positive (0.0023) and significant again in the years 2014-2019. The effect of ERDF over 2008-2014 is non-significant, suggesting the financial crisis might have also influenced the efficacy of the fund. Furthermore, during the financial crisis, the European Commission set a recovery plan that encouraged the use of ESIF for counter-cyclical aims and suggested that Member States shift policy priorities to contain the adverse economic effects of the crisis (European Commission 2008 a, b). The shift in program priorities may have also affected the impact of ERDF on regional productivity growth. Moreover, it is worth noting that the sizeable effect for the last period 2014-2019 suggests that ESIF's impact on TFP growth became more pronounced as new EU regions fully benefitted from the funding after overcoming the financial crisis's immediate challenges.

[10] Note that when the models are estimated by including aggregate EU funds, they turn out to be significant only in the last subperiod, 20014-19.

As for the other funds, their coefficients fail to reach significance in the sub-period analysis, the only exception being the case of ESF in the period 2004-2008, for which we confirm evidence of an adverse effect on productivity growth.

The estimated coefficient for the initial TFP level reveals the evolution of the convergence process over time. Convergence was faster during the first two periods (2000-2004, 2004-2008), while it slowed down during the financial crisis (2008-14) and basically ceased after that (2014-19). Contextual variables overall turned out to be effective in controlling for factors influencing TFP growth, although with varying levels of significance across the sub-periods.

In the next section, our investigation focuses on ERDF to address the issue of potential spatial heterogeneity in its effects.

5.3 ERDF impact over space

In section 3 we documented distinct productivity trends and differences in fund allocation among EU macro areas, which might determine spatial heterogeneous ERDF's impacts. Different impacts could also be determined by different regional pursued objectives. Di Comite et al. (2018) offer a detailed overview of ESIF, emphasizing their significant contribution to developing new transport infrastructure in new EU regions. This strategic choice has strengthened economic relationships between new European territories and central European manufacturing firms, determining a crucial shift in the EU economic framework.

The possible spatial heterogeneity of the ERDF's effect is investigated by introducing two interaction terms between ERDF and the territorial dummies New and South (Table 6). Because our focus is now on ERDF, we have aggregated the other funds in a single variable (Other funds). The results highlight a great deal of spatial and time heterogeneity. In the first period (2000-2004), ERDF had a positive and statistically significant impact (0.0016) for central-northern regions (the reference group). No significant differences are detected with respect to regions located in New accession countries. Conversely, Southern regions significantly underperform, with an overall negative coefficient of -0.0006. Such an effect worsened in the following two subperiods (-0.0022 and -0.0015), but it finally bounced back in the last period (0.0030), signalling a substantial recovery in ERDF effectiveness. However, Eastern regions in New countries, after failing to reap the benefit of ERDF funding during the central subperiods severely characterized by the financial crises, outperformed Southern regions with an overall effect of 0.0055. The ineffectiveness of ERDF in Southern regions for most of the periods analyzed might reasonably be attributed to structural conditions, especially weak regional governance, low quality of institutions and lack of institutional capacity.

Our results reveal that the impact of the ERDF exhibits substantial heterogeneity, varying across both sub-periods and macro-areas. This complements the evidence of spatial variability documented by Di Caro and Fratesi (2022) and Crescenzi and Giua (2020) in their analyses on GDP growth. ERDF has persistently sustained regional productivity in central-northern territories, while its positive and significant impact in other EU areas emerged only in the latest period. This finding is in line with expectations for new EU territories, which started receiving substantial financing only in 2007. In contrast, this raises concerns for Southern regions where, despite long-term funding since 2000, ERDF's effect was negative until 2014.

Overall, ERDF has contributed to narrowing the productivity disparities among EU macro-areas in recent years, fostering productivity, especially in the new EU accession areas with low TFP levels and southern regions with low TFP annual growth rates. The positive impact of the ERDF for 2014-2019 could be attributed to new policy guidelines introduced for the 2014-2020 programming period. These guidelines prioritized innovation, the development of information and communication technologies (ICTs), and the competitiveness of small and medium-sized enterprises (SMEs) (EU Regulation 1301/2013), which likely influenced the fund's impact on productivity.

Results also indicate that the higher impact of ERDF in the newly integrated countries is the primary factor behind the positive overall effect of ESIF from 2014 to 2019.

6. EAFRD and agricultural productivity: an extension

The analysis of ESIF has revealed the positive and significant impact, even if highly heterogeneous, of ERDF on regional TFP growth. In contrast, other funds have not positively affected regional productivity growth. These findings underscore the necessity for more specific evaluations for other funds that pursue idiosyncratic aims and should thus be evaluated using alternative frameworks and outcome variables.

The analysis of Mussida et al. (2023) represents a notable example: the authors have evaluated the impact of funding allocated through the ERDF and ESF under the thematic policy objectives "sustainable and quality employment" and "social inclusion" on material deprivation in the Spanish regions. Their approach, which accounted for personal and regional characteristics, revealed that interventions aimed at social inclusion effectively mitigate the risk of individual material deprivation.

In this section, we propose a specific analysis for the fund devoted to the agricultural sector, the EAFRD, whose amount has steadily increased during the period of analysis, almost reaching the ERDF one in the period 2016-18, as reported in Table 2. EAFRD's main objectives are rural development and the enhancement of agricultural competitiveness through strategic investments.[11] Given its sector-specific objectives, it is crucial to conduct a detailed examination of the fund's effectiveness within this domain. This analysis is essential for accurately assessing EAFRD's role in supporting rural development.

We assess EAFRD impact following the same methodological framework employed for the previous analysis. Using sectoral data on value added, employment and gross fixed capital formation, we first compute the agricultural regional TFP annual average growth rates as in section 3, including country dummies instead of regional fixed effects. The estimated elasticity is around 0.54 for both the capital stock and the labor input (see Table A4).

Table 7 reports some descriptive statistics regarding TFP levels and TFP annual average growth rates across the EU macro areas for different sub-periods. As in the case of the overall TFP, new EU regions show the lowest TFP levels and the highest average growth rates. Conversely, Southern territories, given their productive specialization, show the highest levels of TFP, but the lowest average growth rates, except for the 2004-2008 period. Central-northern countries, on the other hand, present TFP levels and average growth rates that almost align with the EU averages.

[11] In 2005, EAFRD replaced the Guidance section of the former (EAGGF) (Regulation (EC) No 1290/2005).

Main results for the impact of EAFRD on agricultural TFP growth are reported in Tables 8 and 9 and are based on the estimation of Spatial error models.[12] Contextual variables include human capital and social capital, as in the analysis discussed in the previous section, we then included some control variables specific to rural activities. More specifically, we employed the regional number of patent applications in the agricultural field presented at the European Patent Office (EPO) as a proxy for technological capital (Maraut et al., 2008; OECD, 2009; Eurostat, 2011).[13] Moreover, we include regional per capita hectares of utilized agricultural area (Eurostat) to account for the specific endowments of the rural sector.[14] Overall, contextual variables' coefficients exhibited the expected sign, although their significance was mostly confined to the first two sub-periods. The results in Table 8 show no relevant effects of EARDF when the panel model is estimated (column 1). This unexpected result is explained when we perform the analysis by subperiods: a positive and highly significant effect (0.0094) is found for the first sub-period (2004-2008), followed by an almost offsetting effect (-0.0086) in the subsequent period (2004-2008); no relevant effects are detected for the last two sub-periods.

To deepen our understanding of the high heterogeneity of our findings over time, we refined the analysis by examining EAFRD impact across regions with different initial levels of agricultural productivity. We categorized regions into three groups: highest productivity (4th quartile), lowest productivity (1st quartile), and those with levels of productivity within the interquartile range. This categorization is crucial, given that EAFRD focuses on enhancing the competitiveness and productivity of the agricultural sector. Thus, we re-estimate the sub-period models by introducing interaction terms between EAFRD funding and the highest and lowest initial regional TFP quartiles.

Results, reported in Table 9, confirm the positive effect of EAFRD during the first subperiod, 2000-2004, with no significant differences across different levels of initial TFP. In the second sub-period the bottom TFP regions exhibit more than twice the negative effect reported for all the other regions. This adverse effect of EAFRD, although less sizeable, is confirmed in the next subperiod, while no significant effect is found for the last period. Also, top TFP regions show a negative EAFRD impact in the period 2004-2008, but positive and significant effects (0.0075 and 0.0107) during the last two subperiods.

Overall, results indicate that the EAFRD effectively stimulates productivity growth primarily in regions with already high levels of agricultural productivity. In such regions, EAFRD funding may complement existing strengths, amplifying the fund's impact on productivity. However, the effect of EAFRD on total productivity growth is notably different in regions with lower levels of agricultural productivity. It is worth noting that, although EAFRD does not show a positive effect on TFP growth in less productive areas, it may still have beneficial impacts on farmers' income and rural firms' performance.

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[12] We carried out the same testing procedure described in section 4 for detecting the most adequate specification, which was again the spatial error model, except for the model for the period 2000-2004. In the latter case the linear specification with no autocorrelated errors was selected.

[13] For the selection of the agriculture patents, we consider the group A01 in the International Patent Classification. Patents have been regionally distributed considering inventors' residence.

[14] The estimation results for EAFRD remain unchanged if we estimate the model using the same set of controls employed in section 5.

These findings, over and above the effects brought about by the 2008 and 2011 crises, might be due to at least two concurrent explanations. The first acknowledges that bottom TFP regions are especially located in Eastern Europe, an area which, following the EU accession, underwent a deep restructuring of its productive system transforming its specialization from agriculture to low-tech manufacturing. At the same time, the other regions, while delocalizing low-tech productions eastward, increased their specialization in high-tech knowledge intensive productions, including precision farming, by taking advantage of technological advancements in the green economy (Marrocu et al., 2013).

The second complementary explanation is based on the consideration of the long-term orientation of EAFRD investments, which are geared towards gradual improvements in competitiveness and sustainability. Such strategic investments might need more time to manifest their effects given the post-crisis recovery process, which involves a new reorientation of production specializations induced by the global megatrends, such as restructuring global value chains and green and digital transitions. Such processes, especially in the case of less performing regions, require strengthening their internal capabilities in order to reap the benefits of EU funding initiatives.

7. Conclusions and policy implications

This study has investigated the impact of the ESIF on regional TFP growth. A salient contribution of our analysis is that, differently from other studies, we focus on TFP instead of GDP. This allows us to estimate the ESIF's impact more rigorously because by analysing TFP, we can account for all the other relevant sources of regional capital accumulation.

The analysis has been carried out for the period 2000-2019, considering a comprehensive set of 262 NUTS2 European regions. Our main results point to a non-significant effect when ESIF are considered aggregate in a single fund. However, when we focused on the main four funds included in ESIF, we found that the ERDF had a positive effect on TFP growth, unlike other structural funds, which did not exhibit a direct positive influence on regional TFP growth.

To assess possible heterogeneity in the ERDF impact, we carried out a sub-period analysis. This approach revealed varying impacts over time, ERDF was effective in the periods 2000-2004 and 2014-2019, while the positive effects in the intermediate periods failed to reach significance. Interestingly, we also detected varying ERDF impacts across macro-areas. For Southern regions, despite being fund recipients for a long time, the ERDF impact was negative till 2014, but in the last sub-period it was twice as large as the one exhibited by Centre-North regions. The ERDF impact for New accession countries regions was basically in line with the Centre-North ones in the first three sub-periods, but in the last one, they outperformed all other regions, with an impact that was four times as large as the Centre-North one and nearly twice the South one.

These results provide sound evidence of the crucial role played by ERDF in enhancing productivity growth and in favoring the convergence process of new regions, but at the same time, our analysis outlines how the impact of EU structural policy depends on the fund, the period, and the geographic area considered. Such a great heterogeneity underscores the complexity of ESIFs' effects and highlights important policy implications, offering valuable insights into the effectiveness of the programs.

The ERDF has positively impacted regional productivity growth, standing out as the only fund to do so. However, it accounts for only 33% of total ESIF expenditures during the 2016-2018 period, with its share experiencing a gradual decline. This trend raises concerns, especially considering the pervasive 'development trap' affecting EU regions, as highlighted by Diemer et al. (2022). In response to these challenges, the European Union should direct more financial support toward boosting regional productivity, taking full advantage of the ERDF's proven success in stimulating economic growth across the Union.

As mentioned above, the analysis reveals a time-heterogeneous effect of the ERDF, highlighting its limited effectiveness during the 2008 financial crisis. This observed inefficacy might have been determined by the partial shift away from the ESIF original goals to mitigate the adverse economic impacts of the crises. For instance, during the COVID-19 pandemic, 37 billion euros from ESIF were redirected to bolster member states' health systems and support small and medium-sized enterprises (SMEs) (Regulation 2020/460). Additionally, the EU allowed countries to reallocate resources across different regional categories (Regulation 2020/558), and more recently, structural funds have contributed to financing the Repower EU initiative to address the energy crisis triggered by the Russia-Ukraine conflict. While these reallocations toward short-term crisis interventions are justifiable, they may reduce resources from the ESIF core mission of fostering regional economic growth and convergence. This shift highlights the urgent need for crafting alternative strategies that preserve the integrity of ESIF primary objectives, ensuring that immediate crisis responses do not overshadow long-term development goals.

The concerning ERDF ineffectiveness in Southern regions before 2014 might have been caused by different factors. Primarily, Southern EU regions may have struggled to invest these funds efficiently, given their scarce human capital endowment and low institutional quality - a critical issue highlighted by Aresu et al. (2023), Di Caro and Fratesi (2022), and Incaltarau et al. (2020). Additionally, EU targets might not have been aligned with southern territories' economic needs. The turning point came with the policy reforms implemented for the 2014-2020 programming period, which placed a renewed focus on innovation, ICTs, and support for SMEs. This strategy was implemented through initiatives such as the Smart Specialization Strategy (S3), for which some evidence is emerging on its effectiveness in revitalizing the economies of Southern EU countries, as documented by Serafini et al. (2023) and Santos et al. (2023). Given these insights, the EU should maintain and even amplify its commitment to fostering innovation, digital transformation, and SME support in the upcoming programming periods. This strategic orientation not only aligns with the evolving economic landscape but also capitalizes on the demonstrated potential of these domains to trigger economic growth and development in Southern Europe.

Finally, our focus on the EAFRD and its impact on the agricultural sector has allowed us to investigate the fund's impact by considering its specific objectives. Contrary to its non-positive effect on regional aggregate TFP growth, our sector-specific analysis unveiled more insights into the EAFRD effect. We found that regions with higher agricultural productivity can take full advantage of EAFRD funding, whereas the fund's impact in less productive areas tends to be negative.

Our findings highlight the necessity for meticulous evaluations of ESIF impacts, considering each fund's distinct objectives and aims. This emphasizes the need to adopt more accurate analytical frameworks for a deeper understanding of funds' differentiated impacts and providing more effective policy implications.

From a policy perspective, the high degree of variability that we detected in the effectiveness of ESIF across funds, regions and time, suggests a deeply tailored approach to maximize their benefits. Such an approach is particularly needed for ERDF, which has shown a positive impact on regional productivity, especially in central-northern regions and new EU accession areas.

To amplify the ERDF's impact, policies must prioritize several strategic areas. Supporting regional innovation policies, such as the Regional Smart Specialization Strategy, with a specific focus on green and digital transitions, is vital. Strengthening digitalization initiatives across all regions will ensure that even the most remote areas benefit from technological advancements, thereby driving regional productivity. Additionally, the development of network infrastructure, including transportation, communication, and energy infrastructures, is crucial to reinforce regional integration and ensure that regions are not just connected but thriving as integrated economic entities.

The European Agricultural Fund for Rural Development (EAFRD) has shown varied impacts, being more effective in regions with high initial productivity. To harness its full potential, policies should be finely tuned. In high-productivity regions, EAFRD investments should continue to enhance competitiveness and technological advancements, positioning these regions as global leaders in agricultural innovation. In contrast, low-productivity regions require targeted capacity-building initiatives to utilize EAFRD funds effectively. Policies should also encourage sustainable agricultural practices and investments in green technologies to ensure that agricultural productivity growth is both robust and environmentally sustainable.

To bridge the economic divide across European regions, a multifaceted approach is essential. In underperforming regions, mainly in Southern and Eastern countries, weak institutions and governance often impede progress. Capacity-building programs can empower local governments, enhancing their effectiveness and integrity. Additionally, investing in human capital through education and training programs is crucial to equip the workforce with the skills needed for ~~modern~~ advanced economic activities. This tailored and diversified regional strategy is key to bridging productivity gaps, reducing spatial inequalities, and fostering sustainable economic development throughout the EU.

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FIGURES AND TABLES

Figure 1.a: TFP level. Index EU=100. Year 2000

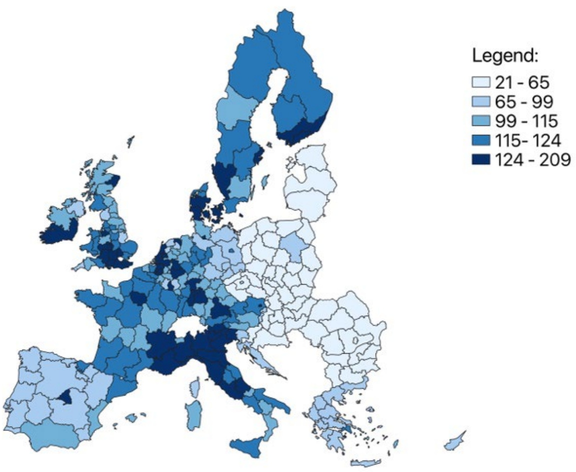

Figure 1.b: TFP annual average growth rate (%) 2000-2019

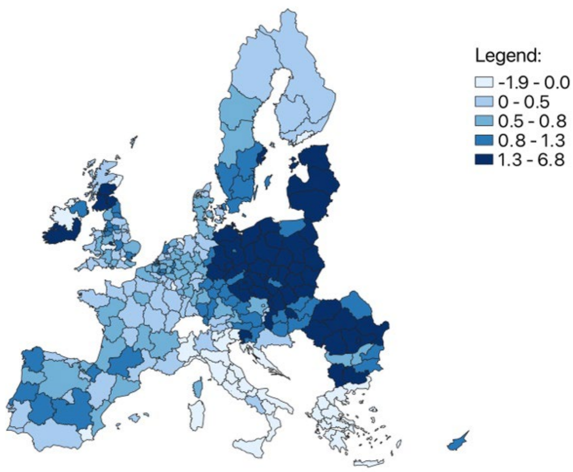

Figure 2: Per capita ESIF over time for macro areas (Euro, constant prices, 2015)

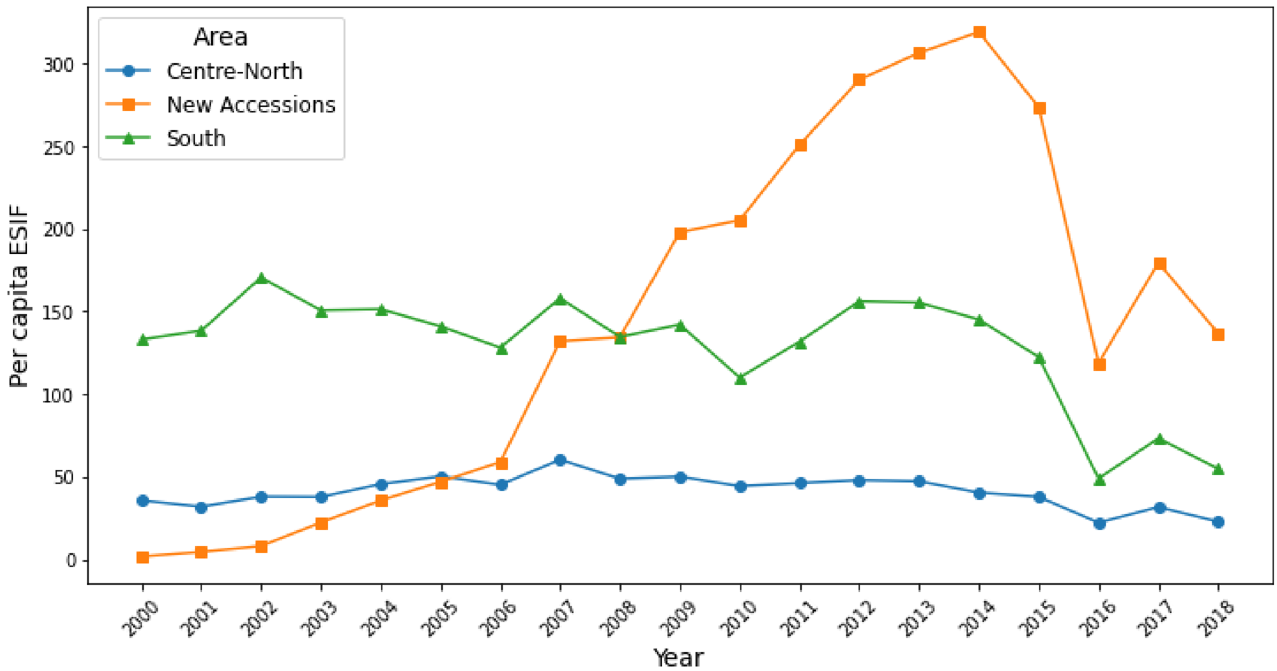

Figure 3: Regional per capita ESIF expenditure, 2018 (Euro, constant prices, 2015)

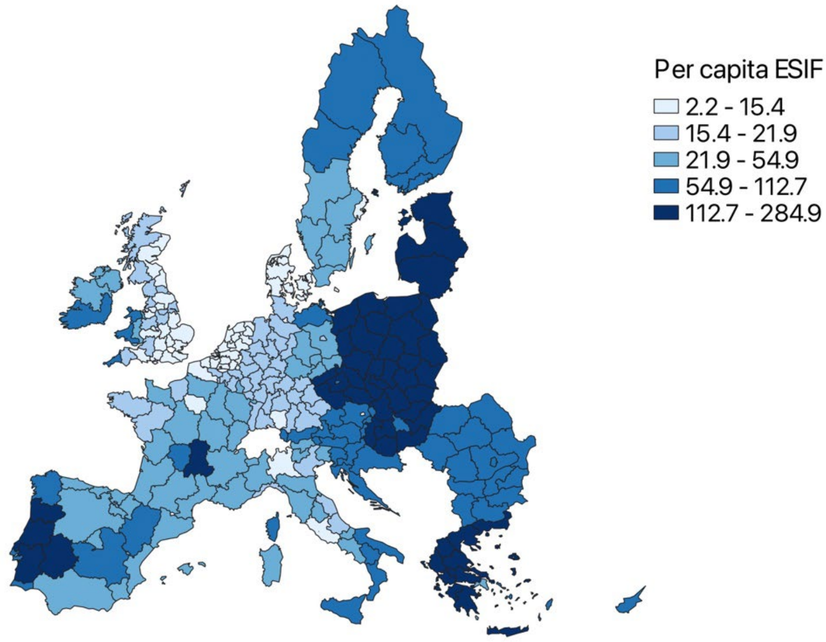

Table 1. Total Factor Productivity in EU macro-areas

	Centre-North	South	New accession	European Union
Index TFP level, EU=100				
2000	119	104	45	100
2004	119	99	50	100
2008	120	95	53	100
2014	121	91	54	100
2019	119	91	58	100
TFP annual average growth rate, %				
2000-2004	1.31	0.06	3.90	1.61
2004-2008	0.83	-0.36	2.30	0.90
2008-2014	0.26	-0.75	0.41	0.08
2014-2019	0.41	0.80	2.12	0.86
2000-2019	0.64	-0.09	1.99	0.78

South: Italy, Spain, Greece, Portugal

New: 12 new accession countries

Centre-North: remaining 11 Western Central and Northern countries

Table 2. Modelled EU funds (average % shares)

Fund		2000-2003	2008-2010	2016-2018
ERDF	European Regional Development Fund	56.1	43.1	32.8
EAFRD	European Agricultural Fund for Rural Development	9.8	22.8	31.2
ESF	European Social Fund	21.9	18.0	16.0
CF	Cohesion Fund	12.3	16.1	15.3
EMFF	European Maritime and Fisheries Fund	0.0	0.0	3.0
FEAD	Fund for European Aid to the Most Deprived	0.0	0.0	1.0
YEI	Youth Employment Initiative	0.0	0.0	0.7
Total		100.0	100.0	100.0

Table 3. Modelled EU funds by macro-areas 2000-2019 (average % shares)

	Centre-North	South	New accession	Europe
ERDF	47.5	57.8	40.3	49.6
EAFRD	26.3	14.8	17.2	18.5
ESF	25.3	15.8	12.6	17.3
CF	0.9	11.6	29.9	14.6
TOTAL	100.0	100.0	100.0	100.0

South: Italy, Spain, Greece, Portugal

New: 12 new accession countries

Centre-North: remaining 11 Western Central and Northern countries

Table 4. Regional contextual factors for macro-areas (index, EU=100)

	Centre-North		South		New accession	
	2000	**2018**	**2000**	**2018**	**2000**	**2018**
Human Capital	125	114	74	85	68	84
Technological Capital	160	150	51	54	12	23
Social Capital (a)	128	134	85	91	49	32
Institutional quality	112	116	91	80	76	78
Population density	108	111	101	104	85	77

South: Italy, Spain, Greece, Portugal

New: 12 new accession countries

Centre-North: remaining 11 Western Central and Northern countries

(a) initial year 2002, final year 2014

Table 5. EU funds and TFP growth

Dependent variable: TFP annual average growth rate

	Panel models		Sub-period models			
	(1)	(2)	(3)	(4)	(5)	(6)
			2000-2004	2004-2008	2008-2014	2014-2019
Total ESIF	-0.0009 **					
	(0.0004)					
ERDF		0.0009 **	0.0015 **	0.00004	0.0006	0.0023 **
		(0.0004)	(0.0007)	(0.0008)	(0.0009)	(0.0010)
EAFRD		-0.0006	-0.0011	-0.0003	-0.0003	0.0019
		(0.0005)	(0.0009)	(0.0011)	(0.0011)	(0.0014)
ESF		-0.0016 ***	0.0002	-0.0023 *	-0.0012	-0.0021
		(0.0006)	(0.0010)	(0.0014)	(0.0015)	(0.0018)
CF		-0.0009 **	-0.00082	0.0006	-0.0010	0.00004
		(0.0004)	(0.0007)	(0.0010)	(0.0008)	(0.0014)
Human Capital	0.0053 ***	0.0062 ***	0.0113 ***	-0.0036	0.0083 ***	0.0028
	(0.0013)	(0.0014)	(0.0020)	(0.0030)	(0.0027)	(0.0033)
Technological Capital	0.0029 ***	0.0028 ***	0.0009	0.0062 ***	0.0011	0.0001
	(0.0006)	(0.0005)	(0.0009)	(0.0011)	(0.0011)	(0.0012)
Social Capital	0.0031 *	0.0029	-0.0011	0.0104 ***	0.0001	0.0072 **
	(0.0019)	(0.0019)	(0.0029)	(0.0038)	(0.0042)	(0.0030)
Population density	0.0015 ***	0.0014 ***	0.0001	0.0031 ***	0.0009	0.0030 ***
	(0.0004)	(0.0004)	(0.0007)	(0.0008)	(0.0009)	(0.0009)
Initial TFP level	-0.0238 ***	-0.0247 ***	-0.0287 ***	-0.0372 ***	-0.0123 ***	-0.0032
	(0.0025)	(0.0025)	(0.0044)	(0.0060)	(0.0049)	(0.0064)
New	0.0052 ***	0.0056 **	0.0083	0.0008	0.0013	0.0161 ***
	(0.0019)	(0.0025)	(0.0058)	(0.0050)	(0.0046)	(0.0056)
South	-0.0041 ***	-0.0028 *	-0.0086 ***	-0.0073 **	-0.006 **	0.005 **
	(0.0012)	(0.0015)	(0.0027)	(0.0033)	(0.0028)	(0.0022)
Spatial error lag	0.8328 ***	0.8330 ***	0.6991 ***	0.5494 *	0.8379 ***	--
	(0.0767)	(0.0770)	(0.2215)	(0.3152)	(0.1318)	
Observations	1016	1016	246	246	262	262

Estimation method: Maximum Likelihood

Model specification: spatial error models, except for the linear 2014-2019 model

Spatial matrix: max-eigenvalue normalized inverse distance matrix with cut-off at 600 km

All right-hand side variables are per capita, log-transformed and refer to initial year of the period considered

New and South are dummy variables for regions in New accession countries or in Southern countries, respectively (see Table 4).

Time dummies included in panel models

Regional observations: 246 regions (2000-2004, 2004-2008), 262 regions (2008-2014, 2014-2019)

4 sub periods: 2000-2004, 2004-2008, 2008-2014, 2014-2019.

RO, BG, HR considered for the period 2007-2019. Before 2007 they were only receiving CF.

Robust Standard Error, in parentheses.

Significance levels: ***(1%), **(5%), *(10%).

Table 6. ERDF and TFP growth in macro areas and sub-periods

Dependent variable: TFP annual average growth rate

	2000-2004	2004-2008	2008-2014	2014-2019
ERDF	0.0016 **	-0.0004	0.0009	0.0015 *
	(0.0007)	(0.0008)	(0.0008)	(0.0008)
ERDF * New	-0.0012	0.0007	-0.00005	0.0040 ***
	(0.0016)	(0.0012)	(0.0009)	(0.0011)
ERDF * South	-0.0021 ***	-0.0018 **	-0.0024 ***	0.0015 **
	(0.0006)	(0.0008)	(0.0007)	(0.0006)
Other Funds	-0.0008 *	-0.0001	-0.0004	-0.0006
	(0.0005)	(0.0006)	(0.0006)	(0.0010)
Human Capital	0.0119 ***	-0.0031	0.0072 ***	0.0030
	(0.0019)	(0.0029)	(0.0024)	(0.0025)
Technological Capital	0.0009	0.0063 ***	0.0011	0.0003
	(0.0009)	(0.0011)	(0.0011)	(0.0011)
Social Capital	-0.0020	0.0094 **	-0.0008	0.0063 **
	(0.0029)	(0.0039)	(0.0041)	(0.0030)
Population density	0.0003	0.0033 ***	0.0008	0.0017 ***
	(0.0007)	(0.0008)	(0.0008)	(0.0007)
Initial TFP	-0.0351 ***	-0.0397 ***	-0.0103 **	-0.0056
	(0.0031)	(0.0057)	(0.0044)	(0.0066)
Spatial error lag	0.7236 ***	0.5285 *	0.8135 ***	--
	(0.2121)	(0.3199)	(0.1481)	
Computed ERDF effect by macro-area				
Centre-North	0.0016	-0.0004	0.0009	0.0015
New	0.0016	-0.0004	0.0009	0.0055
South	-0.0006	-0.0022	-0.0015	0.0030
Observations	246	246	262	262

Estimation method: Maximum Likelihood

Model specification: spatial error models, except for the linear 2014-2019 model

Spatial matrix: max-eigenvalue normalized inverse distance matrix with cut-off at 600 km

All right-hand side variables are per capita, log-transformed and refer to initial year of the period

New and South are dummy variables for regions in New accession countries or in Southern countries, respectively (see Table 4).

Regional observations: 246 regions (2000-2004, 2004-2008), 262 regions (2008-2014, 2014-2019)

RO, BG, HR considered for the period 2007-2019. Before 2007 they were only receiving CF.

Robust Standard Error, in parentheses.

Significance levels: ***(1%), **(5%), *(10%).

Table 7. Agriculture Total Factor Productivity by macro-area

	Centre-North	South	New accession	European Union
Index TFP level, EU=100				
2000	100	140	61	100
2004	105	119	70	100
2008	106	114	71	100
2014	104	122	68	100
2019	101	123	76	100
TFP % annual average growth rate				
2000-2004	3.57	-1.53	7.29	3.31
2004-2008	-0.21	-1.97	-0.12	-0.56
2008-2014	0.09	1.51	-0.12	0.35
2014-2019	-2.04	-0.03	1.18	-0.91
2000-2019	0.20	-0.27	1.78	0.57

South: Italy, Spain, Greece, Portugal

New: 12 new accession countries

Centre-North: remaining 11 Western Central and Northern countries

Table 8. EAFRD and agricultural TFP growth

Dependent variable: agricultural TFP annual average growth rate

	Panel model	Sub-period models			
	(1)	(2)	(3)	(4)	(5)
		2000-2004	2004-2008	2008-2014	2014-2019
EAFRD	-0.0030	0.0094 ***	-0.0086 **	-0.0003	0.0053
	(0.0019)	(0.0031)	(0.0040)	(0.0033)	(0.0059)
Agriculture tecnological capital	0.0093	0.0264 **	0.0304	-0.0155	0.0024
	(0.0080)	(0.0135)	(0.0188)	(0.0120)	(0.0155)
Utilised land	0.0019	-0.0060 *	0.0100 ***	0.0015	-0.0040
	(0.0016)	(0.0032)	(0.0036)	(0.0026)	(0.0041)
Human Capital	0.0124 **	0.0024	0.0300 **	0.0097	-0.0009
	(0.0057)	(0.0101)	(0.0139)	(0.0081)	(0.0128)
Social Capital	0.0151 *	-0.0031	0.0127	0.0316 **	0.0249
	(0.0085)	(0.0141)	(0.0202)	(0.0144)	(0.0166)
Initial TFP level	-0.0566 ***	-0.0675 ***	-0.0446 ***	-0.0530 ***	-0.0273 ***
	(0.0042)	(0.0081)	(0.0103)	(0.0059)	(0.0099)
Spatial error lag	0.7436 ***	--	0.8192 ***	0.5725 *	0.8714 ***
	(0.1272)		(0.2087)	(0.3262)	(0.1257)
Observations	1016	246	246	262	262

Estimation method: Maximum Likelihood

Model specification: spatial error models, except for the linear 2000-2004 model

Spatial matrix: max-eigenvalue normalized inverse distance matrix with cut-off at 600 km

All right-hand side variables are per capita, log-transformed and refer to initial year of the period considered

New and South dummy variables included

Time dummies included in panel model

Regional observations: 246 regions (2000-2004, 2004-2008), 262 regions (2008-2014, 2014-2019)

4 sub periods: 2000-2004, 2004-2008, 2008-2014, 2014-2019.

RO, BG, HR considered for the period 2007-2019. Before 2007 they were only receiving CF.

Robust Standard Error, in parentheses.

Significance levels: ***(1%), **(5%), *(10%).

Table 9. EAFRD and agricultural TFP growth in sub-periods for different productivity level

Dependent variable: agricultural TFP annual average growth rate

	2000-2004	2004-2008	2008-2014	2014-2019
EAFRD	0.0096 ***	-0.0081 *	0.0024	0.0038
	(0.0036)	(0.0044)	(0.0033)	(0.0060)
EAFRD * TFP lowest quartile	-0.000487	-0.0105 *	-0.0098 ***	-0.0033
	(0.0051)	(0.0061)	(0.0023)	(0.0039)
EAFRD * TFP highest quartile	-0.000354	0.0046	0.0051 **	0.0069 *
	(0.0039)	(0.0055)	(0.0025)	(0.0038)
Agriculture tecnological capital	0.0265 *	0.0318 *	-0.0085	0.0011
	(0.0135)	(0.0186)	(0.0117)	(0.0155)
Utilised land	-0.0060 *	0.0100 ***	0.0021	-0.0032
	(0.0032)	(0.0035)	(0.0025)	(0.0041)
Human Capital	0.0024	0.0271 **	0.0096	-0.0034
	(0.0101)	(0.0139)	(0.0080)	(0.0130)
Social Capital	-0.0031	0.0132	0.0349 ***	0.0245
	(0.0142)	(0.0202)	(0.0141)	(0.0166)
Initial TFP	-0.0675 ***	-0.0625 ***	-0.0832 ***	-0.0491 ***
	(0.0101)	(0.0139)	(0.0091)	(0.0172)
Spatial error lag	--	0.8095 ***	0.6754 ***	0.8745 ***
		(0.2167)	(0.2566)	(0.1200)
Computed EAFRD effect by TFP quartile				
Inter-quartile range	0.0096	-0.0081	0.0024	0.0038
Lowest quartile	0.0096	-0.0187	-0.0074	0.0038
Highest quartile	0.0096	-0.0081	0.0075	0.0107
Observations	246	246	262	262

Estimation method: Maximum Likelihood

Model specification: spatial error models, except for the linear 2000-2004 model

Spatial matrix: max-eigenvalue normalized inverse distance matrix with cut-off at 600 km

All right-hand side variables are per capita, log-transformed and refer to initial year of the period considered

New and South dummy variables included

Time dummies included in panel model

Regional observations: 246 regions (2000-2004, 2004-2008), 262 regions (2008-2014, 2014-2019)

4 sub periods: 2000-2004, 2004-2008, 2008-2014, 2014-2019.

RO, BG, HR considered for the period 2007-2019. Before 2007 they were only receiving CF.

Robust Standard Error, in parentheses.

Significance levels: ***(1%), **(5%), *(10%).

APPENDIX

A1. Computation of Total Factor Productivity at the regional level

Following Marrocu et al. (2022), we compute regional TFP levels using a quasi-growth accounting approach. We first estimate labor and capital elasticities from a Cobb-Douglas (CD) production function, and then we compute the regional TFP levels for 2000-2019 by applying the growth accounting method using the estimated factors elasticities, assumed invariant over the considered period.
The CD is log-linearised as follows:

$$\ln(GVA_{it}) = \beta_K \ln(K_{it}) + \beta_L \ln(L_{it}) + \alpha_i + \delta_t + \varepsilon_{it} \quad \text{(A1)}$$

where $i = 1, \dots N$ (262 regions); $t = 2000, \dots, 2019$ (20 years); GVA is Gross Value Added, K is capital stock, and L are units of labor; $\square_i$ are regional fixed effects, $\square_t$ are times dummies, and $\square_{it}$ is the error term. The procedure to construct the capital stock is described in section A2.
To deal with the usual production function endogeneity problem, we apply the Fixed Effects Two Stage Least Squares (2SLS) estimation method, employing the one-year lagged input factors as instrumental variables. Similar results are obtained using the two-year lagged factors as instruments. The estimated elasticities are 0.3 for the capital stock and 0.62 for the labor input. Table A2 reports the estimation results for the Cobb-Douglas production function.

A2. Capital stock computation

Since the lack of data on regional capital stock, the series has been built by employing data on national capital stock published by the IMF (sum of public, private and PPP capital stock) (2017). To fully exploit the IMF dataset, for 14 EU countries (AT, BE, DE, DK, EL, FI, FR, IE, IT, LU, NL, PT, SE, UK) we use series for 1990-2020, by computing the initial value of capital stock in 1989 as the mean value of the national capital stock for 1988-1989. For the other 14 EU countries (BG, CY, CZ, EE, ES, HR, HU, LT, LV, MT, PL, RO, SI, SK) the series have been calculated for 2000-2020, computing the initial value in 1999 considering the annual mean value of national stock for 1996-1999.

The capital stock initial value at the regional level has been computed using the methodology proposed by Gleed and Rees (1979): the initial regional value is based on the regional share of investments (weight 0.75) and the regional share of labour units (weight 0.25) for 1988-1989 for the first group of countries and 1996-1999 for the other. Initial regional capital values have been measured in constant prices (2015) employing the AMECO deflator. The rest of the series have been calculated using the perpetual inventory methodology, which states that the value of the capital stock at time t is equal to the value at time t-1, augmented by investment measured at time t and diminished by depreciation (we assume a 10% depreciation rate). The series of the stock of capital is expressed in constant euros 2015 to avoid variations caused by inflation.

Appendix Tables

Table A1. Variables definition and sources

Variable	Description	Primary Source
Value Added	Constant values at 2015 price	EUROSTAT
Labour Units	Units	EUROSTAT
Gross fixed capital formation	Constant values at 2015 price	EUROSTAT
Capital stock	Constant values at 2015 price	Own calculation
Total Factor Productivity	Estimated index	Own estimation
European Regional Development Fund	Per capita values (constant price 2015)	European Comission
European Agricultural Fund Rural Development	Per capita values (constant price 2015)	European Comission
European Social Fund	Per capita values (constant price 2015)	European Comission
Cohesion Fund	Per capita values (constant price 2015)	European Comission
European funds	Sum of ERDF, ESF, EAFRD, CF	Own calculation
Human capital	% people 25-64 years with a tertiary education level (ISCED 5-6)	EUROSTAT
Research and Development	R&D expenditure, per capita (constant price 2015)	EUROSTAT
Technological capital	Patent applications at European Patent Office per 100,000 inhabitants	OECD
Social capital	% people who have worked in a volunteer organization	Own elaboration on European Social Survey
Quality of Institution	Quality of instituion index	Univ. Gothenburg, World Bank
Production structure	Revealed Comparative Advantage, various sectors, based on employment data	EUROSTAT
Population Density	Resident population per square km	EUROSTAT
Agriculture technological capital	Patent applications at European Patent Office per 100,000 inhabitants in group AO1	OECD
Utilised agricultural area	Per capita hectares	EUROSTAT

262 regions (NUTS 2) (PL90, HU10 NUTS 1 (2013)), 27 countries
SK is not available for 2000, we have considered 2002 as initial values
For Bulgaria, Hungary and Romenia EU funds start in 2007

Table A2. Estimation of Cobb-Douglas production function. 2000-2019

Dependent variable: value added, constant prices 2015	
Labour	0.622 ***
	(0.137)
Capital stock	0.295 ***
	(0.091)
Fixed effect	Yes
Time dummies	Yes

Estimation method: Two Stage Least Squares
Labour and capital variables are instrumented by their own 1-year lag
All variables are log-transformed
Robust Standard Error, in parentheses, are clustered at country level
Significance levels: ***(1%), **(5%), *(10%).
NUTS2 regions: 262
Number of panel observations: 4978

Table A3. EU modelled funds by countries (average % shares)

Country		Macro-area	2000-03	2008-10	2016-18
AT	Austria	Centre-North	1.0	1.7	1.6
BE	Belgium	Centre-North	0.9	0.7	0.6
BG	Bulgaria	New accession	0.1	1.6	2.0
CY	Cyprus	New accession	0.0	0.2	0.3
CZ	Czech Republic	New accession	0.3	4.8	4.7
DE	Germany	Centre-North	14.3	9.7	6.5
DK	Denmark	Centre-North	0.2	0.3	0.4
EE	Estonia	New accession	0.1	1.2	1.3
EL	Greece	South	8.9	6.6	5.2
ES	Spain	South	29.1	11.9	6.3
FI	Finland	Centre-North	1.0	1.0	1.6
FR	France	Centre-North	5.8	4.9	6.6
HR	Croatia	New accession	0.0	0.0	1.1
HU	Hungary	New accession	0.3	5.4	6.7
IE	Ireland	Centre-North	2.7	1.1	1.1
IT	Italy	South	14.5	8.5	7.1
LT	Lithuania	New accession	0.2	2.4	2.4
LU	Luxembourg	Centre-North	0.0	0.0	0.0
LV	Latvia	New accession	0.2	1.4	1.3
NL	Netherlands	Centre-North	0.8	0.8	0.4
PL	Poland	New accession	1.3	15.4	21.0
PT	Portugal	South	10.5	6.4	6.5
RO	Romania	New accession	0.3	3.8	6.4
SE	Sweden	Centre-North	0.9	0.9	1.1
SI	Slovenia	New accession	0.1	1.1	0.8
SK	Slovakia	New accession	0.3	2.5	3.0
UK	United Kingdom	Centre-North	6.1	5.5	4.1
Total			100.0	100.0	100.0
Billion € (Price 2015)			27.5	47.8	29.5

Table A4. Estimation of Cobb-Douglas agricultural production function. 2000-2019

Dependent variable: value added, constant prices 2015	
Labour	0.539 ***
	(0.044)
Capital stock	0.543 ***
	(0.046)
Country dummies	Yes
Time dummies	Yes

Estimation method: Two Stage Least Squares

Labour and capital variables are instrumented by their own 1-year lag

All variables are log-transformed

Robust Standard Error, in parentheses, are clustered at country level

Significance levels: ***(1%), **(5%), *(10%)

NUTS2 regions: 262

Number of panel observations: 4978

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ISBN 9788868515300

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