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Interdependence of government expenditure among European countries: Productivity spillover and strategic interaction

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Abstract: We build an endogenous growth model that distinguishes productive and welfare government expenditures and embeds fiscal externalities. The model yields three testable hypotheses: (i) productive expenditure raises growth (Barro effect); (ii) productive expenditure generates cross-country productivity spillovers; (iii) government expenditure structure exhibits spatial dependence. Estimation with a spatial-panel dataset for 30 European economies (EU27+3) corroborates all three hypotheses. We further show that positive productivity externalities induce an international free-rider problem, causing systematic under-investment in productive expenditure, while negative welfare externalities trigger a "welfare tournament" and over-spending on non-productive expenditure.

Keywords: Fiscal Interdependence; Productivity Spillover; Strategic Interaction; Spatial-Panel; Government Expenditure; Endogenous Growth

JEL: E62; R58

1 Introduction

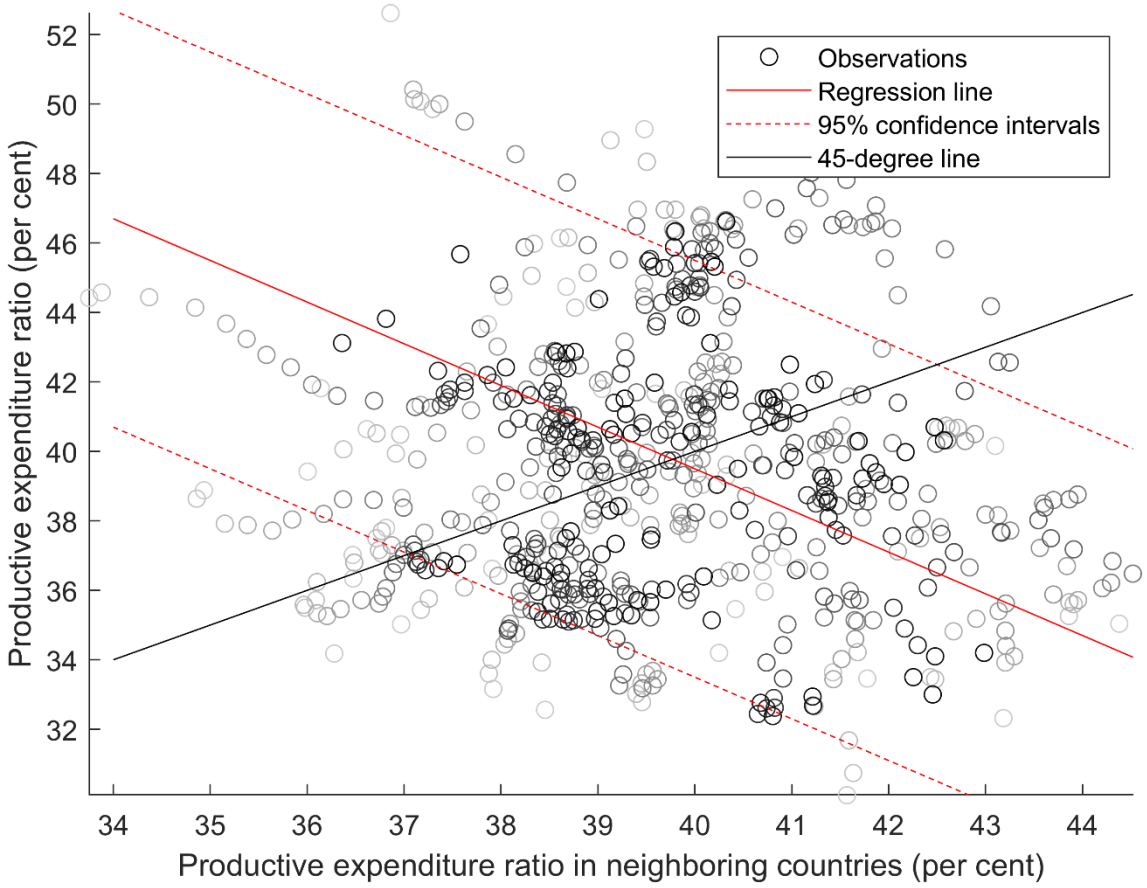
Public goods and services can enhance the returns on private investments and boost overall growth at regional and national levels (Barro, 1990; Chu et al., 2020; Deleidi, 2022). They are usually provided by governments to resolve the "free rider problem" among firms and regions within a country. However, externality can extend beyond borders, leading to an international free rider problem (Foreman-Peck and Zhou, 2023). One typical example is public support on economic affairs such as transport, communication, and R&D. These expenditures can have productivity spillovers to foreign companies with close economic connections, especially those in neighboring countries (Siller et al., 2021). Another example is government expenditure on defense. Most European countries belong to the North Atlantic Treaty Organization (NATO) for collective defense. According to Article 5, an armed attack against one or more NATO members is considered an attack against all members. Therefore, a member country's defense efforts have positive externality to other member states and cause strategic substitution (Zhou and Guo, 2025). These examples illustrate two ways in which government expenditure can be interdependent among countries in an integrated region: *unintended spillover* and *strategic interaction*.

The interdependence of government expenditure differs by the type of government expenditure. In general, government expenditure can be classified as either "productive expenditure" or "non-productive expenditure". According to mainstream literature (e.g., Adam and Bevan, 2005; Chu et al., 2020), productive expenditure is aimed at promoting long-term economic growth and development. Key elements include infrastructure development (e.g., roads, bridges, ports, airports, and utilities), technological development (e.g., support for industries, R&D, and innovation), economic affairs, defense, housing, education, and health. Non-productive expenditure, on the other hand, involves welfare expenditure for a particular group, lacking advantages for the broader population. A key element of non-productive expenditure is social security (Bleaney et al., 2001), which is known as "National Insurance" in the UK, "Sécurité Sociale" in France, "Sozialversicherung" in Germany, "Previdenza Sociale" in Italy, and "Seguridad Social" in Spain. It encompasses a variety of social welfare schemes designed to provide financial support to individuals or families facing particular life situations or challenges, such as pensions, unemployment benefits, and disability benefits.

Notably, European countries collectively and persistently maintain a low share of productive expenditure in public expenditure (30-50%), compared to other major economies like the US (58%) and China (57%). The same pattern holds for the GDP share of productive expenditure in European countries (15.5%), US (22.6%), and China (21.8%). Prior literature attributes the low share of productive expenditure in Europe to cultural, institutional, or political reasons (Creedy et al., 2011; Guo et al., 2024). Yet we propose another crucial dimension to understand

the phenomenon—fiscal externality (Lawson, 2017, 2023). It is contended that a higher productive expenditure in neighboring countries[1] can substitute the need for domestic productive expenditure—a higher productive expenditure ratio in neighboring countries is associated with a lower domestic productive expenditure ratio (Figure 1). In other words, productive expenditure has *positive* externalities (a type of productivity spillovers), which can lead to under-provision of productive expenditure in the region.

Figure 1 Productive expenditure ratio over total government expenditure of European countries (1995-2021)



Note: Each circle represents an observation of a country in a particular year. The horizontal axis variable is the average productive expenditure ratio of all neighboring countries. Lighter circles are earlier observations, and darker circles are later observations, ranging from 1995 to 2021. The regression line is based on a two-way fixed effects model: $Y = 54.14 - 0.40X +$ country fixed effects + year fixed effects, where the coefficient of X is significant at the 1% level ($t = -4.5$). More recent observations (darker circles) are closer to the 45-degree line. Changing towards an equal expenditure structure over time suggests a regional convergence of public expenditure structure.

In contrast, non-productive (especially welfare-related) expenditure in one country may induce *negative* externalities. As Redoano (2003) points out, voters increasingly benchmark their

[1] A neighboring country is defined by the Great Circle formula that produces a k nearest neighbors either sharing border or not, which is carefully elaborated in the KNN Weight Matrix Code by Donald J. Lacombe (http://myweb.ttu.edu/dolacomb/matlab.html).

domestic policy outcomes, including welfare generosity, against neighboring countries, especially in a politically integrated area such as the EU. Governments therefore maintain or expand welfare expenditure to bolster their domestic political support by projecting a socially supportive image. However, "too much" welfare expenditure reduces labor supply, increases fiscal burden, and may also decrease productive expenditures. All these impede economic growth. This process results in a "welfare tournament" (a type of strategic interactions) among European countries. This phenomenon presents an interesting contrast to the "growth tournament" in China, where there is too much productive expenditure (Li and Zhou, 2005; Morck and Yeung, 2016). Building on observations and literature, we develop an endogenous growth model to account for interdependence of government expenditure and derive three testable hypotheses. A spatial-panel dataset of 30 European countries (1995-2021) is then used to empirically confirm these hypotheses.

Our paper is complementary to existing literature on Barro-type endogenous growth models in terms of level of investigation, nature of interdependence, and type of expenditure (Table 1). The seminal paper by Barro (1990) establishes the fundamental relationship between government expenditure and economic growth at the country level, but expenditure externality across countries is ignored. Mukand and Rodrik (2005) address this omission by introducing "appropriateness" and "transparency" of policy specificity. They argue that successful policies in one country may not be transplanted to another country without incurring contextualization costs, which increase with the relative "distance" between the two countries. In a similar vein, Ezcurra and Rios (2020) examine the spillovers of government quality at the subnational level. These two papers essentially regard spatial interdependence of government policies as a process of knowledge diffusion or "informational externality". In contrast, international spillovers of government expenditure can also take effect on the demand side Ilori et al. (2022), but existing literature does not distinguish between productive and non-productive expenditures.

Our paper explores alternative dimensions in explaining spatial interdependence. The first dimension is productivity spillover (rather than information or demand spillovers) of government expenditure. Ojede et al. (2018) find that, regardless of the financing source, productive expenditures like higher education and highway have significant short- and long-run spillover effects on income growth. A similar study to ours is Foreman-Peck and Zhou (2023), who estimate the productivity spillovers of government R&D support at the firm level, while we focus on the effect at the national level. Andersen and Sørensen (2023) show in the theoretical part of their paper that the productivity spillover differs for public consumption and public transfers, but they do not discuss the spatial dimension.

The second dimension is strategic interaction of government expenditure across countries. Redoano (2003) finds evidence for interdependence on tax and yardstick competition among

EU countries. Hammadou et al. (2014) confirm the existence of strategic interactions in relation to public R&D spending among European countries with similar economic characteristics. Zhou and Guo (2025) have done a similar job but only focus on one specific type of expenditure (defense). Naitram (2022) studies fiscal competition on the revenue side (taxation) rather than on the expenditure side. To better explain the "welfare tournament" among European countries, our paper further distinguishes two general types of government expenditure (productive and non-productive).

Table 1 Positioning in literature

Key literature	**Level of Investigation**	**Nature of Interdependence**	**Type of Expenditure**
Barro (1990)	country	not mentioned	productive vs. non-
Mukand & Rodrik (2005)	country	information spillover	government policy
Ezcurra & Rios (2020)	region	information spillover	government quality
Ilori et al. (2022)	country	demand spillover	total expenditure
Foreman-Peck & Zhou (2023)	firm	productivity spillover	R&D subsidy
Ojede et al. (2018)	state	productivity spillover	higher education, highway
Redoano (2003)	country	strategic interaction	tax and expenditures
Naitram (2022)	country	strategic interaction	taxation
Zhou & Guo (2025)	country	strategic interaction	defense
Hammadou et al. (2014)	country	strategic interaction	public R&D
Our paper	country	productivity spillover & strategic interaction	productive vs. non-productive

This paper attempts to make two contributions to the literature on fiscal policy and economic growth. The first contribution is theoretical. We extend the Barro-type endogenous growth model with different types of government expenditure and international externalities. This theoretical framework provides a microfoundation for future research on government expenditure and economic growth. The second contribution is empirical. We perform robust spatial-panel regressions based on 30 European countries (EU27+3). Europe is a highly integrated region in terms of economy, politics, and travel, making it an ideal case for studying fiscal interdependence. There has been a high volume of research based on the EU, but few use an extended set of European countries in analysis. Despite not being part of the EU (or not always being part of the EU as in the case of the UK), non-EU member states like the UK, Switzerland, and Norway are always closely integrated to the region. This extension is a small but necessary progress in the empirical sense.

The next section develops the endogenous growth model and derives three testable hypotheses. Section 3 discusses the data, the empirical model, and the selection of the most appropriate model specification. Section 4 presents and discusses the baseline results, which are then challenged by various robustness and heterogeneity tests. Section 5 concludes.

2 Theoretical Framework

Much literature has been devoted to cross-border spillover effects of foreign direct investments (Stojčić and Orlić, 2020) and supranational funds (Fidrmuc et al., 2024), while interdependence of national government expenditures remains understudied. Following Barro (1990), private capital per capita (k) and government productive expenditure per capita ($\bar{g}$) are used in a constant-returns-to-scale production function $y = Ak^{\alpha}\bar{g}^{1-\alpha}$, where y is output per capita and A is the total factor productivity.

Furthermore, we generalize the concept of the productive expenditure ($\bar{g}$) to include both domestic productive expenditures provided by national government (g) and usable foreign productive expenditure provided by neighboring government (g^*). They form the aggregate productive expenditure pool in the region. This assumption is realistic, especially for European countries where residents and businesses operate within a single market. Following the convention of literature (Barro, 1990), public expenditures from different locations are additive in equation (1). As in continuum-of-firms models, where the aggregate resource is simply the sum of each firm's resources, the total usable public expenditure in our setting, denoted $\bar{g}$, is also the sum of g and g^*. More flexibility can be added to make g and g^* less substitutable[2], but the qualitative conclusions are robust to this assumption.

$$\bar{g} = g + g^*, \text{ where } g = \eta_g b\tau y \text{ and } g^* = \eta_g^* b^* \tau^* y^* \quad (1)$$

In equation (1), τ is the tax rate, and b is the share of tax revenue reserved for productive expenditure. τ^*, b^* and y^* are defined similarly to domestic counterparts τ, b and y. Specifically, the coefficient η_g is the domestic utilization rate of productive expenditure, which is related to the concept of "crowding spillover" proposed by Solé-Ollé (2006). The essence of this assumption is that the foreign use of public expenditure by neighboring countries can crowd out part of the domestic use—a negative externality. So, an increase in the share of productive expenditure in the foreign country (b^*) can mitigate the crowding spillover and increase the domestic utilization rate, $\partial\eta_g/\partial b^* > 0$, which implies that, $\partial g/\partial b^* > 0$.

The coefficient η_g^*, which is assumed to be proportional to the relative economic size y/y^*, embodies the concept of "absorptive capacity" as in Cassiman and Veugelers (2002). The argument is that the absorption of external resources depends on the relative economic capacity.

[2] A more general specification is to assume that $\bar{g}$ follows a CES form to allow for some complementarity. However, as long as the elasticity of substitution is less than or equal to 1 (Cobb-Douglas), the form can lead to zero $\bar{g}$ when either g or g^* is equal to zero, which is counter-intuitive. To avoid such cases, the elasticity of substitution must be greater than 1 (substitutability dominates complementarity). Our assumption is a limiting case (elasticity = ∞) where g and g^* are perfectly substitutable to allow for an analytic solution. Any complementarity only moderates the quantitative results as long as substitutability dominates complementarity.

Thus, the foreign public expenditure available to domestic people g^* can be effectively rewritten as $g^* = z_g(y/y^*)b^*\tau^*y^* = z_g b^*\tau^* y$ after combining: (i) foreign public expenditure pool ($b^*\tau^*y^*$), (ii) the relative economic size to capture absorptive capacity (y/y^*), and (iii) other factors affecting the absorptive capacity (z_g). Obviously, an increase in the share of productive expenditure in neighboring countries can raise the external public resources to be absorbed (positive externality), so we have $\partial g^*/\partial b^* > 0$.

The representative agent maximizes her lifetime utility $U = \int_0^\infty e^{-\rho t}\left[\nu \ln c + (1-\nu)\ln \bar{h}\right] dt$, where ρ is the subjective discount rate, subject to the private budget constraint:

$$\dot{k} + c = (1-\tau)y - \delta k \tag{2}$$

In equation (2), c is the private consumption and δ is the depreciation rate. Symmetrically, $\bar{h}$ is the total non-productive expenditure which includes domestic non-productive expenditure (h) and available foreign non-productive expenditure (h^*). ν is the utility weight for c relative to $\bar{h}$. Again, a more sophisticated specification of imperfect substitution can be introduced into equation (3), but qualitative conclusions hold as long as h and h^* are substitutes rather than complements. Similar interpretations (crowding spillover and absorptive capacity) apply to η_h and η_h^*, and we have the conditions $\partial h/\partial b^* < 0$ and $\partial h^*/\partial b^* < 0$ because a higher foreign share of productive expenditure means a lower foreign share of non-productive expenditure, which can exacerbate the crowding spillover for domestic welfare-related resources and decrease the available foreign welfare expenditure for absorption.

$$\bar{h} = h + h^*, \text{ where } h = \eta_h(1-b)\tau y \text{ and } h^* = \eta_h^*(1-b^*)\tau^* y^* \tag{3}$$

The coefficient $\eta_h^* = z_h(y/y^*)$ is defined as the absorptive capacity of non-productive expenditure, which is similar to η_g^*. This endogenous growth model has a balanced growth path solution for the growth rate (γ). Mathematical derivation can be found in Supplementary Appendix A1.

$$\gamma = \alpha(1-\tau)A^{\frac{1}{\alpha}}\left(\eta_g b\tau + z_g b^*\tau^*\right)^{\frac{1-\alpha}{\alpha}} - \delta - \rho \tag{4}$$

It is easy to see that γ is a monotonic function of b, so the growth-maximizing share of productive expenditure is $b = 1$. The growth-maximizing tax rate is $\tau = 1 - \alpha - \alpha\left(z_g/\eta_g\right)b^*\tau^*$ conditional on $b = 1$. The symmetric solution of the growth-maximizing share of productive expenditure for a neighboring country is $b^* = 1$, conditional on which the growth-maximizing tax rate is $\tau^* = (1-\alpha)/[1+\alpha(z_g/\eta_g)] \leq 1-\alpha$. Note that if we impose a zero absorptive

capacity ($z_g = 0$), then we go back to Barro (1990)'s conclusion on the growth-maximizing tax rate ($\tau = 1 - \alpha$). In other words, our model includes the Barro model as a special case. When the absorptive capacity exists ($z_g > 0$), the growth-maximizing tax rate is smaller due to the international free rider problem.

Note that the fiscal policy parameters (b^*, τ^*) in equation (4) are treated as exogenous to the domestic growth rate γ for two reasons. Theoretically, this setting is consistent with the rest of the model because foreign output dropped out of the optimization problem once absorptive capacity is introduced into equation (1). In other words, growth rate in one country does not feedback to other country's optimal fiscal policies. Empirically, there is a fairly large number of European countries (30 in our sample), so each country's growth rate is too small to substantially influence *all* other countries' fiscal policies. Germany and France may have some impacts, but these are not systematic or decisive.

Based on the solution to growth rate (4), we can now derive the "hypothesis of growth effect" [H1], the "hypothesis of spillover effect" [H2], and the "hypothesis of spatial dependence" [H3]. [H1] is essentially the basic conclusion of any Barro-type endogenous growth models, while [H2] and [H3] are novel to the literature.

[H1] *A higher domestic share of productive expenditure (b) results in a higher growth rate (γ).*

$$\frac{\partial \gamma}{\partial b} = (1-\alpha)(1-\tau)A^{\frac{1}{\alpha}}\left(\eta_g b\tau + z_g b^*\tau^*\right)^{\frac{1-2\alpha}{\alpha}}\eta_g\tau > 0 \tag{5}$$

[H2] *A higher foreign share of productive expenditure (b^*) results in a higher growth rate (γ).*

$$\frac{\partial \gamma}{\partial b^*} = (1-\alpha)(1-\tau)A^{\frac{1}{\alpha}}\left(\eta_g b\tau + z_g b^*\tau^*\right)^{\frac{1-2\alpha}{\alpha}}\left(\underbrace{\frac{\partial \eta_g}{\partial b^*}b\tau}_{>0}{}_{\text{crowding spillover}} + \underbrace{z_g\tau^*}_{>0}{}_{\text{absorptive capacity}}\right) > 0 \tag{6}$$

As shown in the proof of [H2], the spillover effect on growth can be decomposed into a crowding spillover component and an absorptive capacity component. The same applies to the spillover effect on welfare.

If the government's objective function is to maximize social welfare, there must be a higher domestic non-productive share ($1 - b$) at the cost of lower growth due to a lower b (see the proof in Appendix A2). This welfare-maximizing share of productive expenditure prevents economic growth from its full potential, in line with the characteristics of high welfare and low

growth in Europe. Therefore, we have a standard trade-off relationship between growth and welfare documented in literature (Chen et al., 2024).

[H3] *There is spatial dependence in growth rates among neighboring countries if there is regional convergence in expenditure structures.*

$$\left.\begin{matrix}\frac{\partial\gamma}{\partial b}>0,\frac{\partial\gamma^*}{\partial b}>0\\ \frac{\partial\gamma}{\partial b^*}>0,\frac{\partial\gamma^*}{\partial b^*}>0\end{matrix}\right\}\Rightarrow Cov(\gamma,\gamma^*)>0 \text{ if } b,b^* \text{ vary in the same direction.} \quad (7)$$

We can prove [H3] based on [H1] and [H2]. As the domestic productive share b rises, we have a higher domestic growth γ according to [H1] and a higher neighboring growth γ^* according to [H2]. Similarly, as the neighboring productive share b^* rises, γ^* and γ will also rise in the same direction. Both suggest a positive correlation of regional growth rates when productive shares change.

3 Empirical Methodology

Before testing the hypotheses, we discuss the empirical strategies for collecting the data, selecting a model, and choosing a specification. Our choices are directed by the research aim—to test the effects of productive expenditure on regional growth [H1]-[H2] and the spatial interdependence of regional growth rates [H3].

3.1 Data

Our empirical analysis is based on a spatial-panel dataset of 30 European countries (EU27 + UK, Switzerland, Norway) from 1995 to 2021. The data combines EU's Eurostat, OECD database, and World Bank's Development Indicators. A lower regional level (NUTS1/NUTS2) can be used, but many general government expenditure items data are only available at the country level (NUTS0) such as infrastructure, defense, and national healthcare services[3]. To avoid omitting these important spillovers, we choose the country-level data.

The key variable of interest, productive expenditure ratio, is defined as the ratio between the productive expenditure and the total government expenditure. Following the definition of Bleaney et al. (2001), Adam and Bevan (2005), and Chu et al. (2020), we classify government

[3] Health services are partly delivered below the national tier, especially in countries such as Germany, Italy, and Spain where regions run hospitals. But even in highly decentralized systems, sub-national agents fund health services largely with grants or shared taxes appropriated by the central government. Across the OECD sample, sub-national governments execute on average 1.3% of GDP in health spending in unitary countries and 2.7% in federal ones, whereas the corresponding central-government outlays are more than twice as large (WOFI 2022 Synthesis Report). Consequently, the bulk of cross-border fiscal externalities—including those ultimately channeled to regional providers—originates at the national budget.

expenditure on defense, economic affairs, education, and health as productive, and everything else as non-productive. By definition, one percentage rise of the productive expenditure ratio implies one percentage drop of the non-productive expenditure ratio. Thus, the findings of the productive expenditure ratio are the reverse of those of the non-productive expenditure ratio.

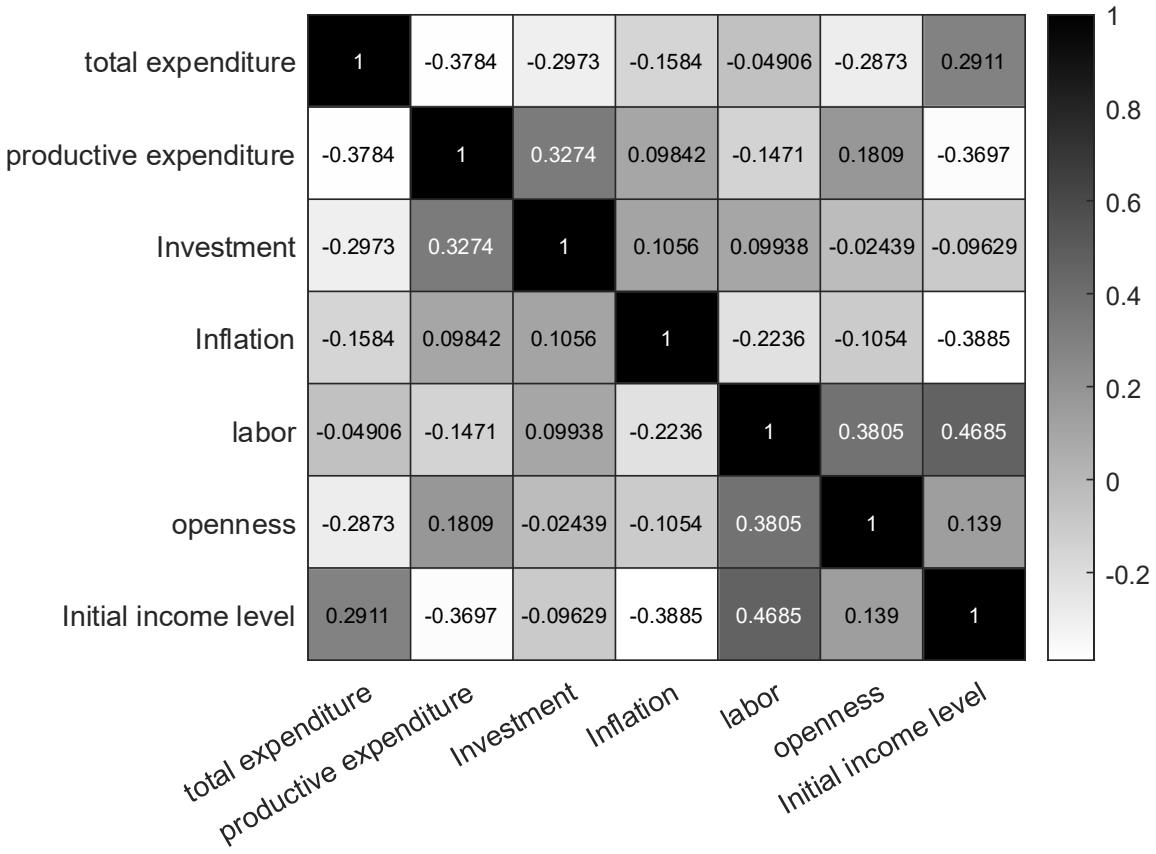
Variables like fiscal variables, investment, and openness take one period lag in the regressions to avoid endogeneity. All the variables in our regressions are in real terms and smoothed by 5-year forward moving averages in terms of Chu et al. (2020) and Järnberg and Värja (2022), which will remove business cycle effects, reduce the sensitive to the choice of baseline year, increase the number of time series observation in our panel data, minimize the reverse causality argument holding in our model and account for endogeneity. Our results are robust if we alternatively follow Devarajan et al. (1996) and Acosta-Ormaechea and Morozumi (2017) to use the values of these independent variables at the beginning of each five-year period. Initial GDP per capita in each five-year period is included to capture "conditional convergence" (Barro, 2015). Table 2 presents descriptive statistics of the data. Through the correlation coefficient matrix and heat map analysis (Figure 2), there is no serious multicollinearity among the independent variables.

Table 2 Descriptive Statistics (1995-2021)

Variable	Obs.	Mean	S.D.	Min	Max
GDP per capita growth rate (γ)	660	2.15	2.34	-5.76	10.93
Productive expenditure ratio (b)	660	39.55	3.88	30.1	52.62
Defense	660	3.04	1.30	0.6	7.34
Economic Affairs	660	11.71	3.14	4.77	22.52
Education	660	11.78	2.23	7.08	17.98
Health	660	13.02	2.79	4.42	19.18
Government expenditure ratio (of GDP)	660	44.40	6.39	26.24	59.02
Fiscal deficit (-) or surplus (+) (of GDP)	660	-2.07	3.68	-15.02	15.87
Tax revenue ratio (of GDP)	660	25.18	6.33	16.1	47.22
Non-tax revenue ratio (of GDP)	660	17.32	4.39	6.43	27.51
Investment ratio (of GDP)	660	18.69	3.40	7.29	36.77
Inflation rate	660	2.81	4.69	-0.48	68.86
Labor force growth rate	660	0.50	1.28	-4.83	5.47
Openness	660	110.76	58.78	40.70	361.49
Initial GDP per capita (log)	660	9.87	0.77	7.96	11.39

Note: Variables are smoothed by five-year moving averages. Periods that cannot form a complete five-year period are dropped. Thus, the usable sample consists of 660 observations from 30 countries and 22 periods. All the variables in our regressions are in real terms. Openness is defined as the sum of export and import over GDP.

Figure 2 The heat map of correlation coefficient matrix



3.2 Spatial-Panel Model

Given that we want to test hypotheses of cross-country interdependence, a spatial model is appropriate to serve the purpose. Alternative empirical methods include BVAR (Ilori et al., 2022) and GVAR (Hebous and Zimmermann, 2013), but they are less effective in capturing the nuanced interdependence resulting from regional adjacency. Among spatial models, a common choice is the spatial autoregressive (SAR) model, which captures spatial dependence in the dependent variable itself (growth rate in our case) through a spatial lag term. An alternative is the spatial error model (SEM) which captures spatial dependence in the error term, assuming that unobserved factors are correlated across neighboring locations. Extensions of the two basic models allow for spatial dependence in the independent variables, resulting in the spatial Durbin model (SDM) (Anselin, 2003) and the spatial Durbin error model (SDEM) (Fingleton and Le Gallo, 2008).

Most research on spillovers of government expenditure adopt the SAR model (Revelli, 2003; Baicker, 2005; Costa et al., 2015; Ferraresi et al., 2018; Järnberg and Värja, 2022), but few provide a solid test for the choice. SEM and SDEM are less popular despite their advantages

in identification (Atems, 2013; Cravo et al., 2015). We follow Ezcurra and Rios (2020) to perform systematic specification tests to select the best model using a nested specification (8).

$$\boldsymbol{\gamma}_t = \rho \mathbf{W}\boldsymbol{\gamma}_t + \mathbf{X}_t\boldsymbol{\beta} + \mathbf{W}\mathbf{X}_t\boldsymbol{\delta} + \mathbf{fn} + \mathbf{ft}_t + \boldsymbol{\epsilon}_t, \text{ where } \boldsymbol{\epsilon}_t = \lambda \mathbf{W}\boldsymbol{\epsilon}_t + \boldsymbol{\xi}_t \quad (8)$$

In this form, $\boldsymbol{\gamma}_t$ is an $N \times 1$ vector of growth rates for a panel of N countries at period t. $\mathbf{X}_t$ is an $N \times K$ matrix of the set of independent variables. Specifically, the key independent variables productive expenditure share and government expenditure share are part of $\mathbf{X}_t$. $\mathbf{W}$ is a $N \times N$ spatial weight matrix indicating how the regions in the sample are spatially interconnected. To better characterize the panel data structure, we also include the two-way fixed effects for the N countries ($\mathbf{fn}$) and T periods ($\mathbf{ft}_t$) to make it a spatial-panel data model. $\boldsymbol{\epsilon}_t$ is an $N \times 1$ disturbance vector, and $\boldsymbol{\xi}_t$ is an $N \times 1$ innovation vector. Note that equation (8) includes the four models as special cases: the SAR model is when $\boldsymbol{\delta} = \mathbf{0}$ and $\lambda = 0$, the SEM is when $\rho = 0$ and $\boldsymbol{\delta} = \mathbf{0}$, the SDM is when $\lambda = 0$, and the SDEM is when $\rho = 0$.

Regarding the specification of $\mathbf{W}$, two widely accepted assumptions are the contiguity-based weight matrix $\mathbf{W}^{(c)}$ (neighboring locations are assigned a weight of 1 while non-neighboring locations have a weight of 0) and distance-based weight matrix $\mathbf{W}^{(d)}$ (weights are inversely proportional to the distance between capital cities of any two countries). In early literature, the choice of spatial weight matrix is usually based on logical arguments (Vega and Elhorst, 2015) rather than statistical tests (Baicker, 2005).

To improve research rigor in capturing proximity, we construct a hybrid spatial weight matrix by incorporating economic distance following Ezcurra and Rios (2020). This is to capture the fact that countries with similar economic characteristics tend to have closer interactions. As a result, the spatial weight matrices are enriched with economic information. The degree of contiguity/distance now accounts for differences in per capita income in the previous year between two countries. The two hybrid spatial weight matrices are denoted as $\widetilde{\mathbf{W}}^{(c)}$ and $\widetilde{\mathbf{W}}^{(d)}$. The calculation method of $\widetilde{\mathbf{W}}^{(c)}$ and $\widetilde{\mathbf{W}}^{(d)}$ are described in Appendix A3.

3.3 Model Selection

To select the most appropriate model specification and spatial weight matrix, we carry out the following three hierarchical steps of tests. This approach is adapted from the Bayesian procedure (Rios, 2017; Debarsy and LeSage, 2018). A more sophisticated approach is to test different specifications under given spatial weight matrices and different spatial weight matrices under different specifications as in Ezcurra and Rios (2020). Nonetheless, the two approaches lead to the same conclusion.

Table 3 Tests of model specification and spatial weight matrix

	Tests	$\widetilde{\mathbf{W}}^{(c)}$	$\widetilde{\mathbf{W}}^{(d)}$
Step 1	Moran's I statistic (H0: no spatial autocorrelation)	18.190	34.392
	P-value	(0.000)	(0.000)
Step 2	LM statistic (H0: SAR is true; HA: SDM is true)	40.746	27.953
	P-value	(0.000)	(0.000)
	Wald statistic (H0: SAR is true; HA: SDM is true)	173.817	167.108
	P-value	(0.000)	(0.000)
	LR statistic (H0: SAR is true; HA: SDM is true)	149.369	141.446
	P-value	(0.000)	(0.000)
Step 3	Bayesian posterior model probability (SDM)	0.06%	99.94%

Step 1. Compare models with spatial autocorrelation (SAR and SDM) and models without (SEM and SDEM) under a given $\mathbf{W}$. As reported in Table 3, the Moran's I test suggests that spatial autocorrelation is present ($\rho \neq 0$). Therefore, the SEM and SDEM specifications are rejected as they do not have spatial autocorrelation ($\rho = 0$). This specification is also consistent with our theoretical model (spatial dependence of growth rates).

Step 2. Compare models with spatial dependence in the control variables (SDM) and models without (SAR) under a given $\mathbf{W}$. Three types of tests (LM, Wald, and LR) are performed on the restricted form (SAR) against the unrestricted form (SDM) in Table 3. It is shown that the unrestricted form (SDM) is preferred to the restricted forms (SAR), i.e., $\boldsymbol{\delta} \neq \mathbf{0}$.

Step 3. Compute posterior model probabilities of the chosen model specification under different spatial weight matrices. Following the practice of (Rios, 2017), the Bayesian estimation is based on 1000 draws with a burn-in sample of 100 draws. To avoid situations where the conclusions depend heavily on subjective prior information, we rely on diffuse prior distributions. It is shown that, under the SDM specification, distance-based hybrid spatial weight matrix $\widetilde{\mathbf{W}}^{(d)}$ has overwhelming support over the contiguity-based $\widetilde{\mathbf{W}}^{(c)}$.

4 Results

In the previous section, we conclude that the SDM specification and the distance-based hybrid spatial weight matrix $\widetilde{\mathbf{W}}^{(d)}$ are chosen as the baseline model. This section presents and discusses the estimation results of this baseline model. The baseline results are then challenged by different measures, methods, subsamples, and specifications to ensure robustness. Heterogeneities across countries and over time are then investigated.

4.1 Baseline

Many empirical studies using spatial-panel data report OLS estimates (e.g., Baicker, 2005; Solé-Ollé, 2006; Costa et al., 2015; Cravo et al., 2015; Ferraresi et al., 2018). Anselin (1988)

criticizes that the standard OLS estimates are inconsistent when spatial weight matrices are used. One way to address this issue is to use the quasi-maximum likelihood (QML) estimator with fixed effects. An alternative is to use the GMM estimator, but it has lower statistical efficiency (Järnberg and Värja, 2022).

OLS and QML estimation results are compared in Table 4. The OLS result in column (1) is based on the specification without spatial feature (i.e., $\rho, \lambda, \boldsymbol{\delta} = 0$). For the QML estimation result of the SDM ($\lambda = 0$), we report the total marginal effects in column (2) and decompose them into the direct effects in column (2A) and the indirect effects (spillover effects) in column (2B) following LeSage and Pace (2009) and Atems (2013).

In spatial regression models, the **direct effect** refers to the impact of a change in an explanatory variable on the dependent variable in the same country, i.e., X → Y. This effect includes both initial impact from X to Y as well as second-round impact from X to Y* and then from Y* to Y (where * indicates foreign variables). The **indirect effect**, also known as the spatial spillover effect, captures the influence that a change in an explanatory variable at one country exerts on the dependent variable at neighboring countries, i.e., X* → Y. This effect arises due to spatial interdependencies modeled through spatial lags or spatial weight matrices. This effect also includes second-round impact from X* to Y* and then from Y* to Y. The **total effect** is the sum of the direct (X → Y) and indirect effects (X* → Y), representing the overall impact of a change in an explanatory variable across all locations. Therefore, we report marginal effects rather than coefficients of the spatial model in Table 4 to be comparable with the OLS result.

We focus on three key findings of the baseline model. First, we have confirmed [H1] that there is a positive effect of productive expenditure ratio on the growth rate within a country. The direct effect (0.118) in column (2A) is the effect of productive expenditure ratio (b) on growth rate (γ). This finding is consistent with prior literature for high-income economies (e.g., Devarajan et al., 1996; Gemmell et al., 2016; Chu et al., 2020). It is also shown that the OLS estimation (0.059) substantially understates the growth effect of productive expenditure due to the omission of spatial effects.

Second, we have confirmed [H2] that there is a positive effect of foreign productive expenditure ratio on the domestic growth rate. Note that the indirect effect measures the impact of a change in X* of *all* neighboring countries, while the direct effect only measures the impact of a change in X of *one* country. So, magnitude-wise, the indirect effect in Table 4 (1.783) should be divided by 29 (N-1 countries): 1.783/29 = 0.06, to have a comparable interpretation against the direct effect (0.118). In other words, if country A raises its productive expenditure ratio by 1%, then country A's growth will increase by 0.118% (direct effect), while neighboring country B's growth will increase by 0.06% (indirect effect or spillover effect).

Third, we have confirmed [H3] that there is spatial interdependence of growth rates among member countries in Europe. The spatial lag coefficient ρ is positive and significant (0.566), which suggests that growth rates in one region tend to comove in the same direction. Appendix Table A1 reports estimated structural parameters, which underly the direct and indirect effects reported in Table 4.

Table 4 Estimation results of the baseline model

	(1) OLS	(2) = (2A) + (2B) QML	(2A) Direct	(2B) Indirect
Productive expenditure ratio $t-1$	0.059**	1.901***	0.118***	1.783***
	(0.023)	(0.559)	(0.027)	(0.545)
Government expenditure ratio $t-1$	-0.183***	-1.147**	-0.203***	-0.944**
	(0.022)	(0.420)	(0.019)	(0.413)
Investment ratio $t-1$	0.065***	-1.155**	0.046*	-1.200***
	(0.022)	(0.432)	(0.023)	(0.427)
Inflation $t-1$	-0.124***	-1.554***	-0.137***	-1.417***
	(0.011)	(0.355)	(0.011)	(0.350)
Labor force growth $t-1$	0.079*	-2.443*	-0.037	-2.406*
	(0.047)	(1.292)	(0.053)	(1.257)
Openness $t-1$	0.027***	-0.384***	0.017***	-0.401***
	(0.004)	(0.120)	(0.004)	(0.118)
Initial GDP per capita	-7.960***	5.269	-10.391***	15.660**
	(0.441)	(6.527)	(0.547)	(6.651)
Country FE ($\mathbf{fn}$)	YES	YES	YES	YES
Year FE ($\mathbf{ft}$)	YES	YES	YES	YES
Spatial lag (ρ)		0.566***		
		(0.085)		
Observation	660	660		
R-squared	0.440	0.858		

Note: To avoid endogeneity, we use lagged values for all regressors except for initial GDP per capita. All regressions include a constant (not shown). Coefficients are reported for the OLS estimation result, while marginal effects are reported for the QML estimation result of the SDM to be comparable. Heteroskedasticity-robust standard errors are reported in parentheses. Significance * 10% ** 5% *** 1%.

To avoid perfect collinearity, productive expenditure ratio b and non-productive expenditure ratio $1-b$ cannot be included in the same regression. The effects of these two variables are exactly opposite to each other. If the level of total government expenditure is not fixed, then we can keep both productive and non-productive expenditure (in levels) in the regression. Their effects are opposite but not exactly the opposite (see Table A2).

Additionally, results on control variables in Table 4 are in line with the literature on regional growth. For example, the negative spillover effect of government expenditure ratio on the growth of neighboring countries (-0.944) is well-documented in the literature on local governance (Baicker, 2005; Ferraresi et al., 2018). Private investment (k) can promote domestic growth but hamper neighbors' growth (-1.200). This is because a higher capital implies a higher

labor productivity and wage, which can attract migration and cause "brain drain" to neighboring countries (Bernard et al., 2014). The same explanation applies to the negative spillover effect of domestic labor force on neighbors' growth (-2.406). Inflation is found to be detrimental to growth as found in Barro (2015). Higher openness facilitates domestic growth (0.017) by exploring the country's comparative advantage in trade (Ghosh and Gregoriou, 2007). Nevertheless, the spillover effect of openness is negative (-0.401) due to regional competition. Openness can increase because of increased trade with partners both inside and outside Europe. When neighboring countries become more open, competition intensifies among regional economies that share similar comparative advantages, which generates negative spillovers. In addition, the negative coefficient of (log) initial GDP per capita supports the conditional convergence hypothesis (Barro, 2015).

A notable result in the baseline estimation is that a higher government expenditure ratio has a negative effect on domestic growth (-0.203). A conventional interpretation posits that an excessive government size increases the tax burden on citizens—either in the present or in the future—resulting in a reduction in private investment k (the crowding-out effect), consequently impeding economic growth (Barro, 1990). This is a common conclusion for developed economies (Romero-Ávila and Strauch, 2008; Chu et al., 2020).

In theory, the overall relationship between government size and growth rate must follow an inverse-U curve inspired by the Laffer curve: zero government intervention ("no order") means low growth at one extreme; full government planning ("no vigor") also causes low growth at the other extreme; so, there must be a turning point at the middle of the curve. This reasoning implies that the welfare-maximizing government size is too large in terms of the growth-maximizing criterion, i.e., European governments are on the declining side of the inverse-U curve. The data has shown that the excessive government size in Europe is mainly attributed to the oversized non-productive expenditure $(1 - b)$, especially the public spending on social security. But why does this phenomenon persist? We explain it by fiscal externality. The explanation has two aspects. The first is related to the positive externality of productive expenditure (productivity spillover) and the consequent "free rider problem". The second is related to the negative externality of non-productive expenditure (strategic interaction) and the "welfare tournament".

As predicted in [H1]-[H2] and confirmed in Table 4, if there is a higher productive expenditure ratio in one country (b), then the growth rates in the entire region are boosted thanks to the crowding spillover mechanism and the absorptive capacity mechanism. The productive expenditure creates a positive externality in the form of productivity spillover, which results in under-provision of public expenditure (g) because the private marginal benefit is smaller than the social marginal benefit. This is a textbook example of the "free rider problem" in an international context.

Reversely, if there is a higher non-productive expenditure ratio in one country $(1-b)$, then the relatively abundant welfare resources in this country can attract talent from neighboring regions (Foreman-Peck and Zhou, 2020), causing a negative externality to neighbors' growth (see Table 4). The non-productive expenditure generates a negative externality in the form of strategic interaction, which leads to over-provision of welfare (h) to compete for the mobile labor force across Europe. This "welfare tournament" in European countries stands in contrast to the "growth tournament" in Chinese provinces (Morck and Yeung, 2016). However, the welfare tournament is essentially an *involution* process as the labor force in Europe, especially the high-skilled, is relatively fixed in the short run. There is no new human capital produced out of this tournament, so the excessive welfare provision leads to a suboptimal growth profile for the entire European community.

4.2 Robustness

To ensure robustness, we challenge the baseline results by different expenditure measures, model specifications, subsamples, and estimation methods.

Expenditure Measure. The baseline model uses the total productive expenditure as the measure. We can further decompose it into sub-categories of expenditure on defense, economic affairs, education, and health following Bleaney et al. (2001), Adam and Bevan (2005), and Chu et al. (2020). Column (1) of Table 5 shows that the direct effects mainly come from defense, economic affairs, and education, while the indirect effects (spillover effects) mainly come from economic affairs and education. We also checked the results when we use alternative measures of government expenditure such as public capital stock (Futagami et al., 1993; Fisher and Turnovsky, 1998; Chen et al., 2017) and alternative measures of government revenue (Kneller et al., 1999; Bleaney et al., 2001; Gemmell et al., 2011; Chu et al., 2020), the conclusions are qualitatively the same as the baseline.

Model Specification. We have chosen the SDM specification as the baseline in subsection 3.3. One alternative is the SDEM specification which assumes spatial dependence in the error term but imposes no spatial dependence of growth rate. Column (2) of Table 5 shows the estimation result under the SDEM specification and it is again close to the baseline. We also test robustness under different spatial weight matrices such as $\mathbf{W}^{(d)}, \mathbf{W}^{(c)}, \widetilde{\mathbf{W}}^{(c)}$ instead of $\widetilde{\mathbf{W}}^{(d)}$. The qualitative findings are maintained.

Subsample. The EU has undergone significant expansion since its establishment in 1993, with several rounds of enlargement bringing in new member states. The first wave of expansion occurred in 1995 when Austria, Finland, and Sweden joined the union. The second and the largest wave to date was in 2004 when ten more Central and Eastern European countries were incorporated. Furthermore, Bulgaria and Romania joined in 2007, while Croatia joined in 2013.

In general, the economy in Europe became more integrated after 2004. To reflect this structural change, we restrict the sample to the post-2004 period. Column (3) of Table 5 shows that the results are robust.

Table 5 Robustness tests

	(1) Measure	(2) Specification	(3) Subsample	(4) Method
Direct Effects				
Productive expenditure ratio $t-1$		0.112***	0.131***	0.104***
		(0.025)	(0.040)	(0.026)
Defense $t-1$	0.329***			
	(0.080)			
Economic affairs $t-1$	0.122***			
	(0.027)			
Education $t-1$	0.206**			
	(0.083)			
Health $t-1$	0.087*			
	(0.045)			
Indirect Effects				
Productive expenditure ratio $t-1$		0.488**	1.482***	1.835***
		(0.193)	(0.515)	(0.659)
Defense $t-1$	-0.139			
	(0.205)			
Economic affairs $t-1$	5.625***			
	(1.028)			
Education $t-1$	1.052***			
	(0.286)			
Health $t-1$	1.518*			
	(0.856)			
Control variables	YES	YES	YES	YES
Country FE (**fn**)	YES	YES	YES	YES
Year FE (**ft**)	YES	YES	YES	YES
Spatial lag (ρ)	0.197*		0.358***	0.572***
	(0.115)		(0.120)	(0.106)
Observation	780	660	480	660
R-squared	0.791	0.833	0.874	0.855

Note: All regressions include a constant (not shown). Marginal effects and robust standard errors are reported. Significance * 10% ** 5% *** 1%.

Estimation Method. For poorly scaled sample, maximum likelihood estimates of standard errors can be inaccurate due to the close-to-singular Hessian matrix. To solve this issue, the Bayesian MCMC algorithm is applied under a dynamic weight matrix (LeSage, 2014). We follow the default prior distributions and the Metropolis-Hastings algorithm in LeSage and Pace (2009) to obtain the posterior means in column (4) of Table 5. The results are again in line with the baseline.

4.3 Heterogeneities

This subsection investigates heterogeneities of the spillover effect across countries and over time. Developed and developing countries are endowed with different levels of capital stocks, so "new" member states of the EU (Czech, Estonia, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Slovenia, and Slovakia) can receive different spillovers from "old" member states (Belgium, Denmark, Germany, Ireland, Greece, Spain, France, Italy, Luxembourg, Netherlands, Austria, Portugal, Finland, Sweden, and the UK). The cross-sectional heterogeneity of the spillover effect can be studied by including a slope dummy D (equal to 1 for "old" member states and 0 otherwise) in front of productive expenditure ratio. Similarly, the temporal heterogeneity can be captured by a slope dummy T (equal to 1 before the global financial crisis and 0 otherwise) in front of the productive expenditure ratio.

Table 6 Heterogeneities across countries and over time

	(1) Across Countries	(2) Over Time
Direct Effects		
Productive expenditure ratio $t-1$	0.242***	0.121***
	(0.034)	(0.026)
Productive expenditure ratio $t-1 \times D$	-0.209***	
	(0.041)	
Productive expenditure ratio $t-1 \times T$		0.037
		(0.025)
Indirect Effects		
Productive expenditure ratio $t-1$	2.548***	2.037***
	(0.590)	(0.581)
Productive expenditure ratio $t-1 \times D$	-1.900***	
	(0.588)	
Productive expenditure ratio $t-1 \times T$		-0.266**
		(0.114)
Control variables	YES	YES
Country FE (**fn**)	YES	YES
Year FE (**ft**)	YES	YES
Spatial lag (ρ)	0.443	0.579***
	(0.095)	(0.085)
Observation	660	660
R-squared	0.864	0.862

Note: All regressions include a constant (not shown). Marginal effects and robust standard errors are reported. Significance * 10% ** 5% *** 1%.

The negative coefficients of a slope dummy D in column (1) of Table 6 imply that "old" ("new") member states enjoy less (more) spillover benefits of productive expenditure on growth. This is consistent with the findings of firm-level spillovers (Foreman-Peck and Zhou, 2022). An important reason is that the "new" countries have less public expenditure to be spilt over compared to the "old" countries as senders, so they benefit more from their developed neighbors

as receivers. Theoretically, there are two mechanisms as shown in equation (6), i.e., the crowding spillover and the absorptive capacity. On the one hand, when migrants and businesses from "new" countries crowd into the "old" countries in pursuit of higher wages and returns, the domestic utilization rate η_g in the "old" countries becomes lower due to the negative externality effect. On the other hand, a higher output level in the "old" countries enables a higher absorptive capacity, resulting in a greater positive externality effect. In our estimates, the crowding spillover (the negative externality) dominates the absorptive capacity (the positive externality), so the net effect is negative.

The regression with a slope dummy T shows that the exogenous event (the global financial crisis) alters the spillover effect. The negative indirect effect in column (2) of Table 6 suggests that the post-crisis spillover effect is weaker compared to the pre-crisis level. Following the global financial crisis, several European countries faced a sovereign debt crisis. Greece, Portugal, Ireland, Spain, and Italy were the epicenter of this crisis. It led to austerity measures as these governments sought to reduce budget deficits and stabilize their economies (Greenwood-Nimmo et al., 2023). The synchronized austerity policies within Europe had substantially reduced the public expenditure pool, so there was less to be spilled over across borders.

Figure 3 Intra-EU openness



Source: Eurostat. Openness = (import within the EU + export within the EU)/GDP of the EU.

In addition, the sharp post-crisis fell in intra-EU openness (Figure *3*) helps explain why fiscal spillovers weakened. In the trade literature, most prominently in Global VAR models (Dees et al., 2007), spillover strength is calibrated with multilateral trade weights derived from the export-plus-import share of GDP. Lower openness therefore reduces an economy's ability both to transmit and to absorb external fiscal impulses. During the 2007-08 crisis the intra-EU trade-to-GDP ratio fell by about 30 percentage points, markedly loosening the trade links that carry fiscal shocks across member states.

5 Conclusion

Regional integration compels countries to compete for businesses, investments, and talents, placing pressure on policymakers to adopt more appealing combinations of government expenditures (Ferraresi et al., 2018). Specifically, European countries are known for collectively and persistently low productive expenditure and high welfare expenditure. To explain this puzzle, we extend the Barro endogenous growth model to account for different types of government expenditure and international externality. We then derive three testable hypotheses from the theoretical model: the hypothesis of growth effect [H1], the hypothesis of spillover effect [H2], and the hypothesis of spatial dependence [H3]. The spatial-panel data of EU27+3 countries are then used to empirically confirm the hypotheses.

Building on the theoretical and empirical results, this paper introduces two novel perspectives to understand the puzzle of European government expenditure structure. On the one hand, productive expenditure has a positive externality (productivity spillover) in an integrated region, so it is under-provided like any public goods. Reversely, non-productive (mainly welfare) expenditure has a negative externality (strategic interaction) due to competition for talents, leading to an involutionary "welfare tournament". It is also found that the strongest spillover effect comes from economic affairs (e.g., infrastructure, R&D). Heterogeneity tests show that "new" EU member states benefit more from the regional integration than "old" ones, and the global financial crisis has weakened the spatial interdependence.

Our findings provide useful policy implications for integrated regions like Europe. First, productivity spillover suggests that fiscal initiatives by the European Commission (e.g., Cohesion Fund) are necessary to mitigate the international "free rider problem". Regional integration must be accompanied by supranational coordination. Otherwise, the benefits of a single market are not fully explored due to the positive externality of productive expenditure. Second, strategic interaction is partly responsible for underperforming growth prospects in the European community. Different from the "growth tournament" in China where competition can bring some evolutionary progress in productivity, the "welfare tournament" in Europe does not generate new human capital as they are competing for given talents within the region. In sum, both "free rider problem" and "welfare tournament" lie on the cost side of being part of an integrated region. Ignoring these externality-induced issues can undermine regional management and lead to unstable unions (e.g., Brexit).

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Supplementary Appendices

A1. The mathematical derivation of equation (4) in Section 2.

The representative agent takes τ and g as given when choosing the optimal consumption path and the optimal capital path $\{c(t), k(t): t \geq 0\}$.

Maximize the objective function $U = \int_0^{\infty} e^{-\rho t}\left[\nu \ln c + (1-\nu)\ln \bar{h}\right] dt$, subject to (1) and (2), we get the first order condition as:

$$\nu / c = \lambda_k \tag{S1}$$

$$\dot{\lambda}_k = \lambda_k[\rho - (1-\tau)A\alpha(\bar{g}/k)^{1-\alpha} + \delta] \tag{S2}$$

where the Hamilton multiplier λ_k is the co-state variable, corresponding to the state variable k. The Euler equation is given by:

$$\dot{c} = c[(1-\tau)A\alpha(\bar{g}/k)^{1-\alpha} - \delta - \rho] \tag{S3}$$

From equation (1), we have:

$$\bar{g}/y = \left(\eta_g b\tau + z_g b^*\tau^*\right) \tag{S4}$$

Combining (S4) and production function $y = Ak^{\alpha}\bar{g}^{1-\alpha}$, the amount of total public capital per unit of private capital is:

$$\bar{g}/k = \left[A\left(\eta_g b\tau + z_g b^*\tau^*\right)\right]^{1/\alpha} \tag{S5}$$

Substituting (S5) into (S3) and (2), then a system of binary differential equations can be derived as:

$$\dot{c} = c\left[\alpha(1-\tau)A^{\frac{1}{\alpha}}\left(\eta_g b\tau + z_g b^*\tau^*\right)^{\frac{1-\alpha}{\alpha}} - \delta - \rho\right] \tag{S6}$$

$$\dot{k} = \left[(1-\tau)A^{\frac{1}{\alpha}}\left(\eta_g b\tau + z_g b^*\tau^*\right)^{\frac{1-\alpha}{\alpha}} - \delta\right]k - c \tag{S7}$$

Thus, (S6) and (S7) constitute a two-equation system in the paths of c and k that determine the representative individual's optimal policy functions.

To ensure that the intertemporal resource constraint is met, the following transversality condition must hold:

$$\lim_{t\to\infty} \lambda_k k e^{-\rho t} = 0 \tag{S8}$$

Using (S2), (S4), (S7) and (S8), private consumption per capital can be expressed as:

$$c/k = \rho + (1-\alpha)(1-\tau)A^{\frac{1}{\alpha}}\left(\eta_g b\tau + z_g b^*\tau^*\right)^{\frac{1-\alpha}{\alpha}} \tag{S9}$$

Equation (2) implies $\dot{k}/k = (1-\tau)(y/k) - c/k - \delta$, and (S9) which implies that c and k must grow at the same rate $\gamma = \dot{c}/c = \dot{k}/k$, which is constant over time, together imply that y/k must be constant and grow at the same rate along the balanced growth path. Therefore, we have:

$$\gamma = \frac{\dot{y}}{y} = \frac{\dot{c}}{c} = \frac{\dot{k}}{k} = \alpha(1-\tau)A^{\frac{1}{\alpha}}\left(\eta_g b\tau + z_g b^*\tau^*\right)^{\frac{1-\alpha}{\alpha}} - \delta - \rho$$

A2. The proof of the welfare-maximizing share of productive expenditure b_U is smaller than the one for growth-maximizing b_G.

If we assume a growth-maximizing government, then the optimal choice of $b = b_G = 1$, which can maximize γ in equation (4). In contrast, welfare-maximizing government's optimal choice $b = b_W$ is derived based on the value function of social welfare.

Substitute the balanced growth path growth rate (4) into the welfare function:

$$\max_b U = \frac{\gamma}{\rho^2} + \frac{1}{\rho}\left\{\begin{array}{c}\ln k(0) - \ln\alpha + v\ln[(1-\alpha)\gamma+\rho] \\ +(1-v)\{\ln[\eta_h(1-b)\tau + z_h(1-b^*)\tau^*] + \ln(\gamma+\rho) - \ln(1-\tau)\}\end{array}\right\} \quad \text{(S10)}$$

To maximize welfare, the government sets $b = b_W$ such that:

$$\left.\frac{\partial U}{\partial b}\right|_{b=b_W} = \left.\frac{\partial \gamma}{\partial b}\right|_{b=b_W}\left[\frac{1}{\rho} + \frac{v(1-\alpha)}{(1-\alpha)\gamma+\rho} + \frac{1-v}{\gamma+\rho}\right] - \frac{(1-v)\eta_h\tau}{\eta_h(1-b_W)\tau + z_h(1-b^*)\tau^*} = 0 \quad \text{(S11)}$$

Define $P \equiv \left.\frac{\partial \gamma}{\partial b}\right|_{b=b_W}\left[\frac{1}{\rho} + \frac{v(1-\alpha)}{(1-\alpha)\gamma+\rho} + \frac{1-v}{\gamma+\rho}\right]$, so that we can rewrite (S11) as:

$$P - \frac{(1-v)\eta_h\tau}{\eta_h(1-b_W)\tau + z_h(1-b^*)\tau^*} = 0 \quad \text{(S11)'}$$

Solving the first order condition (S11)', we have:

$$b_W = 1 - \frac{(1-v)\eta_h\tau - Pz_h(1-b^*)\tau^*}{P\eta_h\tau} \quad \text{(S12)}$$

Given that $b_W < 1$, we have $\eta_h(1-b_W)\tau > 0$, so (S11)' implies:

$$P - \frac{(1-v)\eta_h\tau}{z_h(1-b^*)\tau^*} < 0 \rightarrow (1-v)\eta_h\tau - Pz_h(1-b^*)\tau^* > 0$$

Thus, the second term of (S12) is positive, and we prove that $b_W < 1 = b_G$. In other words, there must be a higher domestic non-productive share $1-b$ of government expenditure to compensate the loss in welfare at the cost of lower growth due to a lower b.

A3. The construction of the two hybrid spatial weight matrices $\widetilde{\mathbf{W}}^{(c)}$, $\widetilde{\mathbf{W}}^{(d)}$

For $\mathbf{W}^{(c)}$, a neighboring country is defined as one whose capital city lies within a specified Great Circle distance from the capital city of another country. For $\mathbf{W}^{(d)}$, the inverse distance is calculated by the latitude and longitude obtained from *Google Map*. The weights $\omega(c)_{ij}$ in $\mathbf{W}^{(c)}$ and $\omega(d)_{ij}$ in $\mathbf{W}^{(d)}$ are commonly row-normalized (divided by the row sum) so that $\sum_{j\neq i}\omega_{ij}=1$. The details of how the $\mathbf{W}^{(c)}$ and $\mathbf{W}^{(d)}$ are calculated can be found in the Distance Based Weight Matrix Code by Donald J. Lacombe (webpage link).

Weight $\widetilde{w}(d)_{ij}$ in the geographic distance-based hybrid spatial weight matrix $\widetilde{\mathbf{W}}^{(\mathbf{d})}$ is calculated by $w(d)_{ij}$ in $\mathbf{W}^{(d)}$ and $w(inc)_{ij}$:

$$w(inc)_{ij}=\frac{1}{|\mathrm{inc}_i-\mathrm{inc}_j|S_i} \text{ where } S_i=\sum_j \frac{1}{|\mathrm{inc}_i-\mathrm{inc}_j|}$$

$$\widetilde{w}(d)_{ij}=\sqrt{w(dis)_{ij}\times w(inc)_{ij}}$$

where $\mathrm{inc}_{i,j}$ are the country's average per capita income over the sample period.

Similarly, weight $\widetilde{w}(c)_{ij}$ in the geographic contiguity-based hybrid spatial weight matrix $\widetilde{\mathbf{W}}^{(\mathbf{c})}$ is calculated by $w(c)_{ij}$ in $\mathbf{W}^{(c)}$ and $w(inc)_{ij}$:

$$\widetilde{w}(c)_{ij}=\sqrt{w(c)_{ij}\times w(inc)_{ij}}$$

This approach is developed by Ezcurra & Rios (2020) and widely used in spatial literature.

Table A1 Estimated coefficients of the baseline model

Coefficients	QML
Spatial lag (ρ)	0.566***
	(0.085)
Productive expenditure ratio $t-1$	0.094***
	(0.023)
W*Productive expenditure ratio $t-1$ (δ)	0.693***
	(0.148)
Control variables	YES
Country FE ($\mathbf{fn}$)	YES
Year FE ($\mathbf{ft}$)	YES
Observation	660
R-squared	0.858

Note: Heteroskedasticity-robust standard errors are reported in parentheses. Significance * 10% ** 5% *** 1%.

Table A2 Estimation results without fixing total government expenditure

	(2) = (2A) + (2B) QML	(2A) Direct	(2B) Indirect
Spatial lag (ρ)	0.581***		
	(0.083)		
△Log(Productive expenditure)	0.059***	1.059**	1.118**
	(0.017)	(0.404)	(0.413)
△Log(Non-productive expenditure)	-0.110***	-1.397**	-1.501***
	(0.028)	(0.517)	(0.532)
Control variables	YES	YES	YES
Country FE ($\mathbf{fn}$)	YES	YES	YES
Year FE ($\mathbf{ft}$)	YES	YES	YES
Observation	660		
R-squared	0.835		

Note: Heteroskedasticity-robust standard errors are reported in parentheses. Significance * 10% ** 5% *** 1%.