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JEL Classification: C32, E27, E32, H30

Keywords: Recovery and Resilience fund, countercyclical policies, Regional inequalities, R&D and human capital investment, Externalities

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November 8, 2021

Abstract

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1 Introduction

July 21, 2020 is considered by many a historical date for the European Union (EU). On that day, the European Council has agreed to a new EU budget for 2021-2027 which, for the first time, includes funds that do not only come from national contributions, but are also borrowed from international financial markets. The Council has also made provisions for backing the borrowing with future union-wide carbon emission, plastic use, and financial transactions taxes, among others. Thus, an embryo of a EU federal fiscal policy has been created. Apart from the regular budget, the agreement has produced the Next Generation EU (NGEU) funds, a package of programs which, through a combination of grants and loans, intends to support the recovery from the COVID-19 pandemic and foster investments leading to a greener, digital economy.

The largest instrument among the NGEU funds, the Recovery and Resilience Facility (RRF), has been especially designed to counteract the negative effects of the COVID19 pandemic and to help countries in difficulties, by covering a portion of the funds national governments have borrowed or will borrow to help workers and firms. It should facilitate the recovery, hopefully back to the growth path existing prior to the pandemic, by creating jobs and favoring the transition to sectors and activities with larger strategic potential. The expected fiscal expansion is huge. The total budget for 2021-2027 amounts to 13 percent and the RRF about 5.5 percent of EU gross national income (GNI). In comparison, the CARES package in the US amounts to 15.9 percent of GNI (3061 billion US$) and the Chinese recovery package is only 4.2 percent of GNI (4.200 billion Yuan).

Will the effort succeed in creating jobs? Will the EU economy go back to the trend after the unprecedented fall of the second quarter of 2020? Will the conversion to a greener economy be smooth? Will the programs jump start national economies to a virtuous growth cycle? While policymakers' expectations are optimistic, the large costs and the uncertain benefits of the programs, together with the unprecedented nature of the current economic situation, call for caution and care in thinking about the consequences of the fiscal expansion the EU will undertake.

The contribution of the paper. This paper studies the regional macroeconomic dynamics produced by two EU structural funds over the last 30 years and presents a model highlighting the main transmission channels EU funds have to a typical European region. We collect stylized facts, provide a theory-based interpretation of the evidence, and offer a historical perspective that helps to evaluate the likelihood of success of the planned fiscal expansion.

The empirical analysis focuses attention on the production, investments, and labor market dynamics generated by the two major EU funds: the European regional development fund (ERDF), launched to foster innovation and research, to favor the digital agenda, and to support small and medium-sized enterprises; and the European Social Fund (ESF), whose aim was to support investments in education and health; and to fight poverty. We shed light on four important questions:

what are their macroeconomic effects? Are they uniform across regions? What may account for the differences? Is the RRF likely to succeed?

We construct a novel database of regional funds and exploit the information contained in the main regional macroeconomic aggregates of 279 European NUTS2 units. We employ an instrumental variable Bayesian approach to measure dynamic multipliers, region-by-region. With the time profile of the distribution of multipliers in hand, we summarize its characteristics using cross-sectional measures and cluster regional statistics along economic, geographical, institutional, or national dimensions.

We study federal fiscal expansions in a New Keynesian model of a monetary union with endogenous growth and externalities. R&D and human capital accumulation are affected by federal expenditure and labor productivity may be altered because of externalities. The mechanisms we build into the model are crucial to qualitatively match the average effects found in the data. We highlight the structural parameters that may generate dynamic heterogeneity and differential growth prospects.

The empirical results. The two funds have substantially different effects. ERDF has statistically significant and economically relevant average positive short-term impact on all regional variables, making it potentially useful for countercyclical purposes. These funds temporarily boost productivity and lead to an expansion of employment, compensation, investments, and production. Nevertheless, on average, the positive impact dies out quickly and gains dissipate almost entirely within three years. Instead, ESF has negative, although often insignificant, impact consequences but it exercises positive average effects on all regional variables after 2-3 years, suggesting that it could be a good instrument to achieve medium term transformation objectives. These funds temporarily affect labor markets, increasing compensation and decreasing hours worked. However, the increase in labor productivity they produce, induces positive and economically important effects on investments, employment, and production in the medium run.

Quantitatively, an increase in ERDF equalling one percent of regional gross value added (GVA) makes GVA growth jump, on average, and cumulatively over three years by 1.0%, while employment growth is 0.9% and investment growth is 1.3% over the same horizon. A similar increase in ESF leads to 5% cumulative increase in GVA growth, to a cumulative increase of 1.6% in employment growth, and to a cumulative increase of 4.3% in investments growth, on average, over three years. Thus, if the growth rate of employment, production, and investments are the yardstick to measure the success of the two programs, ESF dominates ERDF in the medium run.

Average figures hide considerable regional heterogeneity in macroeconomic responses. For example, for all horizons and all variables, about 50% of the units have multipliers which are smaller than half of the average multiplier; and about 30-35% have multipliers larger than twice the average multiplier. We find that membership to the Euro Area, location, national borders, and tenure in the EU matter. For instance, in southern regions, ERDF has positive medium term cumulative growth effects, while these effects are negative in northern regions; and ESF has larger and more significant medium term repercussions. Similarly, for regions belonging to older EU member countries, ERDF produces less negative and ESF more positive medium term growth effects. The level of development is also important and regions whose per-capita income is in the central portion of the distribution benefit most from both programs in the medium-run. More importantly, although the distribution of EU funds is skewed towards poorer, peripheral, and less developed regions, their asymmetric effects may lead to an increase in polarization and regional inequality (see Canova [2004] for an earlier evaluation of income polarization in EU regions). If regional inequality is an important consideration for policymakers, ESF is superior also in this dimension, as it benefits a larger number of regions in the medium-run in a variety of EU countries. The two programs differ also in their spillover effects. ERDF funds generate positive spillovers; ESF funds do not.

The insights of the model. Federal R&D spending affects labor productivity and/or factor accumulation generating an externality on the aggregate level of these services. In such a setup, temporary R&D spending shocks produces persistent dynamics, even without agglomeration effects: they boost aggregate demand, because government absorption of goods and services increases; and they alter the aggregate supply, because factor productivity increases. The relative importance of these two effects determines the time profile of cumulative multipliers.

Federal R&D spending may be locally used in three ways: (a) to directly alter labor productivity, b) to enhance the accumulation of R&D and c) to subsidize firms' investment in R&D. In all cases, the time profile of the cumulative multipliers is decreasing, as it is in the data, but a number of patterns can be generated depending on specification and parameter choices. For example, when the boost in labor productivity is temporary and reversed, multipliers may turn negative at longer horizons; a hump shaped cumulative multiplier profile can be generated when there are gestation lags; and an increasing profile of cumulative multipliers is obtained when federal R&D spending has smaller impact on labor productivity. Thus, variations in the specification of the regional production function can account for the heterogeneity displayed by different groups of regions and over time.

Federal educational spending may have two different local uses: to enhance the accumulation of private human capital or to provide subsidies for education purposes. Both types of spending have similar dynamic effects. In the short run, increases in federal spending decrease employment and output and increase real wages, as workers take advantage of the funds to change their time allocation and acquire better skills. Since human capital enhances effective labor productivity, investment demand increases and there are persistent second round effects on production and employment.

The model is rich also in response to federal educational shocks and a variety of multipliers' time profiles consistent with those in the data, can be generated depending on parameter choices. For example, when physical capital is relatively free to adjust, the larger initial fall in working hours is counteracted by an larger increase in capital investment over the adjustment path, making impact multipliers smaller and medium term multipliers larger. On the other hand, when human capital depreciates fast, the benefits of higher education are washed out, and cumulative multipliers may decline over time.

Given the small open economy nature of NUTS2 regions, the model economy features trade in goods and services and the home region is assumed to be relatively small. The small open economy assumption has implications for the dynamic responses, as the demand effect on union inflation is limited. Thus, the reaction of the interest rate, which is set by the central bank as function of the union inflation rate, is reduced relative to the case when the regional economy is assumed to be large. When the economy is larger, the supply effects of federal R&D shocks are stronger making, cumulative multipliers uniformly larger as in the data. With human capital shocks, the effect is more limited, making impact multipliers only marginally larger. Consistent with the data, differences with the small region setup fade along the adjustment path.

Relationship with the literature. As far as we know, there has been no study analyzing either countercyclical or the medium term effects of EU grants, at regional or at country level. Thus, the paper brings together two unrelated strands of literature. The first studies the effects of EU transfers on income inequality or long-term growth, see e.g. Boldrin and Canova [2001], Canova [2004], Mohl and Hagen [2009], Becker et al. [2013]. We complement this literature by analyzing the cyclical consequences of EU funds on product and labor markets, explicitly taking a regional focus, and differentiating funds by their aim. In the process, we create a usable data set of real per-capita funds; and document the extent of regional heterogeneity following different programs.

The second type of literature examines the dynamic effects of fiscal expansions in monetary unions, see e.g. Canova and Pappa [2007], Nakamura and Steinnson [2014], Dupour and Guerrero [2017], Auerbach et al. [2020]. This literature is concerned primarily with US fiscal expansions, both at federal and local level, and takes into consideration military expenditure, federal transfers to states and counties, or local state expenditure. Recently, the focus has been on federal transfers due the special events, e.g. 2008 financial crisis or natural disasters, see Chodorow-Reich [2019], Deryugina [2017], Canova and Pappa [2021]. We contribute to this literature by employing EU regional data; providing a theoretical perspective about transmission channels, and collecting information about the dynamics of variables typically unavailable in US studies.

Coelho [2019] uses structural fund spending by subnational regions as instruments for annual realized expenditure to measure local employment and output multipliers. Our exercise differs in a number of dimensions. First, she looks at funds that include different objectives, while we examine separately ERDF and ESF funds. Second, she uses nominal rather than real funds data and limits attention to the last two budget cycles (2000-2006 and 2007-2013), while we take a longer perspective.

Third, the average effects she estimates might be biased because the econometric procedure she employs does not allow for dynamic heterogeneity, which is considerable in regional EU data. Finally, we provide a model to explain the dynamics; she does not.

Policy Implications. EU Structural funds have important macroeconomic effects on regional economies. The dynamics they generate differ making them potentially useful for different policy purposes. One type may be used for countercyclical purposes, with the understanding that it could temporarily support regional income, at the cost of producing reverse effects in the medium run. The other type has longer lasting and more homogeneous medium term effects. The higher regional skills induced by the ESF program imply higher workers' compensation, but also higher private investments, and this may potentially ignite a virtuous growth cycle. Given that NGEU funds combine features of the two structural funds we consider, there is hope that the new package of programs will support the recovery and foster economic transformation.

At least one of the funds produces asymmetric regional medium term dynamics. EU funds may create jobs, foster investments, boost private activity, and improve productivity, but in an heterogeneous manner, potentially increasing regional polarization. Moreover, macroeconomic variables in different countries react differently to the flow of funds, and this may account for the tense negotiations taking place in the European Council when NGEU funds were created. Thus, to produce Pareto improving allocations and dynamics, the new funds need to be combined with specific measures that help poorer, newer, and peripheral regions to use the funds more productively.

The outline of the paper. The next section describes the novel regional funds data and the regional macroeconomic data we employ. Section 3 discusses the econometric methodology. Section 4 presents the average multipliers. Section 5 studies regional heterogeneity. Section 6 has the model and analyzes the dynamics of transmission of federal spending shocks. Section 7 concludes with some implications for the planned EU fiscal expansion. The appendix describes the nature of the EU structural funds and has some graphical statistics of the newly constructed data set.

2 The data

The data we use comes from official EU sources. The first, called ARDECO online, is available at https://ec.europa.eu/knowledge4policy/territorial/ardeco-online_en and includes main macroeconomic aggregates for 314 European NUTS2 units. NUTS2 is the classification used to indicate regions of Europe and is intermediate between NUTS1 (covering macro regions) and NUTS3 (covering provinces). It is, thus, comparable to a state classification in the US, which is intermediate between macro regions and counties. The database contains information for EU members and for Albania, Norway, Serbia, Montenegro, Macedonia. In the exercises we run we focus attention on the

279 regions belonging to the EU, singling out, when relevant, the UK, or Euro area regions.

We use annual data on real private GVA, employment, real workers' compensation, population and labor force (which we use to construct the participation rate), real gross fixed capital formation, and construct a series for labor productivity. The starting date of the sample is 1980 and the final date is 2017. For the regions belonging to East Germany, Eastern European countries, or the Baltic states, the sample is shorter and starts only in 1990.

The second official source of data reports the allocation of European structural funds. It is named "Historical data on structural funds by member state", and it is available at https://cohesiondata.ec.europa.eu/Other/Historic-EU-payments-regionalised-and-modelled/tc55-7ysv. As detailed in appendix A, there are four types of grants EU regions received over the sample: the Cohesion fund (CF), the Agricultural fund (EARDF), the Regional development fund (ERDF), and the Social Fund (ESF) [1]. Because CF grants are assigned at country level and the EAFRD targets agricultural support, in our exercises we employ data for ERDF, which is concerned with investments in innovation and research, the digital agenda, and with the support for small and medium-sized enterprises; and for ESF, which is directed to support investments in education, health, and in projects fighting poverty. There are a number of issues with the way the data is reported in the official sources: the available data is reconstructed, because there is a time gap between the expenditure by the regional government (which are not available) and the payments made by EU over each budget cycle; there are mistakes in the coding of the data; and the numbers come in nominal terms. Information about how regional expenditure is estimated is in appendix B. Details concerning the construction of a usable database of real regional structural funds are in Canova et al. [2020].

3 The econometric procedure

To examine the dynamic effects of ERDF and ESF funds on regional macroeconomic variables we employ a Bayesian framework. Given the potential endogeneity of structural funds to EU economic conditions, we use their innovations as instruments in dynamic regression equations. Innovations are constructed as the residuals of a regression of each real structural fund series on a constant and five aggregate Euro area variables: GDP, employment, GDP deflator, nominal interest rate, and nominal effective exchange rate. This way we account for the fact that EU funds are affected by the economic conditions in the region, as they come as transfers from national governments [2]. Annual Euro data goes from 1980 to 2017 and comes from the same EU sources. Because the sample is short, a prior is used to regularize individual estimates; but it does not affect the average estimates we present.

The dependent variable in regression equations is the cumulative growth rate at horizon h of

[1] Since the 2014-2020 budget cycle a Fishery fund (EMFF) is also available.

[2] Ideally one would like to use EU variables to construct innovations. For our purposes, Euro area variables suffice since there is a very high correlation in the economic cycle of Euro and non-Euro area EU members

the macroeconomic variable of interest, i.e, $y_{i,t,h} = \sum_{j=1}^{h} \frac{Y_{i,t+j-1} - hY_{i,t-1}}{Y_{i,t-1}}$. The relevant independent variable is the cumulative change in the relevant fund, scaled by regional GVA, i.e. $x_{i,t,h} = \sum_{j=1}^{h} \frac{G_{i,t+j-1} - hG_{i,t-1}}{GVA_{i,t-1}}$. We scale the spending variable by regional GVA rather than regional income, as it is common in the literature, see e.g. Dupour and Guerrero [2017] or Ramey and Zubairy [2018], since the measurement of the regional component of the public sector is problematic. The equation includes a constant and one lag of the dependent variable only, as degrees of freedom are scarce. Thus, for each macroeconomic variable, the estimated equation is

$$y_{i,t,h} = a_{i,h} + b_{i,h} y_{i,t-1,h} + c_{i,h} x_{i,t,h} + e_{i,t,h} \tag{1}$$

where i refers to region, t to time, and h to the horizon. Because of the way the predicted value $\hat{x}_{i,t,h}$ is constructed, $c_{i,h}$ represents the average cumulative multiplier at horizon h of an unexpected increase in a structural fund at each t (Euro change in private income per Euro change of grants) in region i. Using innovations as instruments avoids typical biases in the estimates of $c_{i,h}$ due to the heterogenous persistence exhibited by $x_{i,t,h}$, see e.g. Canova [2020b].

Given the short time dimension, we focus attention on h=1,2,3. We employ a normal prior for $(a_{i,h}, b_{i,h}, c_{i,h})$ with zero mean and fixed variance and a non-informative prior on the coefficients and the covariance matrix of the error term of the instrumental variable equation. These choices imply that the estimator we use is equivalent to a IV ridge estimator.

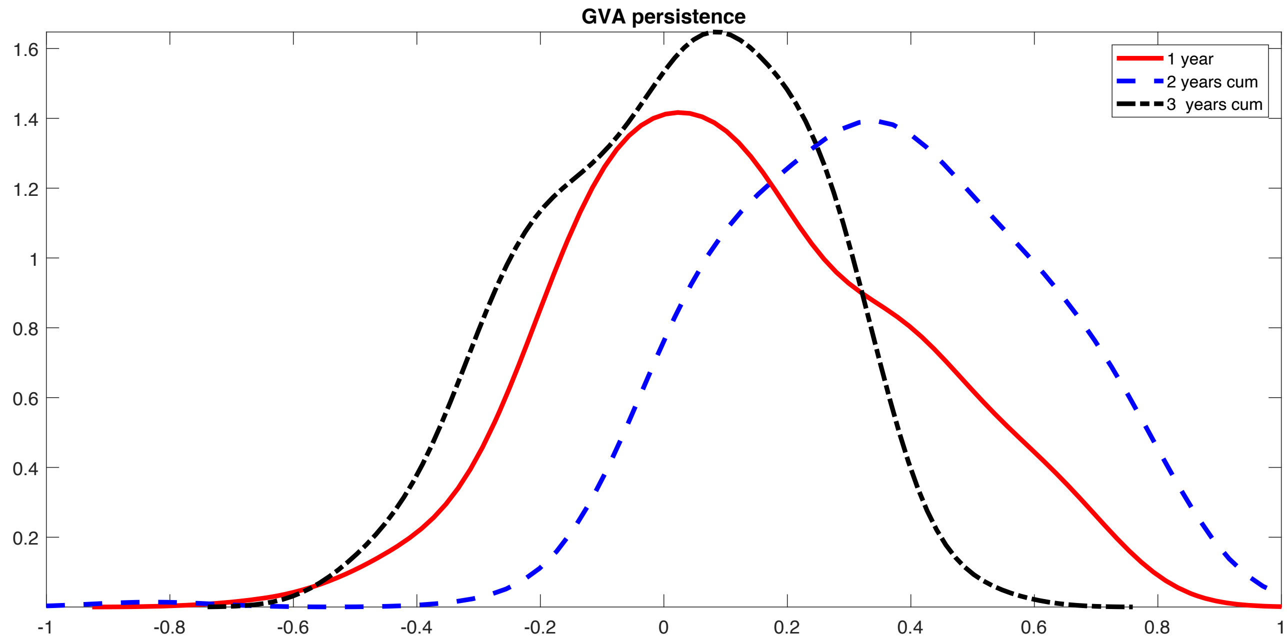
Once estimates of $c_{i,h}$ are obtained for each i and h, we compute cross-sectional averages by trimming the top 10 and bottom 10 percent of the estimates [3]. To characterize other features of the distribution of regional multipliers we group cross-sectional estimates in a number of ways. In particular, we group regional multipliers by location and tenure in the EU and report the average trimmed multipliers at horizon h for each of the two groups. We also cluster regional estimates using the level of regional development, as measured by the average GDP per-capita and report the average multipliers at horizon h in each quartile of the per-capita income distribution. Finally, we cluster multipliers for each horizon using national borders.

Two important issues deserve a brief discussion. The first is one of predictability. The EU budget works in seven years cycles and an allotment of funds to the country for the whole fiscal cycle is made at the beginning of each cycle. Regional projects need to be approved by federal authorities; reimbursements of (a portion of) the expenditure are made when national authorities provide receipts, and at that point expenditures are recorded in the EU budget. Thus, there two types of issues that one needs to control. First, real expenditures occur prior to the appearance in the official EU data. The EU tries to account for this feature by constructing expenditure profiles of different regions and spreading yearly recorded expenditure differently according to the these profiles. Thus, for example, if a region typically asks for reimbursements only in the last two years of the budget cycle, expenditures

[3] While magnitudes change, the qualitative features we discuss remain unchanged if medians are used as location measures.

are smoothly spread over the previous years. Second, expectations of expenditure may be produced that induce private agents act prior to the actual expenditure taking place. Because of the length of EU budget cycle and the need of EU approval for the projects, these anticipatory effects may occur one or at most two years in advance.

Although not reported here for reason of space, we did examine whether this second type of predictability occurs by shifting the time index in the independent variable of (1) one or two years forward and proceeding similarly for the corresponding instrument. The results are available on request. Coelho [2019] employs expenditure commitments, rather than estimated expenditure entries, to account for predictability. This selection fails to address the problem because commitment data refer to the aggregate assigned to a country in a specific year and not to a specific project. For example, in 2000 commitments do not represent anticipation of 2001 projects as they may contain commitments for projects approved in 1999 which may be undertaken in 2002.



Note: Plotted is the cross sectional distribution of the persistence coefficient in equation (1) when the dependent variable is GVA.

Second, when constructing average multipliers, especially with a short time dimension, it is common to pool cross sectional units when running regressions like (1), see e.g. Nakamura and Steinnson [2014] or Chodorow-Reich [2019]. That is, one would omit the subscript i from the coefficients in (1), include a time effect and omit the lag dependent variable. However, if the dependent variable in (1) is serially correlated and the dynamic evolution of $y_{i,t}$ in response to EU funds differs across regions, such an approach leads to inconsistent estimates of the quantities of interest, see Canova [2020b].

To show that the problem is relevant for the data we consider, Figure 1 plots the cross sectional distribution of b_h when the dependent variable is GVA and $h = 1, 2, 3$. Clearly, dynamic heterogeneity is important - there is no evidence that the distribution for each h collapses at one point or that it becomes more concentrated as h increases; hence, a pooling approach to compute average multipliers will fail to give consistent estimates. As an alternative, we estimate (1), region by region, and take the trimmed mean of the cross-sectional distribution of $c_{i,h}$ for different h as our location measure. This average estimator corresponds to the (trimmed version) of the mean group estimator suggested by Pesaran and Smith [1995], which is very commonly used when a panel features dynamic heterogeneity. If regions were dynamically homogeneous, the average multiplier we construct would asymptotically approach the multiplier constructed with a pooled estimator, for the appropriate choice of the prior mean, but would be less efficient. Thus, the estimator we employ works, whether the cross section is dynamic homogeneous or not.

4 The time profile of average multipliers

Table 1 reports one, two and three year cumulative average multipliers for the six regional variables of interest, separately for ERDF and ESF programs, when all 279 EU regions are considered.

Innovations in the grants distributed by the two funds have different dynamic effects. ERDF is, on average, expansionary in the short run: the multipliers for all variables are positive and significantly different from zero on impact. Quantitatively, in response to an increase in ERDF of one percent of regional GVA, private GVA grows by 1.8%, investments by 5.9%, labor productivity by 2.4%, and the growth rate of employment is 0.85%. Hence, ERDF seems more effective in boosting the production side than the labor market side of the average European region.

The expansionary effects of ERDF is temporary and after three years little remains of the initial expansion: the three years cumulative employment multiplier is about the same as the one year multiplier; the three years cumulative GVA multiplier is half of its one year counterpart; and the investments, compensation, and labor productivity cumulative multipliers are insignificantly different from zero. Only the participation multiplier increases persistently and significantly.

The dynamics of regional investments appears to be key to understand the outcomes. ERDF shocks temporarily boost investment growth and induce an outward shift in labor demand; in the medium term, investment growth becomes negative and employment demand falls. The medium term labor market slackness is confirmed by the response of compensation growth, which turns negative after the initial increase.

One possible explanation for these dynamic patterns has to do with the momentum created by the funding of projects that the federal government supports. Public expenditure may decrease private R&D unit costs and, and because of externality effects, increase the expected profitability of privately funded R&D projects. Hence, subsidized firms have an incentive to invest more in R&D activities and this additional investment, which comes over and above the level firms would have undertaken without public support, may generate an indirect positive effect, explaining why the output multiplier is large on impact. However, when public support is reduced or eliminated, firms might be prone to decrease their private R&D investment, wiping out the dynamic gains that were previously generated or, if the project requires a number of years, to finance the remaining portions with funds which would be otherwise used for perhaps more profitable activities. In both cases, output, labor productivity, and investments would be considerably reduced, leading to reduced medium term multipliers. We formalize these considerations in section 6.

Table 1: Average cumulative multipliers, all EU regions

	ERDF program			**ESF program**		
Horizon	1 year	2 years	3 years	1 year	2 years	3 years
GVA	1.83	1.58	1.08	-0.51	2.57	5.09
	(0.19)	(0.32)	(0.32)	(0.64)	(0.80)	(0.83)
Employment	0.85	0.37	0.88	-0.31	1.23	1.61
	(0.16)	(0.28)	(0.29)	(0.23)	(0.37)	(0.27)
Compensation	2.19	0.70	0.98	2.10	2.79	3.54
	(0.36)	(0.68)	(0.80)	(0.39)	(0.58)	(0.69)
Investments	5.89	3.46	1.28	0.30	5.60	4.25
	(1.70)	(2.92)	(2.28)	(1.60)	(1.33)	(2.17)
Labor productivity	2.41	0.42	-1.02	2.81	1.77	3.59
	(0.37)	(0.77)	(0.75)	(0.70)	(0.90)	(0.91)
Participation	0.99	1.57	1.61	2.67	4.32	4.03
	(0.17)	(0.20)	(0.19)	(0.30)	(0.77)	(0.36)

Note: Standard deviations of the estimates are in parenthesis.

ESF shocks directly affect the labor market in the short run, increasing workers' compensation and decreasing employment, albeit not significantly. Since these funds are primarily designed for education and human capital accumulation, they induce a backward shift in the labor supply, as households take advantage of the programs to acquire a higher skill level. This substitution crowds out private GVA and increases labor productivity on impact. Investments do not significantly react while participation surprisingly increases, perhaps because discouraged workers restart search activities to try to take advantage of the program.

In the medium run, the dynamics change. The cumulative GVA and employment multipliers become positive and economically important; the investment multiplier is significantly positive at the three years horizon, while the compensation, the labor productivity, and participation multipliers increase and remain significant. Thus, after the initial fall, job creation does take place, the productivity (and the compensation) of workers further increases, investments take off, and the private sector expands as the result of the increased productivity of labor services.

Quantitatively, the medium-term effects of ESF grants are larger than those of ERDF grants. For example, an increase in ESF of one percent of regional GVA, in response to a ESF shock, induces a three years cumulative GVA multiplier of 5.09%, a cumulative employment multiplier of about a 1.6% and a cumulative investments multiplier of 4.2% with the bulk of the GVA and employment growth taking place in the years after the arrival of the funds.

Thus, the reaction of the regional economies to the two funds is different. Conditional on the quality of the available data, ERDF seem to have an important countercyclical role, as it expands economic activity in the short run, on average; but its macroeconomic effects are temporary and the medium term gains in investments and job creation are quite limited. On the other hand, ESF has insignificant production, employment, or investments effects in the short run, but has economically important medium term effects: it boosts the average growth rate of private output, investments, and productivity; and exercises a statistically significant influence on the growth rate of employment and of workers' compensation. Interestingly, both type of funds encourage labor market participation, probably in expectation of higher job creation in sectors targeted by the programs.

Some robustness exercises. Table 1 considers all EU regions as of 2020. Because the UK will not benefit from NGEU grants, and it is also the country with the largest number of regions (40), multipliers estimates may look different if UK regions are omitted from the computations. The top panel of Table 2 shows that the qualitative patterns we described for ERDF do not change if UK regions are omitted. For example, one year multipliers are generally positive and significant and three years cumulative multipliers are generally smaller than one year multipliers. However, two quantitative differences are noticeable. The whole term structure of multipliers is shifted upward and if we exclude investments, all medium term multipliers are now significantly positive. Furthermore, the three years compensation multiplier is now larger than the one year multiplier.

For ESF the conclusions are similar. Excluding UK regions makes, qualitatively, no difference. Quantitatively, the average medium term effects are enhanced and an increase of ESF grants of one percent of regional GVA, in response to an innovation in ESF, produces a cumulative GVA multiplier of 6.4%, a cumulative employment multiplier of 1.9%, and a cumulative investment multiplier of 8.4% at the three years horizon.

Monetary policy is centralized in the Euro area, but not in the EU. Although the space for monetary independence for the smaller EU countries, such as Denmark and Sweden, or newly added EU members is limited, it is possible that domestic monetary policy, by manipulating the real rate of interest in response to the fiscal expansion, may change the magnitude of the real gains EU funds produce in the regions of these countries. For this reason, the middle panel of Table 2 recomputes the average multipliers using only Euro area regions.

The effects of ERDF on GVA, employment, and labor productivity change: they are smaller on impact, but become more persistent; and the multipliers are significantly positive in the medium run.

Table 2: Average cumulative multipliers, robustness

	ERDF program			ESF program		
Horizon	1 year	2 years	3 years	1 year	2 years	3 years
	Without the UK					
GVA	1.83	1.55	1.23	-0.17	4.09	6.44
	(0.23)	(0.36)	(0.36)	(0.75)	(0.94)	(0.97)
Employment	0.77	0.11	0.66	0.00	1.61	1.87
	(0.19)	(0.23)	(0.30)	(0.27)	(0.44)	(0.32)
Compensation	1.28	0.26	2.33	-0.39	2.95	4.90
	(0.37)	(0.67)	(0.55)	(0.46)	(0.66)	(0.62)
Investments	6.37	2.68	2.40	1.46	9.40	8.42
	(1.99)	(3.42)	(2.67)	(1.88)	(1.56)	(1.65)
Labor productivity	1.91	1.32	1.08	1.07	3.49	6.17
	(0.35)	(0.55)	(0.51)	(0.82)	(1.06)	(1.06)
Participation	0.95	1.40	1.40	2.72	4.01	3.85
	(0.19)	(0.24)	(0.23)	(0.35)	(0.31)	(0.25)
	Only Euro area					
GVA	1.49	1.45	2.33	-0.69	4.78	8.02
	(0.30)	(0.48)	(0.47)	(0.97)	(1.22)	(1.27)
Employment	0.59	0.29	1.21	-0.33	1.89	2.42
	(0.17)	(0.30)	(0.39)	(0.35)	(0.57)	(0.42)
Compensation	-0.19	0.61	3.63	-0.90	4.08	6.98
	(0.35)	(0.69)	(0.72)	(0.56)	(0.85)	(0.81)
Investments	3.18	1.87	2.78	-1.95	8.92	10.57
	(2.61)	(4.48)	(3.50)	(2.44)	(2.04)	(2.14)
Labor productivity	0.92	0.48	1.72	0.04	3.63	7.03
	(0.34)	(0.58)	(0.61)	(1.07)	(1.38)	(1.38)
Participation	1.01	1.73	1.58	2.98	4.44	4.35
	(0.17)	(0.28)	(0.30)	(0.46)	(0.41)	(0.32)
	After 2000					
GVA	1.44	2.43	2.01	-0.51	2.57	5.09
	(0.37)	(0.41)	(0.34)	(0.64)	(0.80)	(0.83)
Employment	0.22	1.32	1.23	-0.31	1.23	1.61
	(0.15)	(0.29)	(0.29)	(0.23)	(0.37)	(0.27)
Compensation	3.58	4.89	1.80	2.10	2.79	3.54
	(0.31)	(0.60)	(0.63)	(0.39)	(0.58)	(0.69)
Investments	2.44	5.35	3.89	0.30	5.60	4.25
	(2.01)	(3.41)	(2.99)	(1.60)	(1.33)	(2.17)
Labor productivity	3.50	2.56	3.24	2.81	1.77	3.59
	(0.41)	(0.64)	(0.62)	(0.70)	(0.90)	(0.91)
Participation	1.60	3.34	3.08	2.67	4.32	4.03
	(0.14)	(0.33)	(0.28)	(0.30)	(0.77)	(0.36)

Note: Standard deviations of the estimates are in parenthesis.

Moreover, if we exclude investments, the three years multipliers are larger than one year multipliers. Quantitatively, at the three years horizon, ERDF grants induce a cumulative GVA multiplier which is four times larger in the Euro area than in the EU; and a cumulative employment multiplier which is three times as large. Hence, while the expansionary effects are more moderate on impact, they become more economically important in the medium run. We investigate in section 6 what regional characteristics could drive these differences.

The qualitative features of ESF grants are unchanged, but as with ERDF, the term structure of cumulative multipliers is tilted with impact effects being more negative (albeit not always significant) and medium terms effects being typically larger. For example, the three years cumulative GVA, employment, and investment multipliers are now 8.0%, 2.4% and 10.5%, respectively.

Overall, EU funds appear to have stronger medium term effects in the average region of the Euro area. While the patterns we uncover need not be connected with differential central bank responses to macroeconomic dynamics, it suggests that regional heterogeneities may matter when evaluating the success of the programs, a theme we will come back in the next section.

Finally, the effectiveness of EU funds may have changed over time, in particular if regional governments have improved their ability to identify projects which could receive EU support. Thus, it is worth examining if the conclusions are altered when post 2000 data are used. Considering post 2000 data is also useful because it makes the comparison between the two programs easier, as ESF is available only from that date. While the sample is short, and the uncertainty around point estimates larger, the bottom panel of Table 2 indicates that the medium term reversal for ERDF, noted in the full sample, is absent if only the last three budget cycles are considered. For example, GVA, employment and investments growth multipliers at the three years horizon are all positive and larger than those at the one year horizon. This occurs because the peak response is shifted at year two. Thus, since 2000, federal government R&D activities have more persistent effects on economic activity.

Discussion Chodorow-Reich [2019] suggested a simple formula to convert output multipliers into employment multipliers when only one of the two series is available. The formula requires knowledge of the average output-per-worker, of the share of labor in the production function, and of the elasticity of hours-per-worker to total employment; and has some empirical support in the estimates reported by Nakamura and Steinnson [2014]. Under a standard parameterization of the labor share and of the elasticity of output-per-worker, the formula simplifies to:

$$c^Y_{i,h} \approx (Y/E)_i c^E_{i,h} \tag{2}$$

where $c^E_{i,h}$ is the employment multiplier and $c^Y_{i,h}$ the output multiplier of region i at horizon h. Because for EU regions, $(Y/E)_i$ varies between 2.5 and 5, (2) roughly rationalizes the average employment and GVA multipliers reported in Tables 1 and 2. This is comforting because the formula requires two assumptions which, at first look, may appear to be inconsistent with the dynamics we have described. First, (2) is constructed assuming that capital is constant over the adjustment path, while Tables 1 and 2 demonstrate that investment dynamics are sizable, both in the short and the medium run. Second, in many EU regions hours-per-worker is, to a first approximation, constant over time and adjustments occur on the extensive rather than the intensive margin (workers rather than hours are adjusted). Thus, the formula has a certain appeal, even for economies like the EU, where labor markets behave differently and capital accumulation may be an important driver of the dynamics of regional variables.

The multipliers presented in Tables 1 and 2 are larger than those typically reported for the US, see e.g. Dupour and Guerrero [2017]. For a proper comparison, one should keep in mind three different issues. First, in analyses with US regions or counties, one employs military expenditure, see e.g. Auerbach et al. [2020]; infrastructure investment, see e.g. Ramey [2020b], state expenditure, see e.g. Canova and Pappa [2007] or even the federal disaster grants, see e.g. Deryugina [2017] to compute multipliers. Because EU funds are meant for investment projects that foster R&D, education and economic transformation, they are fundamentally different from the types of government expenditure analyzed with US data. In particular, important externality effects on the supply side economy may boost the output effect making the multipliers larger. Second, EU grants require regional governments to pledge part of the total costs of the project. Thus, they represent both "federal" and "state" expenditures and this may also account for the larger size of the multipliers. Finally, while studies employing US data compute multipliers scaling government expenditure by total income (so that the units are dollar change in regional income per dollar change in regional expenditure), our multipliers are computed scaling expenditure by GVA, making the scale of the multiplier naturally larger, even when the first two effects discussed above are absent. We use GVA as scaling factor since the measurement of the regional component of government expenditure is difficult and regional price deflators for the government sector are not readily available. Hence, the different nature of EU funds, the co-financing feature they require, and the alternative scaling we employ make the magnitude of the multipliers we present non-comparable to those in the literature.

Spillovers The estimates reported in Tables 1 and 2 are likely to provide only a lower bound to the regional effects of EU funds, since they disregard spillovers in regional economic activity. For example, firms taking advantage of ERDF may employ workers living in neighboring regions, and ESF may use teachers living outside of the region where the funds accrued, thus, depressing regional activity elsewhere. Alternatively, the additional wages the funds generate could be spent on goods produced in other regions, hence boosting production, employment and, perhaps, investments elsewhere.

Because both labor and product markets may be affected, quantifying the magnitude of the spillovers is complicated, as the overall effect may be larger or smaller, depending on whether economic activity in other regions are crowded out or crowded in. Nevertheless, two observations may allow

Table 3: Average cumulative multipliers with national spillovers, all EU regions

	ERDF program			**ESF program**		
Horizon	1 year	2 years	3 years	1 year	2 years	3 years
GVA	2.07	2.15	0.60	-0.64	2.22	3.73
	(0.11)	(0.23)	(0.25)	(0.25)	(0.45)	(0.55)
Employment	1.24	0.63	-0.10	0.09	0.90	1.12
	(0.06)	(0.11)	(0.22)	(0.09)	(0.22)	(0.29)
Compensation	1.80	0.40	0.62	2.05	2.05	2.82
	(0.32)	(0.64)	(0.67)	(0.37)	(0.55)	(0.61)
Investments	6.72	3.47	1.52	-0.34	-0.02	-1.47
	(0.28)	(0.57)	(0.74)	(0.47)	(1.13)	(1.39)
Labor productivity	3.46	1.92	1.17	2.24	1.15	1.93
	(0.28)	(0.57)	(0.58)	(0.34)	(0.53)	(0.63)
Participation	0.89	0.99	0.98	2.03	2.98	3.33
	(0.05)	(0.09)	(0.09)	(0.07)	(0.15)	(0.14)

Note: Standard deviations of the estimates are in parenthesis.

us to simplify the computation. Because of language barriers and of institutional constraints, labor mobility is typically restricted to national markets. In addition, transportation costs for delivery of regionally produced goods in national markets are smaller than the costs for delivery in international markets. Hence, an approximate estimate of the magnitude of the spillovers can be obtained by comparing the average multipliers that regional EU funds have on regional vs. national variables. If spillovers are small or negative, the multipliers computed using average national growth rates should be considerably smaller than those computed using regional growth rates. On the other hand, if the boost in economic activity affects positively a number of neighboring regions, the opposite should occur. We compute national variables by weighting regional variables by their size in the nation.

Table 3 shows that ERDF multipliers obtained with average national growth rates are larger on impact for most variables than those obtained with regional growth rates. Thus, spillovers via acquisition of new goods and services for consumption or investment purposes may be important. Still, the qualitative patterns present in Table 1 are unchanged: multipliers are larger on impact than in the medium run; and except for output, investments and participation three years multipliers are insignificantly different from zero. Thus, spillovers reinforce average regional effects of ERDF. On the other hand, the cumulative three years multipliers of ESF are somewhat smaller than those shown in Table 1, suggesting limited spillover effects. Very noticeable is the effect on investments: here the three years cumulative multiplier is negative, although not significant. Thus, ESF do not seem to generate significant spatial effects, perhaps because of geographical substitution.

5 A closer look at regional heterogeneity

Table 2 implicitly suggests that there is important regional heterogeneity in the dynamics induced by EU funds. For example, at the three years horizon, and for ERDF in Euro area regions, the interquartile range for cumulative GVA multipliers is [-2,5] and for cumulative employment multipliers is [-0.5, 2.3]. Furthermore, in all panels of Table 2 and for all variables, the median multiplier is about half of the mean multiplier, and less than 20 percent of the distribution at all horizons is located between half and twice of the mean value. Hence, not only the distribution of regional multipliers is quite spread out; non-normal differences seem to exist across regions. The task of this section is to explore, on the one hand, potential asymmetric effects of EU funds and, on the other, search for reasons leading to the asymmetries. To do this, we cluster regional multiplier estimates using indicators that reflect geographical, political, institutional, and economic development of each region.

Location and tenure grouping. Table 4 reports the average cumulative multipliers when regions are grouped according to their geographical position (North vs. South) or their tenure with the EU (old vs. new members). In the southern group we include regions belonging to Bulgaria, Cyprus, Greece, Spain, Croatia, Hungary, Italy, Portugal, Romania and Slovenia; young EU members are from "new accession countries"; thus, regions belonging to Bulgaria, Cyprus, Czech Republic, Estonia, Croatia, Hungary, Latvia, Poland, Romania, Slovenia and Slovakia are included in this group.

Location is important when evaluating the macroeconomic success of ERDF. In fact, at the three years horizon, cumulative multipliers for all variables in southern regions are positive on average, while those for northern regions are generally negative. Differences are large and economically significant. For example, there is an almost two percentage points difference in the cumulative GVA and employment multipliers at the three years horizon. Large differences are also present in response to ESF. Here, southern regions tend to positively respond even on impact and multipliers at the three years horizon are quite large. Furthermore, differences in medium term multipliers are important: for GVA, employment, and investments the cumulative multiplier in southern regions is at least four percentage points larger than in northern regions.

Tenure in the EU similarly matters. For instance, for ERDF the GVA and employment cumulative multipliers at the three years horizon are positive on average for regions of old EU members, but negative on average for regions of newer member countries. For ESF, sign differences occur for employment, compensation and investments and the medium term cumulative multipliers are, on average, positive for regions with older tenure and negative for regions with more recent tenure. Even when multipliers have the same sign in the two groups, magnitude differences are important. Regions with older tenure have a medium term average cumulative GVA multiplier that exceeds by four percentage points the one of regions with more recent tenure. In general, in regions with younger tenure, ESF shocks have some impact effect but the economic impulse dies out quickly.

Table 4: Average cumulative multipliers

		ERDF program			ESF program		
Northern vs. southern regions							
		1 year	2 years	3 years	1 year	2 years	3 years
GVA	North	2.33	1.27	-0.02	-1.45	0.89	3.82
	South	2.63	2.21	1.86	2.96	6.90	7.85
Employment	North	0.66	-0.01	-0.64	-1.03	-0.04	0.61
	South	2.15	2.10	1.66	2.34	4.69	6.06
Compensation	North	6.15	1.56	-4.80	4.92	2.73	3.31
	South	0.45	-0.50	6.04	0.38	2.37	3.44
Investments	North	3.40	0.62	-1.28	-1.98	-2.41	0.69
	South	16.50	5.75	2.20	8.09	9.89	8.73
Labor productivity	North	5.79	-0.58	-7.61	4.72	-0.19	0.93
	South	2.21	1.62	4.86	3.31	6.18	4.32
Participation	North	1.03	3.19	3.39	2.33	5.19	3.85
	South	1.71	1.49	1.31	3.95	3.07	4.43
Older vs. younger tenure regions							
		1 year	2 years	3 years	1 year	2 years	3 years
GVA	Old	2.58	2.10	1.63	-0.82	2.78	6.02
	Young	1.86	-0.37	-3.32	2.78	2.75	1.53
Employment	Old	0.97	0.37	1.39	-0.64	1.68	3.76
	Young	1.68	1.62	-2.82	2.56	0.92	-3.14
Compensation	Old	2.97	1.60	0.34	2.84	4.11	5.84
	Young	9.50	-1.89	-7.88	5.99	-3.04	-6.07
Investments	Old	2.34	0.98	-0.27	-1.27	6.60	8.50
	Young	26.25	6.75	0.07	10.45	-2.27	-16.86
Labor productivity	Old	3.13	0.05	-3.90	3.96	-0.18	1.49
	Young	10.17	0.28	-3.06	9.29	9.30	3.89
Participation	Old	1.38	3.13	3.48	3.09	5.61	5.02
	Young	0.71	0.94	0.05	1.87	0.41	0.26

Note: The table reports cumulative ERDF and ESF multipliers for different variables and groupings.

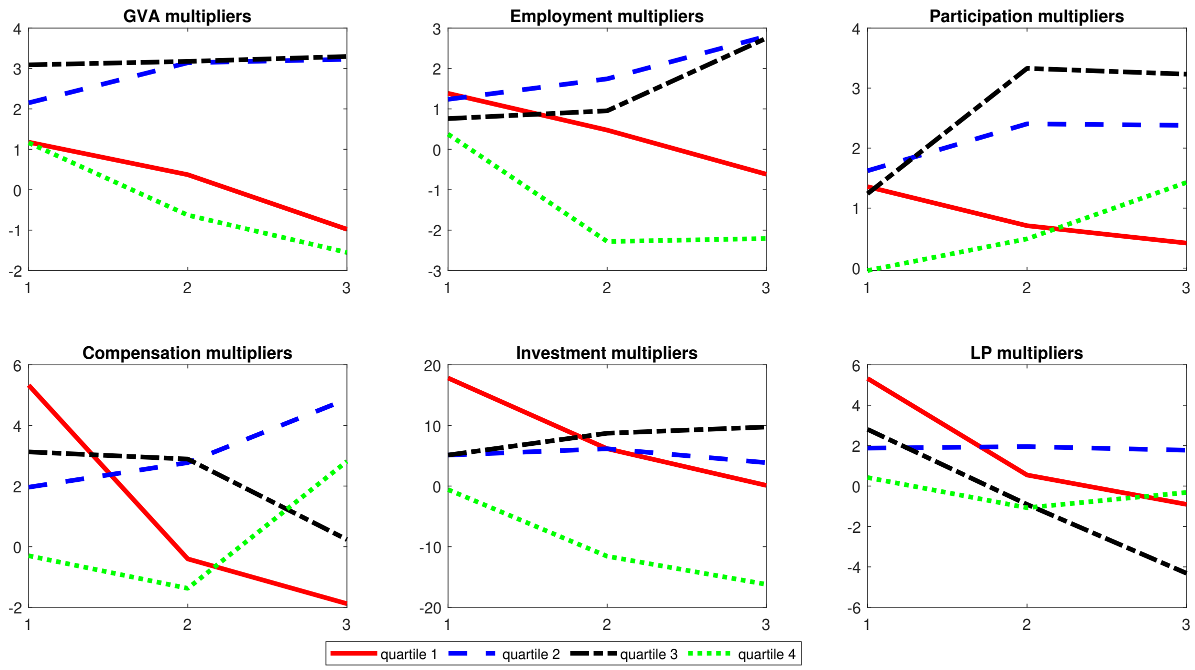
Thus, for these regions, ERDF and ESF have similar dynamic repercussions [4]. We try to interpret these patterns in the next section.

Income quartile groupings. The level of regional development may also shape multipliers dynamics. For example, poor regions may be unable to take full advantage of the funds because they lack local entrepreneurship; they may not have enough local funding to qualify; or the effects in terms of private investments may be temporary or limited in scope. One can also conceive the possibility

[4]Regions of the newer member states are allowed to use up to 50 percent of ERDF for purposes different than support of small and medium enterprises or innovation and research. While this could account for level differences between old and new members, it can not explain the differential profile of the multipliers we obtain. For ESF this diversion of funds is not possible.

that in certain regions education improvements may be small, because of the lack of sufficient average skills. All these factors may contribute to generate differences in multipliers estimates, even factoring in the fact that poorer regions receive larger amounts of per-capita funds.

Figure 2: Cumulative multipliers by quartiles, ERDF



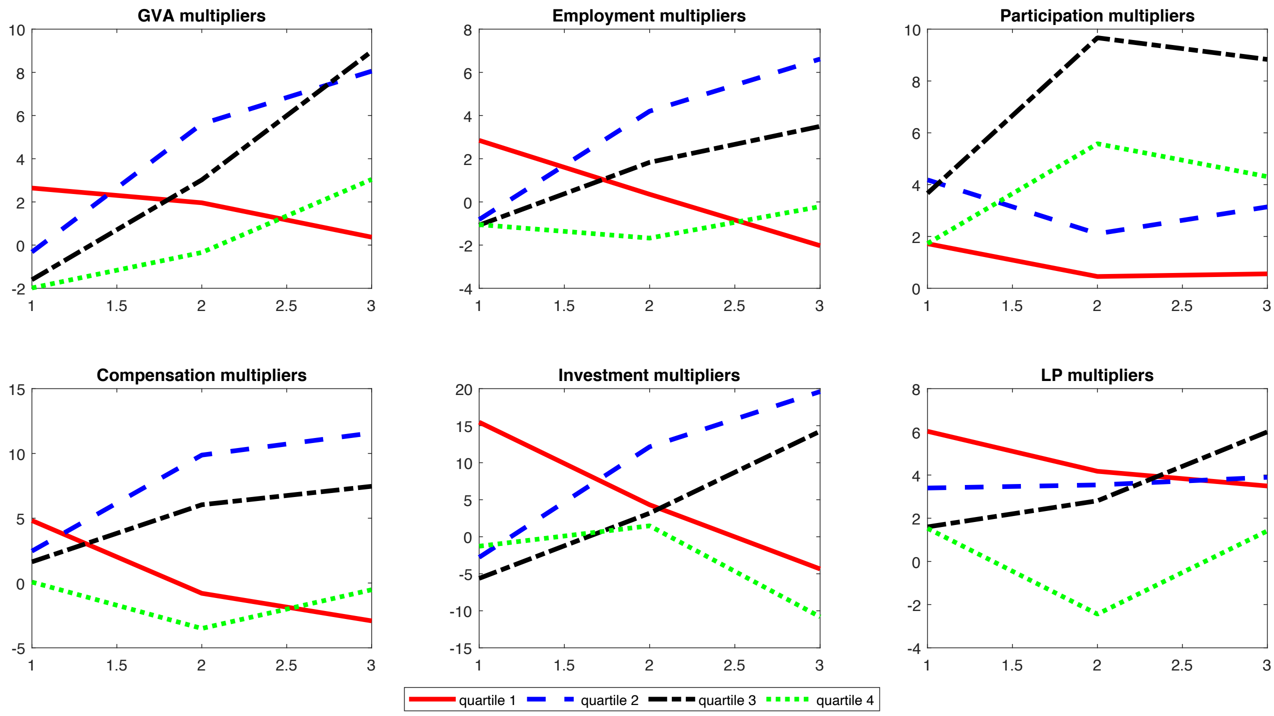
Note: The figure plots the cumulative ERDF multipliers for different variables and for the four quartiles of the income distribution.

Figures 2 and 3 plot the profile of the average multipliers for income quartiles, separately for ERDF and ESF, where quartiles are computed using the average regional per-capita GDP.

Regions in the central portion of the income distribution benefit most from ERDF: their GVA, employment, participation, and investments cumulative multipliers are all positive in the medium term. Since the cumulative multipliers for these variables in regions belonging to the top quartile of the income distribution are negative, catch up around some common long-run value in response to ERDF shocks seems to take place. However, regions belonging to the first quartile of the income distribution feature positive GVA, employment, participation, compensation and labor productivity impact multipliers which turn negative at the three years horizon. For these regions only investments multiplier remains positive after three years, albeit quite small.

Hence, over the adjustment path, income and labor market differences among regions in the top three quartiles narrow, but those between these regions and those in the bottom quartile tend to increase. These medium term adjustments are consistent with the long run polarization of income per-capita in EU regions estimated in Canova [2004], where the poor remain poor, and the rest of the regions converge toward a common higher standard of living. They also suggest that ERDF may lead to increased long run regional inequalities, unless it is combined with measures that persistently revamp the economy of poorest regions.

Figure 3: Cumulative multipliers by quartiles, ESF



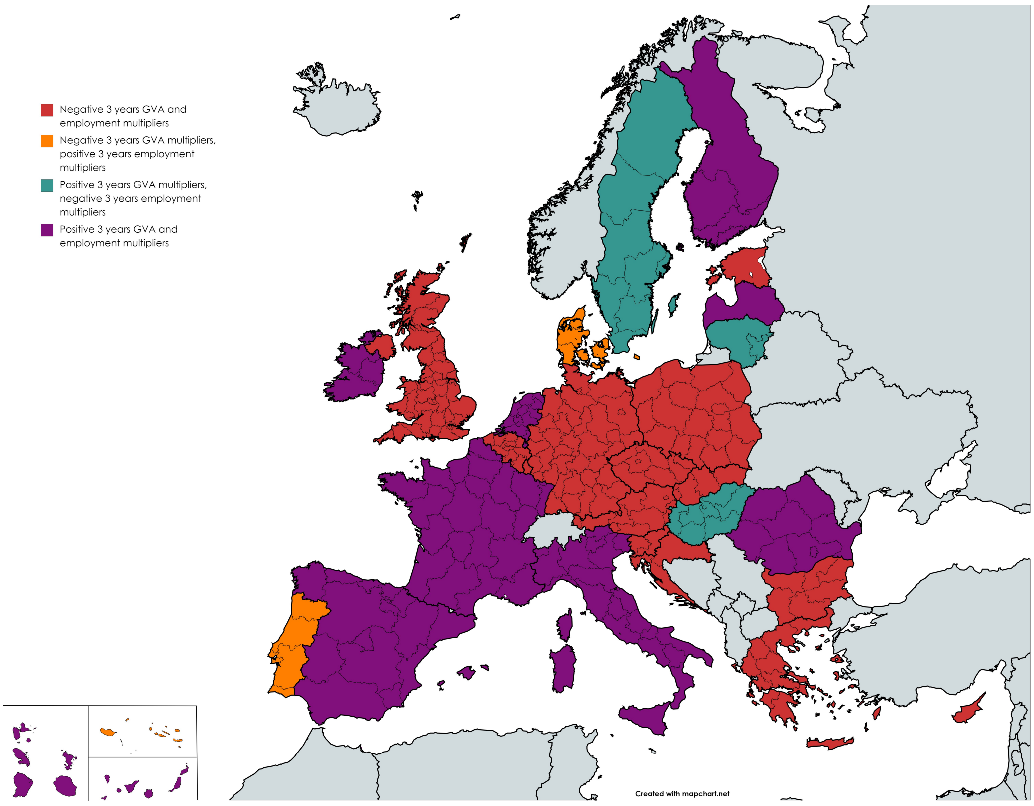
Note: The figure plots the cumulative ESF multipliers for different variables and for the four quartiles of the income distribution.

For ESF, quartile differences are also evident. Regions belonging to the two central quartiles of the income distribution benefit most in terms of GVA, employment, participation, compensation, and investments at the three years horizon. The employment and the investment multipliers for the other two quartiles are instead negative in the medium term and GVA and participation multipliers are positive but considerably smaller. Notably, regions in the bottom quartile are not able to extract substantial medium term benefit from ESF grants. Thus, ESF also tends to twist the regional income distribution along the adjustment path leaving poor regions behind.

Country groupings. To better identify the losers and winners of the two programs, we cluster regional multipliers using national borders. There are institutional and cultural reasons for grouping regions this way. If, say, labor markets institutions matter, regions of a country should respond more homogeneously to the fiscal stimulus, as far as GVA and employment multipliers are concerned, and country specific labor market outcomes should explain differences in national dynamics.

Indeed, there is more homogeneity in the macroeconomic responses to shocks in the funds within a country. Furthermore, there are important similarities in the joint dynamics of GVA and employment growth within a country. Figures 4 and 5 map on a NUTS2 chart the joint distribution of GVA and employment multipliers by country at the three years horizon, separately for the two types of funds.

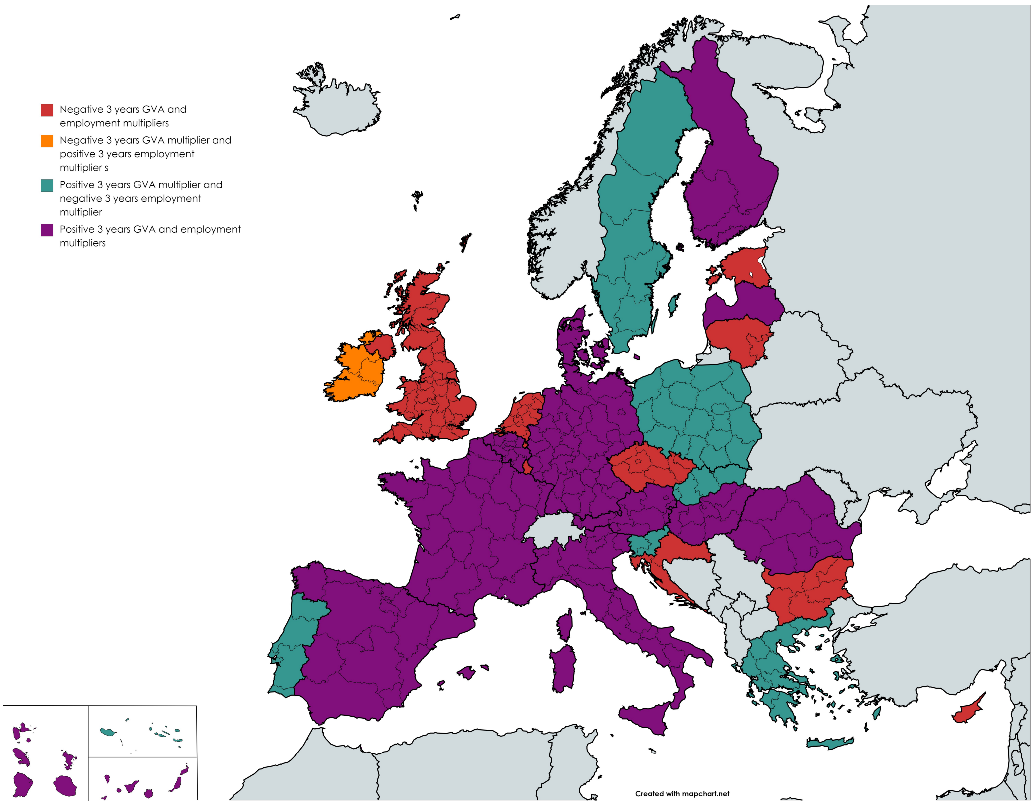
Figure 4: Country multipliers ERDF



Note: The figure plots the geographical distribution of the three year cumulative ERDF multipliers for GVA and employment, clustered along national borders. Different colours represent different combination of signs for GVA and employment multipliers.

For ERDF grants, there is considerable concordance in the signs of GVA and employment multipliers. For instance, the UK, Belgium, Germany, Austria, Slovenia, Croatia, Poland, Czech Republic, Slovakia, Bulgaria, Greece, Estonia, Luxembourg, and Cyprus have significantly negative average three years cumulative GVA and employment multipliers. On the other hand, Spain, the Netherlands, Italy, France, Finland, Ireland, Romania and Latvia feature a positive and significant average three years cumulative GVA and employment multipliers. The remaining countries display either negative GVA and positive employment multipliers (Portugal and Denmark), or positive GVA and negative employment multipliers (Sweden, Lithuania, Hungary and Croatia). Thus, apart from the UK and some peripheral countries (Greece, Cyprus, Estonia, and Bulgaria), ERDF shocks have negative medium term effects primarily in the central regions of the EU.

Figure 5: Country multipliers ESF



Note: The figure plots the geographical distribution of the three year cumulative ESF multipliers for GVA and employment clustered along national borders. Different colours represent different combination of signs for GVA and employment multipliers

For ESF, the number of countries displaying positive and significant average cumulative medium term GVA and employment multipliers increases (Austria, Hungary, Germany and Denmark join the club) and now only the UK, the Czech Republic, Croatia, Lithuania, Luxembourg, The Netherlands, and Bulgaria display cumulative three years multipliers that are both negative.

Perhaps more interesting for the purpose of evaluating NGEU grants is the fact that in Spain, Italy and France, three of four major Euro countries, both ERDF and ESF create jobs, increase GVA, boost investments, and lead to productivity improvements in the medium run. Because these three countries are also among the most battered by the COVID-19 pandemic, one may be mildly optimistic that the new RRF, which combines features of ERDF and ESF, will jump start these economies, help with the transformation to a greener economy, and drive the EU back to the pre-2020 growth path. Furthermore, given that ESF benefits a larger number of EU countries and that can be used for health care, there is also hope that these investments will pay off down the road.

It is useful to provide a simple back of the envelope calculation to put some numbers into the argument. Spain is expected to receive from RRF 140 billion Euros over three years; this is a considerable amount, given that the Spanish GVA in 2019 was 1035 billion Euros (according to World Bank calculations). If the ESF estimates are reliable to measure the dynamic effects of NGEU grants, one should expect Spanish GVA to go up, roughly, by 1.2% and employment by 0.5% cumulative over a three years period. Since according to INE (Instituto Nacional de Estadistica) 19,75 million people were employed in Spain on average in 2019, the RRF will create about 98,750 new jobs in the next three years. This does not compensate the job loss due the COVID-19 pandemic (currently estimated by INE at around 500,000), but it will make up for one-fifth of it. With the recovery of the service and tourism sectors, employment figures should look even better.

As Figures 4 and 5 demonstrate macroeconomic outcomes are far from uniform across countries and this may explain the hard negotiations taking place at the EU Council in July 2020. Note that in central European nations, the expected GVA benefits from NGEU grants are moderate, and those in terms of employment are small. In the past, job creation, in particular, in response to ERDF, did not happen in these countries and the subdued investment growth may be responsible for it. Furthermore, a number of peripheral and recently added EU members, have not (yet) benefited from the flow of structural funds either in terms of GVA or employment; and again, this is particularly true for ERDF. Thus, the new programs may exacerbate cross country inequalities.

Summing up Our empirical investigation uncovered four important facts. First, the two types of funds may serve different purposes: ERDF seems useful for short run purposes; ESF is better suited to foster medium term objectives. Second, the macroeconomic effects of the ERDF are less persistent than those of ESF. While care needs to be employed, as excluding regions or using a shorter sample may alter the conclusion, the mechanics of transmission of the unexpected changes in the two funds appear to be different and work along different margins.

Third, regional dynamic responses are heterogeneous and country specific features, location, tenure in the EU, and level of development are, in part, responsible for these differences. Fourth, in response to the programs, lower income, peripheral, and newly tenured regions of the EU do not take full advantage of the funds and underperform in terms of recovery and transformation.

Hence, NGEU funds have a good probability of success on average. The current downturn could be contrasted as long as the measures enhance the production possibility frontiers of the regional economies, either along the R&D or human capital margins. When this happens, the chance that the average region will go back to the pre-2020 growth path is non-negligible, and the transformation of the EU economy is a solid possibility.

Nevertheless, historical evidence suggests that NGEU funds will not have uniform effects, nor help those who currently lag most behind. In these regions the recovery and the transformation process may not happen, even if a larger amount of funds is channeled to them, perhaps because of government inefficiencies, lack of medium term planning, shortage of entrepreneurship, or low average level of education and of skills. Thus, the threat that income polarization and regional inequalities will increase, and the "recovery and transformation" process will be a multi-gear one is not trivial, unless important social transformations will take place correcting for these distortions.

Finally, it is important to note that our analysis considers the effects of grants from the EU central authority to finance specific projects. Since the Recovery and Resilience Facility includes both grants and loans, estimates should be interpreted with caution as loans may have different macroeconomic effects. Section 6 returns on this issue. In addition, RRF rules require the grant component to be committed by the end 2023 (with payments available until 2026). This tight deadline might be challenging in terms of absorption capacity, as it requires member states to have developed a pipeline of investment projects of a sufficient large scale and quality, centering on economic transformation, to absorb the funding. Hence, with limited planning time, a portion of the funding may remain unused lowering the economic impact of the newly created EU programs.

6 Interpreting the dynamics

This section uses a dynamic equilibrium model to understand the mechanics of propagation of unexpected changes in the flow of EU funds to the regional economies, and to identify the structural features that may account for the heterogeneity in the multipliers we document.

To limit the dimensionality of the exercise and the cross-sectional complexities, we make three simplifying assumptions. First, we focus attention on a monetary union. Given that in many non-Euro EU countries the exchange rate with the Euro is fixed, this seems a reasonable working assumption. Second, we consider two representative regions: the "home" economy, and the "foreign" economy, which is interpreted as a conglomerate of all other regions in the union. Third, we do not explicitly model participation decisions, even though they are probably relevant in the EU context, as they require a specification with a home production sector and region specific labor market frictions.

The basic features of the model are similar to many in the literature, see e.g. Pappa and Vassilatos [2007], Gali and Monacelli [2008], Nakamura and Steinnson [2014], and Corsetti et al. [2017]. We differ in two important aspects: we allow a number of margins along which the regional economy can adjust in response to the shocks; we examine the effects of R&D and human capital federal spending disturbances, rather than consumption spending or infrastructure investment shocks. Short run nominal rigidities allow us to capture demand effects on production; and endogenous R&D and human capital accumulations create supply side effects in response to federal expenditure disturbances.

Time represents years. Each region is populated by a continuum of identical, infinitely lived agents. Union-wide population is normalized to one and the share of home economy population is $0 < n < 1$. Regions are identical in terms of preferences and technologies. The representative household in each region is endowed with one unit of time and derives utility from consuming a basket of goods produced in both regions, and from leisure. The remaining time is split between working and educational activities. Labor and capital are immobile. Firms produce output using effective capital and labor inputs and labor productivity may be endogenous and affected by federal expenditure. Disturbances are observed before agents make their optimal decisions.

There are complete financial markets where households trade state-contingent nominal bonds. A central bank sets the union wide interest rate as a function of aggregate variables. Tax collection occurs at the regional level; there is no local spending and the proceeds of the tax collection are transferred to the federal government, which uses the funds to finance consumption, R&D, human capital expenditures and subsidies. This setup mimics the way the EU budget works, and the fact that part of the budget funds may be used for non-productive purposes.

Households. The representative households maximize utility given by:

$$E_0 \sum_{t=1}^{\infty} \beta^t \frac{(C_t(1-L_t-M_t)^{\chi})^{1-\sigma}}{1-\sigma} \tag{3}$$

where $0 < \beta < 1$ is the discount factor, χ controls the Frisch labor supply elasticity, σ is a risk aversion parameter; C_t is consumption of the composite good, L_t is working hours, M_t is education hours and E is the expectation operator. This utility function is compatible with balanced growth, see e.g Boppart and Krussel [2020].

Households own human capital and choose how much time to spend in education. The law of motion of human capital is:

$$H_{t+1} = (1-\delta_H u_{H,t}^{\xi_H})H_t + \Theta(H_t M_t)^{\vartheta}(\bar{H}_t \tilde{G}_t^{HK})^{(1-\vartheta)} \tag{4}$$

where δ_H controls the steady state human capital depreciation rate and ξ_H the concavity of the depreciation function. The second term on the right hand side of (4) is the quantity of human capital produced at t. It consists of four terms: Θ is a productivity parameter; $H_t M_t$ is effective human capital produced by the household at t; $\bar{H}_t$ is the aggregate stock of human capital that households take as given, $\tilde{G}_t^{HK} = \frac{G_t^{HK}}{\bar{H}_t}$ is federal expenditure measured in aggregate per-human capital units and $0 < (1-\vartheta) < 1$ is an externality parameter: the larger is $(1-\vartheta)$, the larger is the effect of aggregate human capital and government spending on next year individual's human capital.

Households purchase consumption goods and state contingent bonds with after-tax labor, profit and financial income. The maximization problem is subject to the constraint:

$$C_t + T_t + E_t \pi_{t+1} \Lambda_{t,t+1} B_{t+1} = (1-\tau_t) w_t H_t L_t + s_t^M H_t M_t + B_t + \Xi_t \tag{5}$$

where B_{t+1} are holdings of the state contingent real bonds paying one unit of currency at $t+1$ if a specified state is realized, $\Lambda_{t,t+1}$ is the real price of these bonds at t, π_t the inflation rate, w_t is the real wage rate, τ_t is a labor income tax, T_t is a lump-sum tax/transfer; Ξ_t is profit income from the ownership of monopolistic competitive firms; and s_t^M is a federal education subsidy.

Letting C_{Ht} be a composite of domestically produced goods, C_{Ft} a composite of imported goods, and $0 < \eta < 1$ the weight of the imported goods in home consumption, the consumption basket is

$$C_t = \frac{C_{Ht}^{1-\eta} C_{Ft}^{\eta}}{(1-\eta)^{1-\eta}\eta^{\eta}} \tag{6}$$

When $\eta < 0.5$ there is home bias in consumption. We assume that total federal expenditure G_t, is also a composite and aggregates the public goods produced across regions analogously to (6).

Home and foreign produced consumption goods are aggregated into the composite with a standard CES aggregator, and elasticity of substitution $\varepsilon > 1$. For any good $0 < z < 1$, optimal allocation of expenditure yields the demand functions:

$$C_{H,z,t} = \left(\frac{P_{H,z,t}}{P_{Ht}}\right)^{-\varepsilon} C_{Ht}, \quad C_{F,z,t} = \left(\frac{P_{F,z,t}}{P_{Ft}}\right)^{-\varepsilon} C_{Ft} \tag{7}$$

where $P_{it} = \left(\int_0^1 P_{i,z,t}^{1-\varepsilon} dz\right)^{\frac{1}{1-\varepsilon}}$ is the price index of goods produced in region $i = H, F$. Optimal allocation of expenditure in the home country implies $P_{Ht}C_{Ht} = (1-\eta)P_tC_t,\ P_{Ft}C_{Ft} = \eta P_t C_t$ where $P_t = P_{Ht}^{1-\eta}P_{Ft}^{\eta}$, the home CPI price index used to deflate variables in (5).

Firms set prices in the sellers' local currency and the law-of-one-price holds. Thus, $P_{Ht} = P_{Ht}^*$, $P_{Ft} = P_{Ft}^*$, as the cost of imported goods in the home consumption basket is the price charged by foreign exporting firms, given that the nominal exchange rate is fixed. The real exchange rate is:

$$Q_t = \frac{P_t^*}{P_t} = \left(\frac{P_{Ft}}{P_{Ht}}\right)^{1-2\eta} \tag{8}$$

Note that, even under the law of one price, Purchasing Power Parity may not hold, i.e., $P_t \neq P_t^*$, since the two regions may consume goods in different proportions due to home bias.

Retail sector The problem of the firms in the retail sector is standard: they purchase wholesale goods at nominal price $P_{Ht}\varpi_{Ht}$ and convert them into differentiated final goods sold to domestic and foreign households and to governments at the price $P_{H,z,t}$. Monopolistic retailers are indexed by z, and produce one differentiated good. The representative firm in the home region solves:

$$\max E_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau} \Xi_{H,z,t+\tau}^R, \tag{9}$$

subject to the demand function

$$Y_{H,z,t} = \left(\frac{P_{H,z,t}}{P_{Ht}}\right)^{-\varepsilon} Y_{H,t}; \quad Y_{H,z,t}^* = \left(\frac{P_{H,z,t}}{P_{Ht}}\right)^{-\varepsilon} Y_{H,t}^* \tag{10}$$

where $Y_{H,t} = C_{H,t} + G_{H,t}, Y^*_{H,t} = C^*_{H,t} + G^*_{H,t}$ and real profits are given by:

$$\Xi^R_{H,z,t} = \left\{ \left(\frac{P_{H,z,t}}{P_{Ht}} - \frac{P_{Ht}\varpi_{Ht}}{P_{Ht}} \right) - \frac{\Psi_P}{2} \left(\frac{P_{H,z,t}}{P_{Hz,t-1}} - \pi_H \right)^2 \right\} (Y_{H,z,t} + Y^*_{H,z,t}) \tag{11}$$

where $\left(\frac{P_{H,z,t}}{P_{H,z,t-1}} - \pi_H \right)^2$ are Rotemberg-style adjustment costs per unit of output and Ψ_P is a parameter determining the size of those costs.

Wholesale sector Each wholesale firm has the same production function. It produces goods according to $Y_t = f(u_{k,t}, K_t, Z_t, u_{H,t}, H_t L_t)$, where Z_t is labor augmenting technological progress $u_{q,t}, q = K, H$ are utilization rates, K_t is physical capital and $H_t L_t$ is effective labor. Firms own physical and R&D capital. Their accumulation law is:

$$\begin{aligned} K_{t+1} &= (1 - \delta_K u^{\xi_K}_{K,t}) K_t + \Phi_K \left(\tfrac{I_t}{K_t} \right) K_t \\ D_{t+1} &= (1 - \delta_D u^{\xi_D}_{D,t}) D_t + \Phi_D \left(\tfrac{S_t}{D_t} \right) (\tilde{G}^{RD}_t)^{\omega_{RD}} D_t \end{aligned} \tag{12}$$

where I_t is the amount invested and K_t is the stock of physical capital; S_t is the amount invested and D_t is the stock of R&D; $\xi_q, q = K, D$ controls the concavity of the depreciation function and δ_q the steady state level of depreciation; $\Phi(.)$ is a concave adjustment cost function, specified as

$$\Phi_K \left(\frac{I_t}{K_t} \right) = \varphi_{K,1} + \frac{\varphi_{K,2}}{1 - \frac{1}{\psi_K}} \left(\frac{I_t}{K_t} \right)^{1 - \frac{1}{\psi_K}} \tag{13}$$

$$\Phi_D \left(\frac{S_t}{D_t} \right) = \varphi_{D,1} + \frac{\varphi_{D,2}}{1 - \frac{1}{\psi_D}} \left(\frac{S_t}{D_t} \right)^{1 - \frac{1}{\psi_D}} \tag{14}$$

see Jermann [1998], where $\varphi_{j,l}$, $j = 1, 2$, ψ_q, $q = K, D$, are parameters. $\tilde{G}^{RD}_t = \frac{G^{RD}_t}{\bar{D}_t}$ is federal R&D expenditure per unit of R&D capital, $\omega_{RD} \geq 0$ and $\bar{D}$ the aggregate stock of R&D. Accumulation of R&D expenditure is affected by government spending and ω_{RD} controls the size of the externality. Because of adjustment costs, the shadow prices of physical and R&D capital are time varying.

Wholesale firms sell their goods to retailers at the nominal price $\varpi_{Ht} P_{Ht}$ and chose effective labor, physical and R&D investment, to maximize their real profits:

$$\Xi^W_t = \varpi_{Ht} Y_t - w_t (u_{Ht} H_t L_t) - I_t - (1 - s^{RD}_t) S_t \tag{15}$$

where s^{RD}_t is a stochastic federal R&D subsidy. Firms optimize subject to the law of motions for R&D and physical capitals, and the production function.

Fiscal authorities The economy has two local and one federal fiscal authorities. The local fiscal authorities levy labor income and lump-sum taxes, and transfer the tax collection to the federal government which uses the funds to finance expenditures and to pay for subsidies. Thus, the federal budget is balanced by varying local lump sum taxes.

In per-capita terms, federal spending in region $i = H, F$ is $G_{it} = G_{it}^{C} + G_{it}^{RD} + G_{it}^{HK} + s_t^{RD} S_t + s_t^{M} M_t H_t$ where G_{it}^{C} is a zero mean, AR(1) consumption expenditure process , while $G_{it}^{RD}, G_{it}^{HK}, s_t^{RD}, s_t^{M}$ are constant mean AR(1) processes. Total spending in the home and foreign regions are nG_{Ht} and $(1-n)G_{Ft}$, respectively.

Because Ricardian equivalence holds, the assumption of perfect financial markets implies that any risk associated with regional variation in lump-sum taxes is absorbed via risk sharing.

Monetary Policy The central bank sets the interest rate, R_t according to:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\vartheta_R} \left(\frac{\pi_t^u}{\pi}\right)^{\vartheta_\pi} \tag{16}$$

where $\pi_t^u = n\pi_t + (1-n)\pi_t^*$ is the union-wide inflation rate; π_t and π_t^* the domestic and foreign CPI inflation rates, R and π the steady state nominal rate and inflation rate, $\vartheta_R, \vartheta_\pi$ are policy parameters.

Risk sharing Combining the home and foreign consumption Euler equations, the assumption of complete financial markets yields the risk sharing condition:

$$\frac{u_c(C_t^*, L_t^*, M_T^*)}{u_c(C_t, L_t, M_t)} = \left(\frac{C_t^*(1-L_t^*-M_t^*)^\chi}{C_t(1-L_t-M_t)^\chi}\right)^{-\sigma} \left(\frac{(1-L_t^*-M_t^*)}{(1-L_t-M_t)}\right)^{\chi} = \upsilon_t \varsigma_t \tag{17}$$

where υ_0=1, so that, initially, the representative households in the two regions have equal amounts of wealth; $\varsigma_t = \frac{P_t^*}{P_t}$ is the real exchange rate; and variables with asterisks denote variables of the foreign region. The risk sharing condition links the real exchange rate and the marginal rate of substitutions between consumption in the two regions. Hence, all households face identical relative prices of consumption goods in the world market.

Equilibrium We consider a symmetric equilibrium, where all firms produce the same amount and charge the same price. We assume that contingent bonds are in net zero supply, $B_t = 0$. The resource constraint for the home economy is

$$Y_t = nC_{Ht} + (1-n)C_{Ht}^* + I_t + S_t + nG_{Ht} + (1-n)G_{Ht}^* + \frac{\Psi_P}{2}\left(\frac{\pi_{Ht}}{\pi_H} - 1\right)^2 nY_t, \tag{18}$$

where $\frac{\Psi_P}{2}\left(\frac{\pi_{Ht}}{\pi_H} - 1\right)^2 Y_t$ is the per-capita domestic output cost of adjusting prices.

The specification for preferences and technologies allows for a balanced growth path solution. This is true even when the two regions grow differently in the steady state. Since the aggregate consumption baskets are Cobb-Douglas, differences in consumption growth rates are neutralized by a secular trend in relative prices. Notice also that while the growth rate of domestic production depends on the domestic factor accumulation, the growth rate of private and public consumptions reflect both domestic and foreign factor accumulation. The risk sharing condition guarantees that these trend growth differences will appear as differences in the steady state inflation rates of the two regions and this, in turn, implies a secular trend in the real exchange rate. Thus, as in Abbritti and Weber [2019], when the home region features a higher R&D or human capital growth, it will also experience a lower inflation rate and a real exchange rate depreciation. We obtain an equilibrium in deviation from a balanced growth path, scaling all variables by D_t or H_t.

6.1 R&D expenditure shocks

To understand the dynamics induced by a shock in the ERDF funds, we examine the propagation of federal R&D expenditure disturbances in the home region, setting human capital accumulation to zero, and dropping education choices from the optimization problem. Thus, $H_t = \bar{H}_t = 1, u_{H,t} = 1, M_t = 0, \delta_H = 0, \forall t$, and the production function for wholesale firms is:

$$Y_t = (u_{K,t} K_t)^{\alpha} (Z_t L_t)^{1-\alpha} \tag{19}$$

where α is the capital share and:

$$Z_t = (\tilde{G}_t^{RD})^{\mu_{RD}} (u_{D,t} D_t)^{\zeta} (\bar{u}_{D,t} \bar{D}_t)^{1-\zeta} \tag{20}$$

where μ_{RD} and $1 - \zeta$ are, respectively, an efficiency and an externality parameter.

Together (19) and (20) imply that labor productivity has an endogenous component, depending on the amount of individual effective R&D services, $u_{D,t} D_t$, and on the aggregate level of effective R&D services, $\bar{u}_{D,t} \bar{D}_t$, and an exogenous component driven by $\tilde{G}_t^{RD}$. The fact that labor productivity depends on the utilized stock of aggregate R&D captures the idea that accumulated knowledge facilitates the creation of new knowledge via technological spillovers. $(1 - \zeta) \in (0, 1)$ governs the "size" of the externality due to the utilized aggregate R&D stock. When μ_{RD}=0, federal R&D expenditure has no productive use and is as wasteful as federal consumption expenditure. When, $\mu_{RD} \neq 0$, federal R&D spending positively impacts labor productivity.

With the specification we employ, federal R&D expenditure may thus affect the home region in three ways: i) directly via Z_t; ii), indirectly, by altering the accumulation of R&D investments; iii) indirectly, by changing the costs per unit of R&D investment.

Parameterization. For the baseline scenario, we use standard parameter values. We select $n = 0.1, \eta = 0.35, \beta = 0.992^4; \sigma = 2, \chi = 2, \delta_k = 0.08, \delta_D = 0.06$ $\tau = 0.25, \epsilon = 10, \alpha = 0.3, \zeta = 0.65$ (which we take from Kung [2015]) $\Psi_p = 10, \vartheta_R = 0.75, \vartheta_\pi = 1.5$ $\psi_K = 3, \psi_D = 2.5$ (which are slightly smaller than those in Bonciani and Oh [2020] and adjusted to match our annual frequency); steady states

R&D subsidies are equal to 0.1. We also assume that in the steady state R&D grows at 0.5 percent a year and that utilization and Tobin's Q are all equal to 1, as are the regional inflation rates. The AR(1) coefficient of the shocks is set to 0.25. These choices imply that the real interest rate is four percent a year, that price stickiness is low, that adjustment costs are moderate, that there is home bias in consumption, and that federal R&D shocks die out quickly.

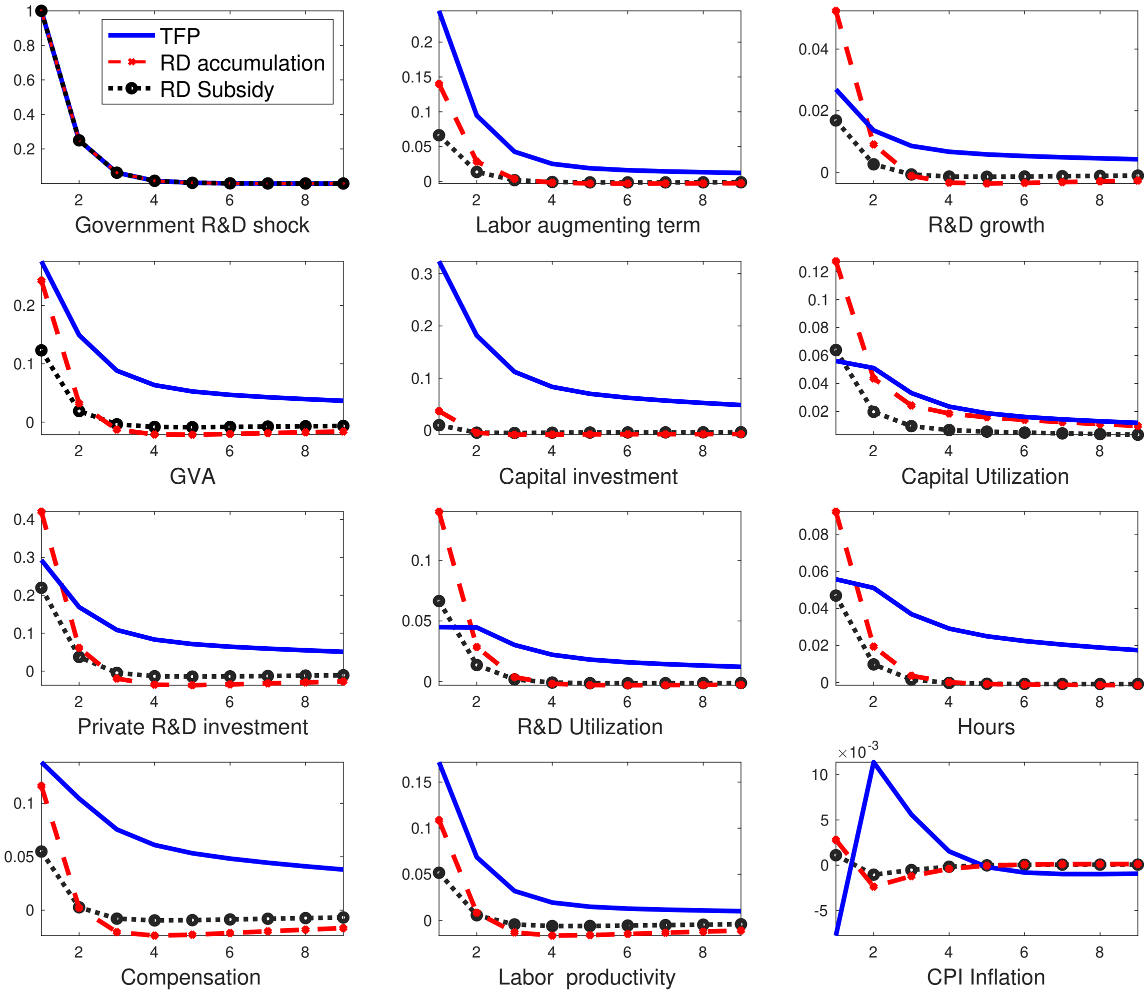
Figure 6 plots responses to a federal R&D expenditure shock in the stationarized model for three scenarios. In the first, we assume that federal R&D shocks only affect Z_t and set $\mu_{RD} = 0.2, \omega_{RD} = 0$ (continuous line named "TFP"); in the second that they only affect R&D accumulation and set $\mu_{RD} = 0, \omega_{RD} = 0.4$ (dashed line named " RD accumulation"); in the third that they only affect R&D investment costs and set $\mu_{RD} = 0, \omega_{RD} = 0$ (dotted line named "RD subsidy").

R&D funds affecting Labor Productivity. When R&D directly affects Z_t, the shock immediately appears in the labor augmenting term and it is accompanied by an increase in the utilization of the two types of capitals, to take advantage of the labor productivity increase. Because the supply side of the economy is positively affected, private output, hours, investments in physical and R&D capital, the real wage and labor productivity all instantaneously increase. Note that although output is demand determined, the supply effects of the shock dominate on impact: in fact, there is a downward pressure on marginal costs, which more than counteracts the increase in aggregate demand, leading to an instantaneous fall in CPI inflation.

This pattern of instantaneous responses differs from those generated by government consumption spending shocks in standard, closed economy, New Keynesian models because the R&D shock has an effect on a) labor productivity and b) the accumulation of both physical and R&D capital. In standard models government consumption expenditure shocks generate a negative wealth effect and a positive demand effect, see e.g. Ramey [2019] or Pappa [2021]. The negative wealth effect, arising because households are Ricardian, increases the labor supply; the positive demand effect, due to increased public sector absorption, increases labor demand, real wages, and private output. The increase in demand also rises current and expected future inflation. Thus, when monetary policy is conducted with a Taylor rule, increases in the nominal (and real) rate counteract most of positive demand effects, generally producing insignificant or even negative responses of private output and investments. These conclusions may be altered when some agents consume all of their current income; however, in no case increases in government consumption give rise to the positive instantaneous comovements we observe in the data. In our setup effects a) and b) increase factor utilization and labor demand in response to the shock therefore making supply effects large.

Instantaneous responses also differ from those generated by a federal physical capital investment shock. Here, an unexpected increase in spending has three effects: two similar to those induced by government consumption shocks, and an additional positive wealth effect, due to future productivity

Figure 6: Dynamics in response to federal R&D shocks



Note: The figure plots the impulse responses to government R&D shock when they affect labor productivity (continuous line), the R&D accumulation (dashed line) or are distributed as subsidies (dotted line).

enhancement see e.g. Leeper et al. [2010] or Ramey [2020a]. Together these effects imply that real wages and employment mildly increase on impact, while investments and output increase with a lag, spreading the effect of the shock over time as capital accumulation increases. In our setup, the externality operates instantaneously and the enhancement of labor productivity implies that investments and output increase on impact.

As time unfolds, the initial boost to labor productivity dies out making all regional variables converge back to the balanced growth path. Nevertheless, because the shock persistently increases labor productivity and R&D growth, regional responses are persistent and convergence to the steady state is slow - 10 years after the shock the economy has not yet returned to the steady state. Hence, temporary demand shocks have important medium term consequences, since they positively affect the economy production possibility frontier. Since a shock may drive cyclical, medium term and long term dynamics, standard trend and cycle decompositions are inappropriate, see also Canova [2020a].

R&D funds affecting R&D capital accumulation The qualitative pattern of responses in the other two specifications is similar, but there are important differences in the impact effects and in the persistence of the responses. Impact differences occur because when shocks affect the R&D accumulation equation, the relative importance of supply and demand effects is altered. With the parameterization we have used, the magnitude of the labor augmenting term responses is uniformly smaller, making the demand effect relatively stronger (see e.g. the response of CPI inflation). However, they could be made much smaller if e.g. the steady state subsidies, which now cover about 10 percent of the costs, are increased. The less persistent impulse results because the dynamic responses of R&D growth are more temporary and this implies , e.g., that capital investment, hours and GVA responses turn negative after about 2 years and converge to the steady state from below. Note that when R&D funds affect capital accumulation firms prefer to meet the increased demand by varying the utilization rate of R&D and capital, instead of increasing the physical capital stock. Because the effects on the physical capital stock and R&D are systematically lower, assuming that federal spending in R&D enhances its accumulation generates uniformly less persistent effects.

Table 5: Cumulative multipliers, theory: R&D shocks

	TFP		**RD accumulation**		**RD subsidy**	
Horizon	1 year	3 years	1 year	3 years	1 year	3 years
GVA	2.86	2.15	1.36	0.82	0.90	0.65
Employment	0.75	0.52	0.29	0.08	0.24	0.09
Compensation	2.14	1.99	0.90	0.66	0.51	0.46
Investments	6.48	4.99	2.60	1.59	1.68	1.23
Labor productivity	1.66	1.35	0.97	0.77	0.56	0.59

Note: Reported are the cumulative multipliers under different assumptions on the use of the funds.

Table 5 presents cumulative multipliers for horizons h=1 and h=3. They are computed accumulating at each h the discounted growth rate of the variables of interest in response to the shocks, once the balanced growth path is added, and scaling the amount by the accumulated discounted growth rate of federal spending, again adding the balanced growth path.

In agreement with Table 1, the cumulative multipliers the model generates for h=3 are generally smaller than those at h=1 for all three specifications. However, only in the R&D accumulation specification, where supply effects are diluted, multipliers seem to die out fast enough to be consistent with the data. Hence, when considering all EU regions and the full sample, R&D funds must have been used, on average, to enhance the accumulation of R&D capital, directly or through subsidies, and this choice did not induce the physical capital accumulation needed to produce sustained growth.

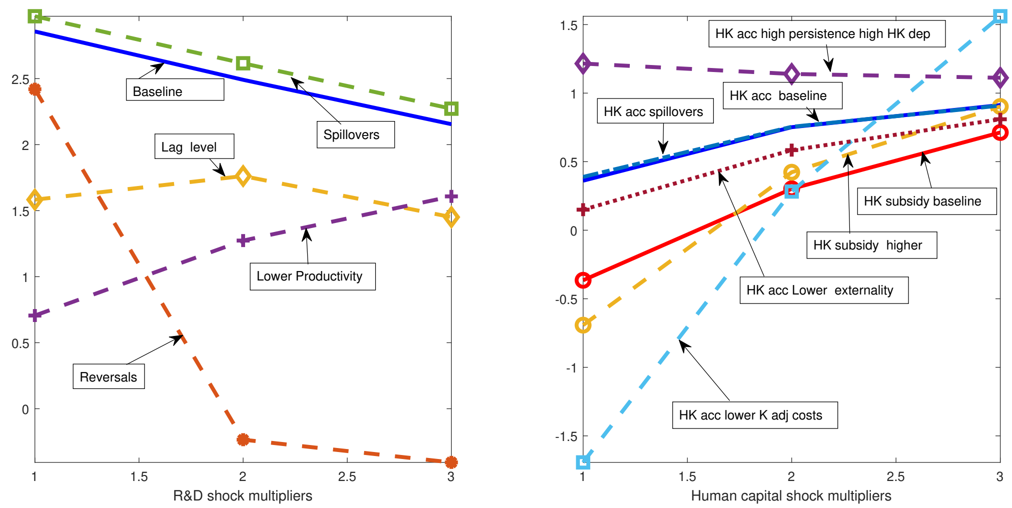
Heterogeneities. Given the widespread heterogeneities present in the data dynamics, it is worthwhile to examine whether different specification choices can account for some of the alternative patterns average multipliers display for different groups of regions. Recall from section 5 that, for the case of ERDF, there are three types of relevant heterogeneity: for regions in the North, belonging to new members states, or in the first and fourth quartile of the income distribution the initial boost to economic activity vanishes fast and after three years cumulative multipliers are generally negative; certain regions have the time profile of the multipliers which are systematically larger than in others; after 2000 the peak multiplier is lagged. The left panel of Figure 7 depicts how such patterns can be generated in the "TFP" specification.

The continuous line represents the profile of the multipliers for the baseline setting presented in Table 5, the dashed lines the profile of the multipliers for a number of alternatives. The line named "Reversal" assumes that current federal R&D spending positively impacts on labor productivity, yet past expenditure deteriorates it. In this case the labor augmenting term is $Z_t = (\psi^{RD}_{t-1}/\bar{D}_t)^{\mu_{RD}}(u_{D,t}D_t)^{\zeta}(\bar{u}_{D,t}\bar{D}_t)^{1-\zeta}$ where $\psi^{RD}_t = \frac{\widetilde{G}^{RD}_{t-1}}{\widetilde{G}^{RD}_{t-2}}$ and the persistence of $\widetilde{G}^{RD}_t$ is increased to 0.5. With this setup we capture the idea that, in many regions, government effort in R&D activities may not be sustained and reverses once EU grants are withdrawn. The line named "Lag level" assumed that federal spending in R&D enters Z_t with one period lag and it is intended to capture the idea that there may be gestation lags in the way the region employs the funds. The line name "Lower productivity" assumes that $\mu_{RD} = 0.05$ and captures the idea that the local economy may not be able to productively absorb the new funds.

These modifications impart a different time profile to the multipliers. For example, with expenditure reversals, cumulative multipliers fall quickly into the negative territory after the initial boost. Intuitively, this occurs because the labor productivity increase is very temporary and the growth rate of R&D reverses after two periods. In this situation, physical capital accumulation is weak and the initial impulse to the regional economy dies out as soon as the federal funds are withdrawn.

Hence, whether the level or the growth rate of federal R&D spending enters Z_t is important to

Figure 7: Time profile of theoretical multipliers: alternative specifications



Note: The figure plots cumulative multipliers for federal R&D spending shocks affecting Z_t (left panel) and federal human capital spending (right panel) under different structural features.

determine how fast the initial positive effect decays providing an explanation, for example, for the difference between northern vs southern or old vs. new member regions present in Table 4. The current legislation allows for the possibility that younger tenure, lower income regions use part of the EDRF grants (up to 50 percent) for purposes other than R&D support. Table 4 shows that in these regions cumulative multipliers turn negative very quickly. Our model tells us that this would be the case when there are reversals and the productivity of federal R&D expenditure in Z_t is low.

When there are gestation lags, the profile of multipliers are humped shaped qualitatively matching the average dynamics on the bottom panel of table 2. Here, the demand effects of the shocks are dominant on impact and the supply effects, driven by the increase in labor productivity, alter the production possibility frontiers only with a delay.

A comparison between the baseline setup and the lower productivity specification is also interesting because differences in these two scenarios capture variations in the dynamics of Solow residuals across regions. When productivity is lower, there is a reduced impact effect due to the fact that the labor productivity boost is smaller and demand factors again dominate in the short run. The stronger propagation in the medium run is instead driven by the fact that the supply effects are smoother leading to a peak response in the cumulative multipliers at horizons larger than 3. Thus, differences in productivity dynamics may account for the differences between EU and non-EU regions and for the different multipliers profiles among different quartile of the income distribution.

Finally, regional spillovers are difficult to characterize in a two-region economy. However, if we think of a country as a larger region in which the magnitude of the impulse remains the same, then increasing the size of the region should approximately produce the effect we care about. Indeed, the "Spillover" line shows that when the region is larger, the multiplier effects of government R&D spending shocks become uniformly larger, as it is the case in the data. However, magnitude differences with the baseline specification are relatively small.

In sum, the model is quite rich. Depending on the way R&D spending is channeled to the local economy, and the specification and the parameters of the production function, we can produce different time profiles of multipliers and account for a number of stylized facts present in the data.

6.2 Human capital expenditure shocks

To mimic the effects of ESF funds shocks, we set $u_{D,t} = 1, \delta_D = 0, D_t = S_t = \delta_R = 0,\ Z_t = 1,\ \forall t$ and specify the production function to be

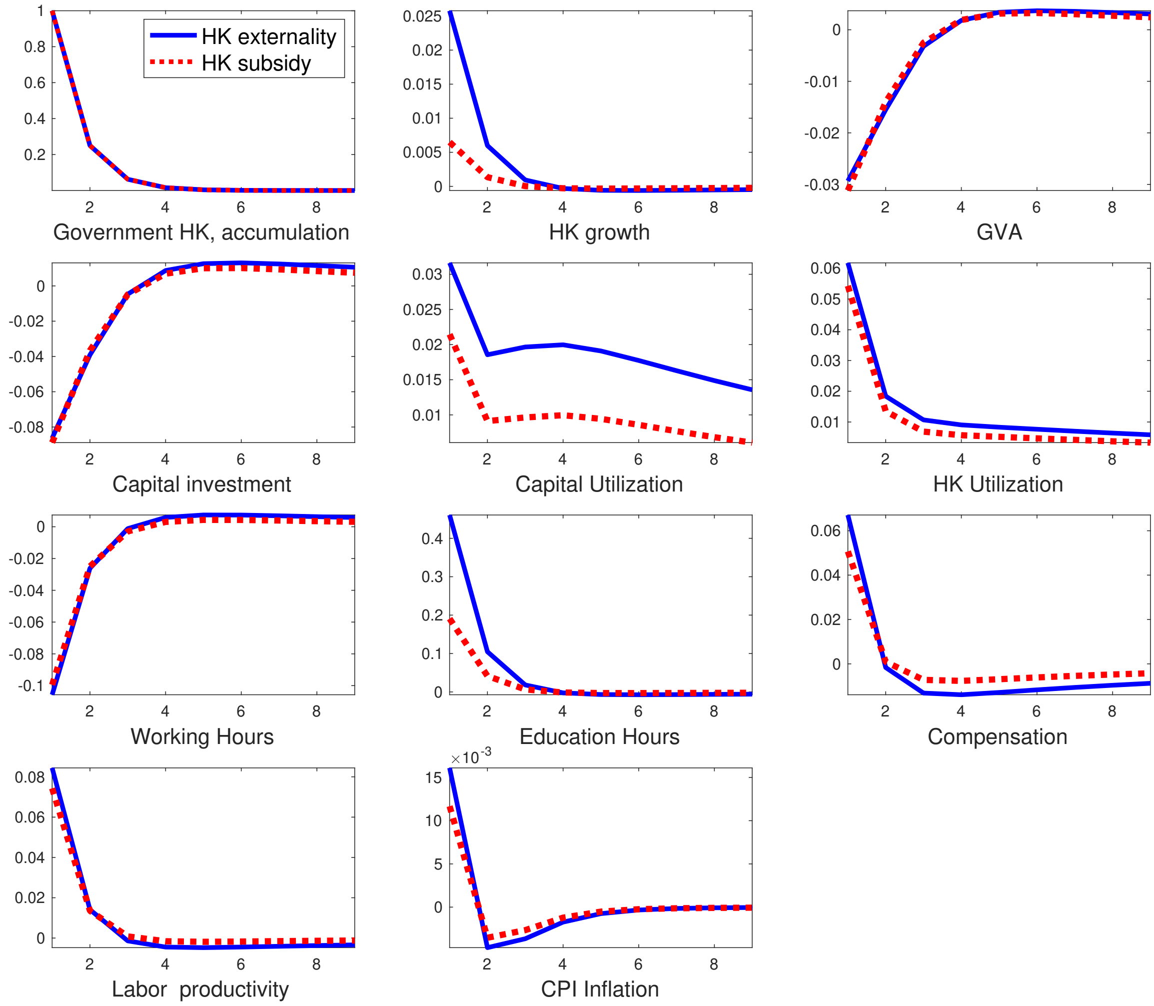
$$Y_t = (u_{K,t} K_t)^{\alpha} (u_{H,t} H_t L_t)^{1-a} \tag{21}$$

where $(u_{K,t} K_t)$ are effective capital services and $(u_{H,t} H_t L_t)$ effective labor services. Thus, federal spending in human capital does not directly affect the regional production possibility frontier. Instead, it alters the accumulation of human capital or household education choices through subsidies.

Parameterization. The version of the model with human capital expenditure, features four additional parameters. Evidence from Jones and Manuelli [2005] and Dinerstein et al. [2020] suggests annual depreciation values for human capital of teachers between 4 and 6 percent. We set $\delta_H = 0.04$. There is not much empirical evidence to select ϑ, the share of individual human capital in the accumulation equation. Estimates by Malley and Woitek [2009] suggest a value around 0.6. In the baseline experiment, we set $\vartheta = 0.65$. The persistence of federal human capital spending ρ_{HK}, is set to 0.25, to mimic the fact that EU programs last one or two years. Finally, the steady state value of the human capital subsidy is 0.1. All other parameters are kept to the values mentioned in the previous subsection. Figure 8 plots the responses to an impulse in federal human capital expenditure. There are two lines in each box: one represents the dynamics when expenditure affects the human capital accumulation equation (continuous line named "HK externality"); and the other the dynamics in the subsidy specification (dotted line named "HK subsidy").

The outcomes. When federal education spending affects human capital accumulation, working hours and investments fall while education hours, the real wage and labor productivity increase on impact, regardless of how the funds are employed. This combination of responses occurs because the shock induces households to shift time away from work towards education and this tightens the labor market. While GVA responses are negative, the fall is contained since both physical and

Figure 8: Dynamics in response to federal human capital shocks



Note: The figure plots the impulse response to a shock to a federal human capital shock when they affect human capital accumulation (continuous blue line) or are distributed as subsidies (red dotted line).

human capitals are utilized more intensively, counteracting the fall in working hours. Since labor costs increase, CPI inflation instantaneously moves upward.

The initial jump in education hours is not persistent because federal spending is temporary. Thus, working hours, investments, and private output responses become positive after four years and converge back to the steady state from above. The opposite occurs for real wages and labor productivity, which converge to the steady state from below. Note that the increase in training hours raises human capital growth. With subsidies the effect on human capital growth is uniformly smaller because, with the assumed steady state level of subsidies, workers are less incentivated to increase their education hours, and this makes capital utilization and in human capital growth react less. When the level of steady state subsidies is higher, so that the federal government covers a large portion of the training costs, the dynamics in the two scenarios are quantitatively similar.

Interestingly, the pattern of responses displayed in Figure 8 is qualitatively similar to the one produced by temporary negative labor supply shocks. These shocks induce agents to take more leisure on impact and work more later on. The twist here is that the externality induced by federal expenditure affects the accumulation of human capital. Hence, more persistent effects are produced.

Table 6: Cumulative multipliers, theory: Human capital shocks

	HK accumulation		**HK subsidy**	
Horizon	1 year	3 years	1 year	3 years
GVA	0.36	0.91	-0.36	0.71
Employment	-0.69	-0.01	-1.47	-0.24
Compensation	0.76	0.63	0.56	0.26
Investments	-0.22	0.99	-1.62	0.82
Labor productivity	1.13	0.92	1.25	0.96

Note: Reported are the cumulative multipliers under different assumptions on the use of the funds.

Table 6 reports the cumulative multipliers in the two scenarios. The model accounts for two important stylized facts present in the data: (i) the impact multiplier on private output, investments, and hours is negligible or even negative; (ii) the cumulative multiplier for these variables at the three years horizon is positive and larger than on impact. However, it falls short in matching the medium term boom present in Table 1. One reason for this shortfall is the fact that capital investment is not recovering fast enough after the initial fall and does not contribute to ignite a medium term boom when workers have better skills. Another reason is that the supply elasticity of working and education hours is the same. If the latter is larger, larger medium term multipliers could be generated.

The model can also generate a persistent, albeit small, medium term multiplier in compensation and, despite the rudimentary specification of the labor market we employ, it can produce a positive medium term labor productivity multiplier. To generate labor productivity (and compensation) multipliers that look more like those in the data, one needs to have at least two types of workers:

unskilled who do not train, and skilled, who spend time improving their skills. When skilled workers return to their working activities, they command a higher wage (making average compensation persistently increase). Furthermore, because they have higher marginal product, average labor productivity should increase in the medium term. As the scope of the current section is to interpret the pattern of GVA, investments, and employment multipliers found in data, we leave these extensions, which may produce more realistic medium term multipliers, for future work.

Heterogeneities ESF disturbances also create considerable heterogeneity in the responses of macroeconomic variables across regions. The right panel of Figure 7, which plots the profile of cumulative multipliers after a shock in federal human capital spending for alternative parameters, tries to understand why. The solid lines report the multipliers for the two baseline specifications. The dashed lines the multipliers obtained with alternative settings. As in the case of R&D shocks, the time profile of the multipliers depends on the specification of the primitives and on parameter choices.

For example, it is possible to generate larger medium term cumulative multipliers by decreasing capital adjustment costs (see the " HK acc Higher K adj cost" line in Figure 7). This change forces a larger initial drop of investments but allows larger capital accumulation over the adjustment path, boosting the medium term effects and stretching over time the effect of the shock. Thus, smaller capital adjustment costs can twist the time profile of multipliers. Higher steady state subsidies can also twist the time profile of multipliers, making the slope of the cumulative multiplier steeper (see the " HK subsidy higher" line in Figure 7). When they are larger, they boost the growth enhancing role of subsidy shocks and, at the same time, make the initial fall in working hours larger, thus implying more negative impact multipliers and larger medium term cumulative multipliers. A lower value of the parameter regulating the human capital accumulation generates uniformly lower multipliers (see the " HK acc lower externality" line in Figure 7). Since the externality is reduced, the effect on all macroeconomic variables is smaller. Hence, regional variations in this parameter can account for some of the differences we observe across regions in e.g. Table 4 and Figure 3.

Finally, as in the data, spillover effects are minor (see the "HK acc spillover" line in Figure 7). When the region is larger, magnitude differences with the baseline setup are small and the time profile of the multipliers identical.

We have seen in Table 4 and in Figure 3 that for some of the regions the cumulative multipliers in response to ESF shocks are declining and become zero or negative at the three years horizon. While our setup can not produce negative multipliers, it can produce declining multipliers if shock persistence is high and human capital depreciation is large (see the " HK acc high persistence high HK dep"in line Figure 7). Here the benefits of training are washed out by the fact that human capital fades at a high rate. To have negative medium multipliers in response to federal human capital shock, one must allow for labor movements across regions. If the newly trained workers find better jobs in regions others than those where they were trained, it is possible to generate polarization/ agglomeration effects similar to the ones observed in Figure 3, when regions with high stock of human and physical capital attract newly trained workers, thus effectively making the return to education in the local economy negative.

Although we do not report it to avoid redering the figure unreadable, with higher price stickiness, the demand effects of the shocks are stronger making the cumulative multipliers roughly constant across horizons. Higher price stickiness limits the initial fall in working hours by making real wages (and marginal costs) increase substantially and forces an initial increase in capital accumulation. As time goes by, the demand effect dies out and macroeconomic dynamics are mostly driven by the dynamics of the growth rate of human capital. These two effects imply that, relative to the baseline case, the multiplier is much higher on impact and stays higher at all horizons of interest. .

In sum, the pattern observed in the data is consistent with the idea that federal human capital expenditure has a direct positive effect on private human capital accumulation and an indirect effect on physical capital accumulation. To make sure that the physical capital accumulation supports the increase in human capital and, thus, ignites a virtuous cycle, it must be the case that capital adjustment costs are small, steady state subsidies are large or the externality term in the human capital accumulation is sufficiently high. Differential regional values for these parameters may, hence, account for some of the heterogeneity present in the data.

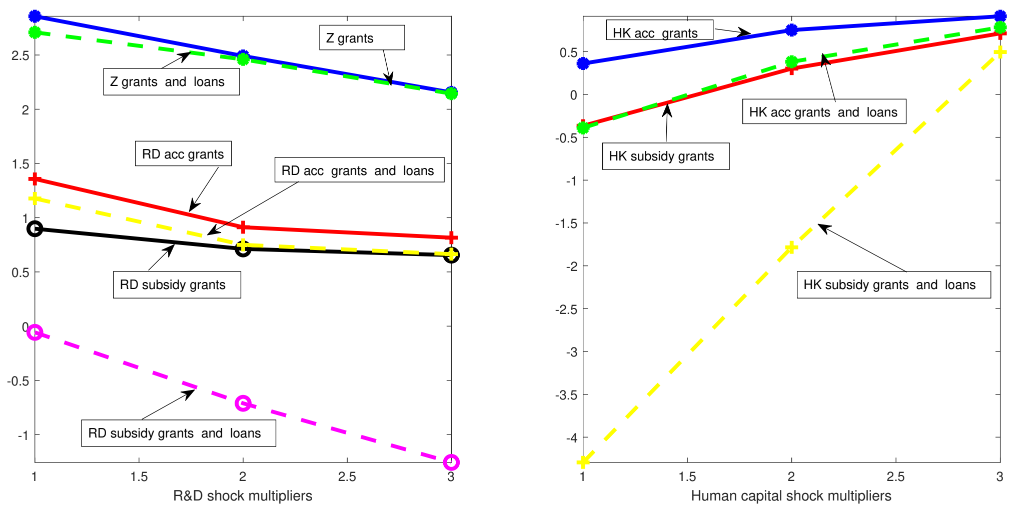
6.3 A counterfactual

One distinguished feature of the RRF is that it provides a combination of grants and loans in almost equal proportions. However, loans need to be repaid by individual countries and will enter the national stock of debt by 2023. The distinction between the two sources of financing is relevant because some countries, for example Italy and Greece, have decided to use both, while others, for example Spain and Germany, will only use grants.

While the data does not allow us to understand the consequences of these two modes of expenditure financing, the model can be altered so that federal support comes in the form of grants and loans.Thus, one can form an idea of what will happen when the second option is exercised. Given what Italy and Greece have pledged to do, we assume that 50 percent of the federal support is in the form of loans and that they will be repaid with funds raised via distorting labor taxation.

Figure 9 reports the profile of cumulative multipliers obtained in the baseline specifications (Tables 5 and 6) and when half of the regional funds come in the form of loans. Clearly, in the grants-loans scenario, multipliers become uniformly lower on impact for both types of shocks and for all the possible uses of the funds. When distorting labor taxation is employed to cover the cost of the loans, the demand effect of the shock is reduced since real wages and marginal costs increase considerably and the impact multiplier decreases. The effect is important for human capital disturbances when

Figure 9: Time profile of the multipliers: grants versus 50% loans and 50% grants



Note: The figure compares cumulative multipliers for federal R&D shocks (left panel) and human capital shocks (right panel) in the baseline setup and in the alternative where both loans and grants finance the spending.

the funds are used for subsidies. Here, income taxation implies a very large instantaneous fall of investments and this is responsible for the large negative impact multiplier.

Multipliers are generally lower also in the medium term and this is particularly true for R&D disturbances in the subsidy specification, where they turn negative at the three year horizon. Once again labor taxation makes hours fall persistently, prevents accumulation of physical capital and makes the expansion of the production possibility frontier temporary. One can twist the time profile of the multipliers by allowing debt and postpone the loans payment to later dates. However, the conclusion that in the medium run (intended in this case as the period when the debt is paid back) multipliers of both types of shocks are smaller or more negative remains.

The policy implication of Figure 9 is clear. Countries that only employ the grant portion of the RRF are in better position to recover, because multipliers are larger and accumulated government debt will not jeopardize the recovery at some future date.

7 Conclusions

This paper provides empirical evidence on the dynamic effects of the two most important structural funds the EU has granted to regions of member states over the last 30 years. Given that NGEU funds have features resembling those of ERDF and ESF funds, we use historical evidence to evaluate the likely consequences of the planned fiscal expansion on the EU regional economies.

On average, ERDF innovations have statistically significant and economically relevant positive short term effects on all regional macroeconomic variables, making the funds potentially useful for countercyclical purposes. Nevertheless, the positive impact dies out quickly and gains dissipate almost entirely within three years in many regions. ESF innovations, instead, have negative (although often insignificant) consequences on impact but exercise a positive effect on all regional variables after 2-3 years, making them good instruments to achieve medium term transformation objectives. Quantitatively the two programs produce average regional multipliers with quite different magnitudes. If employment, production, and investments growth are the yardstick to measure the success of the two programs, ESF dominates EDRF in the medium run.

Both programs produce considerable heterogeneity in regional macroeconomic outcomes. The level of regional development, tenure with the EU, membership to the Euro, location, and national borders are all important to explain the asymmetric transmission. Although the distribution of EU funds is skewed toward poorer, peripheral, and less developed regions, the heterogeneous dynamic patterns we discovered indicate that these funds have led to increased polarization and regional inequality. If minimization of regional distortions is important, the ESF program is preferable, as it benefits a larger number of regions in a number of countries.

To interpret the dynamics and to give a structural interpretation to the mechanism we document, we extended a standard workhorse New Keynesian model of a monetary union to allow for endogenous growth. We do this through two separate channels: R&D and human capital accumulation. ERDF innovations, which we model as federal R&D shocks, change the productivity of labor and the production possibility frontier. ESF innovations, which we model as shocks affecting the human capital accumulation, alter instead the labor/leisure/schooling margins. We show that the model can replicate a number of stylized facts and account for certain regional asymmetries.

What have we learned from the exercises that can be useful to predict the macroeconomic effects of NGEU funds? EU grants can have a useful role in counteracting the COVID-19 recession and in boosting job creation and investments that may lead to economic transformation. Thus, the creation of NGEU funds is a good idea and the choice of borrowing to finance them seems correct, because they are likely to produce gains that can sustain the cost of borrowing and avoid persistent accumulation of debt. However, because EU funds benefit some regions more than others, and the less fortunate turn out to be poorest, peripheral, and non-Euro regions or recently added countries, the adjustment and transformation process will be unequal.

There are no obvious corrections whose implementation avoid increases in regional inequalities. However, there are examples of EU regions, which managed to escape the poverty trap and join the wealthy club. Studying in details what has made a difference would be instructive to avoid repeating mistakes made in the past. In general, administrative and structural reforms, efficiency checks and, perhaps, generational changes may help to spread the gains more uniformly across EU regions.

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Appendix A: EU regional funds

EU regional policy targets all regions of the European Union with the goal of supporting job creation, business competitiveness, economic growth, sustainable development, and to improve the quality of life of EU citizens. To reach these goals and to deal with the heterogeneous stages of development of different EU regions, a portion of the total EU budget is set aside for the so-called Cohesion policy in each budget cycle. For example, for the 2014-2020 cycle, the Cohesion policy program is endowed with over 355 billion Euros, almost a third of total EU budget.

The European Structural and Investment (ESI) funds, the main tools to achieve the Cohesion policy goals, comprises four different programs: the European Regional Development Fund (ERDF), the Cohesion Fund (CF), the European Social Fund (ESF), the European Agricultural Fund for Rural Development (EAFRD). In the most recent budget cycle, the European Maritime and Fisheries Fund (EMFF) has been added. ERDF covers over 40 percent of the total budget, EAFRD over 20 percent, and ESF and CF less than 20 percent each.

The funds should be used to implement the Commission's priorities. Thus, the grants to member states and regions are subject to conditions. The priorities vary with the budget cycle but are growth, employment and social equality have been long lasting themes in the EU agenda. For the 2014-2020 budget cycle the Commission has five targets:

• Employment: at least 75 percent of the population 20-64 year-old should have a job.

• Research & Development: 3 percent of the EU's GDP should be invested in R&D.

• Climate change and energy sustainability: greenhouse gas emissions should be reduced by 20 percent; energy from renewable sources should increase by 20 percent; and energy efficiency should increase by 20 percent.

• Education: the rate of early school leavers should be reduced below 10 percent.

• Fighting poverty and social exclusion: people in or at risk of poverty and social exclusion should be reduced by at least 20 millions.

The bulk of Cohesion Policy funding is concentrated on less developed European countries and regions. The idea is to help them to catch up and to reduce economic, social and territorial disparities that still exist in the EU. For the 2014-2020 budget cycle over 50 percent of the funds are targeted to less developed countries and regions.

ERDF is available since 1989 (and thus available from the first budget cycle), aims at strengthening economic and social cohesion in the area and focuses on several key priority areas (known as 'thematic concentration') which include: innovation and research; the digital agenda; support for small and medium-sized enterprises; and the low-carbon economy. The resources allocated to these priorities depend on the region. In developed regions, at least 80 percent of funds must focus on, at least, two of these priorities; in transition regions, the amount drops to 60 percent; and in less developed regions to 50 percent.

Under the European Territorial Cooperation programs, at least 80 percent of funds must be concentrated on the four priority areas but allowances are made for specific regional characteristics. Furthermore areas that are naturally disadvantaged because remote, mountainous, or sparsely populated benefit from special treatment.

Contrary to ERDF, which is distributed according to regional characteristics, CF target countries whose per-capita Gross National Income is less than a fixed percent of the EU average. In the past, it was 75 percent; in the current budget cycle is was increased to 90 percent. The fund aims at reducing economic and social disparities and at promoting sustainable development. For the 2014-2020 period, the Cohesion Fund is operative for Bulgaria, Croatia, Cyprus, the Czech Republic, Estonia, Greece, Hungary, Latvia, Lithuania, Malta, Poland, Portugal, Romania, Slovakia and Slovenia. In the past, Ireland also received grants from this fund.

CF was created in 1993 (and thus it is available from the second budget cycle) and allocates funds for two main activities. First, for infrastructures connected with trans-European transport networks. Second, for projects related to energy or transport, as long as they benefit the environment in terms of energy efficiency, use of renewable energy, development of rail transport, strengthening public transportation, etc.

The funds allocated by this program can be suspended by a Council decision (taken by qualified majority) if a member state shows excessive public deficit and if it has not resolved the situation or has not taken the appropriate actions to do so.

ESF was created in 1999 (and thus it is available from the third budget cycle) and invests in people, focusing on improving employment, human capital, and education opportunities across the EU. It also aims to improve the situation of the most vulnerable citizen at risk of poverty. The fund covers all EU regions and there is a special provision to foster youth employment.

For the 2014-2020 budget cycle, ESF focuses on four thematic objectives:

• Promoting employment and supporting labor mobility.

• Promoting social inclusion and decreasing poverty (20 percent of the grants should be committed for this scope).

• Investing in education, skills, and lifelong learning.

• Enhancing institutional capacity and an efficient public administration.

ERDF, CF, and ESF are subject to the same rules as far as programming, management, and monitoring. Given their nature, ERDF should be broadly considered investments in manufacturing and R&D; CF investments in infrastructures; and ESF investments for human capital and education development.

Finally, EAFRD is available since 1992 (and thus available from the second budget cycle) and finances regional rural development. Programs are designed in cooperation between the European

Commission and the member states, taking into account the strategic guidelines for rural development policy adopted by the Council and the priorities laid down by national strategy plans.

While up to the 2007-2013 budget cycle, the fund was treated independently, in the latest programming period, EAFRD is included in the policy framework of the European Structural and Investment funds and subject to the Common Provisions Regulation.

For the 2014-2020 programming period, the fund focuses on three main objectives:

• Fostering the competitiveness of agriculture.

• Ensuring sustainable management of natural resources and climate actions.

• Achieving a balanced territorial development of rural economies and communities, including the creation and maintenance of employment.

The European Maritime and Fisheries Fund (EMFF) is a new fund created for 2014-2020 budget cycle. It is designed to:

• Help fishermen in the transition to sustainable fishing.

• Support coastal communities by diversifying their economies.

• Finance projects that create new jobs and improve the quality of life along European coasts.

• Make it easier to access financing.

For the 2021-2027 budget cycle a number of changes will take place, some funds will be eliminated and the allotted amounts will be available for grants or for loans. According to the July 2020 agreement, the new long term EU budget (now called Multi Annual Financial Framework) will be endowed with 1074 billion Euros, and the Next Generation EU funds is created with an endowment of 750 billion Euros. The Next Generation EU funds are supposed to create jobs, repair the damage caused by the COVID-19 pandemic, and to support the EU's green and digital priorities. They will be financed from international financial markets, and backed by introducing plastic waste, carbon emission, digital levy, and transaction EU taxes. 390 billions will be available for grants and the rest for loans at low interest.

As for other budget cycles, member states must set out their reform and investment plans for the Commission to assess before funds are disbursed. A conditionality mechanism allows a qualified majority in the European Council to hold up the flow of funds to member states that fail to follow through on reforms. Another provision could block disbursements from the funds and the EU budget to countries that fail to uphold the rule of law. Loans will be capped at 6.8% of a recipient's Gross National Income and will only feed through to government debt, once countries borrow in the open market to repay the debt to the EU (supposedly from 2028).

The Recovery and Resilient Facility is the largest of these funds with a budget of 672 billion Euros and should support cohesion, civil protection, health and the recovery from the COVID pandemic. The allocation mechanism for the first two years the RRF takes into account the unemployment rate for 2015-2019, the inverse of GDP per-capita and the population share of each region; for 2023 the unemployment rate is substituted by the drop in GDP for 2020 and 2021 as observed in 2022.

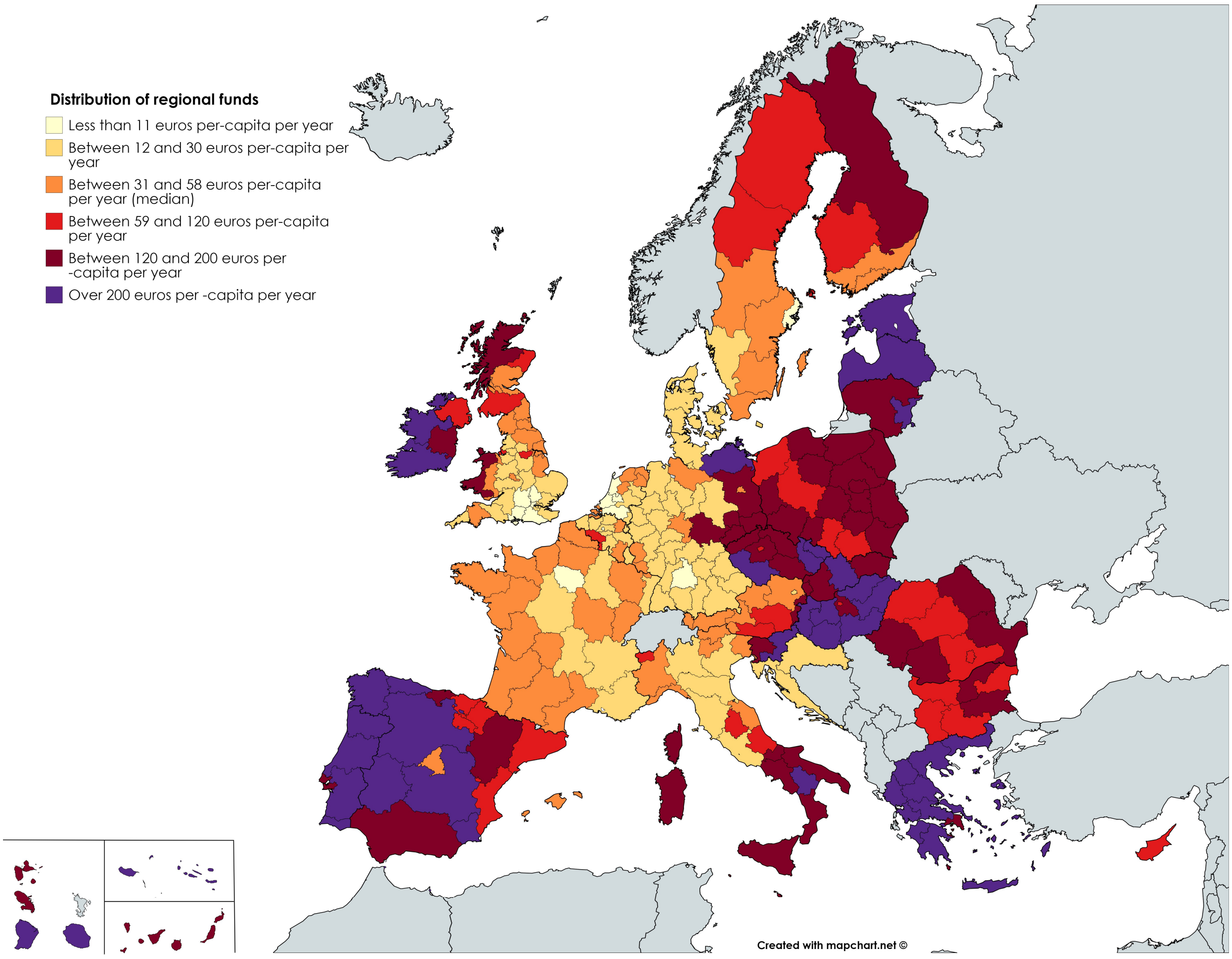
EU transfers are typically made after actual expenditure incurred by the states in a region. Thus the use of EU data payments may distort economic analyses since it creates a lag between the time the expenditure takes place and the time expenditure appears in the EU accounts. To avoid this problem the data we employ use a modified estimate of the real expenditure made by each region, for each fund, in each year.

Table A.1 reports top and bottom recipients of ESI funds on average in per-capita terms and Figure A.1 the geographical distribution of average per-capita EU funds.

Table A.1: Top and Bottom recipients, ESI funds

Region	Acronym	Average yearly per-capita real funds
Azores	PT20	851,29
Ceuta	ES63	714,31
Madeira	PT30	569,69
Melilla	ES64	526,75
Alentejo	PT18	525,11
Anatoliki Makadonia-Traki	EL51	487,45
Dytiki Makadonia	EL53	444,62
Sostines	LT01	429,43
Ipeiros	EL54	428,67
Voreio Aigeio	EL41	426,76
Algarve	PT15	422,86
Hampshire-Isle of Wright	UKJ3	10,68
Outer London 1	UKI7	10,68
Zuid-Holland	NL33	10,48
Noord-Holland	NL32	10,46
Stuttgart	DE11	9,95
Inner London 2	UKJ2	9,72
Bruxelles	Be10	9,34
Inner London 1	UKJ1	9,29
Paris	FR10	8,25
Stockholm	SE11	7,99

Figure A1: Geographical distribution of average real per-capita ESI funds



Appendix B: Estimation of regional funds

Regional funds data are estimated using two types of information: payments made by the EU to a country in a year and an index of specificity, which describes how the region spends the allocated money within the programming period.

Payments follow the cycle of reimbursements to member states. The typical pattern consists of i) advance payments, ii) payments following certification during the period, iii) closure payments at the end of the period, iv) financial corrections after the closure of the period. In a given year, all four types of payments may occur and may refer to projects started at different time and, for the years corresponding to the beginning and the end of the cycle, for projects in different budget cycles. Given that there is no information on the type of payments, the estimation problems amount to allocate the accounting quotas to different years. According to EU documents (see, Regionalization of ESIF payments 1989-2015, European Commission, 2017) this is done by employing an index of regional specificity of expenditure which accumulates expenditure over budget cycles and compares the cumulative sum to a uniform expenditure pattern. Thus, regions that tend to spend most of the amounts at the end of the budget cycle are treated differently than regions that spend more uniformly or more at the beginning of the budget cycle.

The allocation rule used gives a fraction ϕ_z of the expenditure to the year in which the EU payment appears while $1-\phi_z$ is distributed to the previous years. ϕ_z is set using $\phi_z = \phi_{\max} - \mu_z(\phi_{max} - \phi_{min})$ where ϕ_{max} and $\phi_{\min}$ are in the range (0.8,1) and (0.2, 0.4) and μ_z is the index of regional specificity. The remaining amount is allocated using $A_{z,p+q-k} = \frac{(1-\phi_z)2^{k-1}}{\sum_{k=1}^{l} 2^{k-1}}$ where $l = int(\mu_z(q-1)) + 1$, p is the first year of the programming period, q is the number of years up to the current. In words, in the remaining years the remaining amount is spread so that each year expenditure is twice as large as in the previous year. The scaling factor depends on l which in turns depends on μ_z. When μ_z is close to zero payments are allocated over a smaller number of years. When μ_z is close to 1, expenditure is distributed over the entire q range of years.

Given that the allocation rules depend on ϕ_{max}, ϕ_{min} the estimated data provided in excel format are constructed as mean value randomizing these two parameters within their range. EU sources mention that the accuracy of the allocation procedure is stronger for data after 2000 and that the information on the index of specificity is more reliable for ERDF than for ESF.

Because of the way the data is constructed, the index of specificity differs across regions. As a result, different gestation lags between the proposal, the approval and the implementation projects across regions can not be excluded. In general, because measurement errors are likely to be large, the exact timing of the effects described in the paper is subject to considerable uncertainty.