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Modelling Economic Policy Issues

Short and longer-term effects of European regional policy[☆]

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ABSTRACT

We quantify the system-wide impact of the European Structural Funds 2014–20 using a large-scale spatial general equilibrium model, calibrated for 89 regions in the EU and the UK. We find that policies that stimulate private and public investment have larger and longer-lasting effects than demand-side policies. In the latter case, the model shows a rapid adjustment to the post-policy equilibrium, which limits the legacy effects of the interventions. In addition, we show the importance of agents' expectations in assessing the impact of the interventions supported by the funds. A model with perfect foresight tends to predict smaller impacts than a model with myopic agents would imply. The regional distribution of the differences in GDP impact between the two variants of the model suggests that the largest deviations are recorded for net beneficiary regions, with interesting implications for perceived policy persistence, the nature of interventions, and their long-term effects.

1. Introduction

Cohesion policy is the second largest item in the European Union (EU) budget. For the period 2014–2020, around 75% of the funds (almost €260 billion) were channelled through the European Regional Development Fund (ERDF) and the Cohesion Fund (CF), with the aim of reducing disparities in the level of development between the Member States and the regions of the Union (European-Commission, 2021).

There is a rich literature assessing the impact of cohesion policy using a variety of techniques, including econometric analysis, partial and general equilibrium modelling, and counterfactual impact assessments (see, for example, Fratesi and Wishlade, 2017; Casas et al., 2024). Quantifying the impact of cohesion policy poses several major challenges. Given the multiplicity of objectives involved, it is often difficult to adequately account for each policy instrument, and assessing system-wide effects is even more difficult when policies are designed to generate spillovers and improve links between regions.

Numerical and computable general equilibrium models, which take into account the structural linkages of the economy, are able to capture the direct, indirect, and system-wide effects of policies (Lemelin and Savard, 2022; Nugroho et al., 2021; Blouri and Ehrlich, 2020; Arrow, 2005). In addition, the incorporation of interregional trade links in this type of models makes them well equipped to capture trade and competitiveness spillovers, as well as other types of spillovers arising from the mobility of

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production factors (see, for example, Figus et al., 2018; Johnson, 2014). Studies based on general equilibrium modelling can also better differentiate the channels through which the different types of interventions included in the ERDF and CF packages generate their effects and thus better disentangle the contribution of each policy measure to the overall effect.[1]

Korzhenevych and Bröcker (2020) use a spatial forward-looking model to evaluate European regional policy investments in 25 EU regions. This application disaggregates the policy programme into two broad groups of investments, implying either an increase in private or public investment, without accounting for the additional economic mechanisms that may be activated by the interventions. Moreover, private and public investment behave similarly and have the same marginal returns. Nevertheless, in this paper, consumers and investors make intertemporal decisions and have perfect foresight, which is a significant improvement over previous impact assessments based on spatial general equilibrium models with myopic agents (who make decisions based only on the present and past circumstances, and are unable to anticipate future developments).

Accounting for intertemporal substitution is considered an important feature when analysing the potential impact of a multi-annual development policy (Partridge and Rickman, 2010), as agents' expectations may have strong implications for consumption smoothing and investment decisions in response to policy shocks. This is even more important when the policy has direct supply-side effects (such as cohesion policy) with longer-term implications as shown by Allan et al. (2021), who found that imperfect foresight investment models produce more negative, longer-lasting and unstable adjustment paths. The use of an intertemporal model with forward-looking agents is therefore well suited to the analysis of the EU cohesion policy, which is implemented within a multi-annual financial framework.

In this paper, we develop a spatial intertemporal dynamic general equilibrium model covering 89 NUTS 1 regions[2] of the EU and the UK to analyse the macroeconomic impact of investments financed by the ERDF and the CF over the period 2014–2020. We perform a systematic and comprehensive impact evaluation of cohesion policy in a large-scale intertemporal spatial general equilibrium modelling framework. We first simulate the full policy package and then consider the separate responses of each policy channel (the policy shock is introduced with a combination of increases in government current expenditure, government capital expenditure, private investment subsidies, and taxes to finance the interventions). To shed light on the role of agents' expectations, we compare the short-run and long-run results obtained under the assumption of forward-looking agents with perfect foresight with an alternative version with myopic agents who form expectations based only on the current and past state of the economy.

The rest of the paper is structured as follows. Section 2 outlines the model used in this study, while Section 3 is dedicated to the calibration of the model. Section 4 illustrates the simulation strategy used for the analysis and then the results are presented in Sections 5 and 6. Conclusions are drawn in Section 7.

2. The dynamic spatial general equilibrium model

2.1. A sketch of the model

The model represents a decentralised market economy based on the assumption that producers maximise their profits and consumers maximise the utility they derive from their consumption, with market prices adjusting endogenously to maintain equilibrium between supply and demand in all markets.

The model consists of $R = 89 + 1$ regions, of which 85 are endogenous NUTS1 regions representing the EU27 Member States, plus 4 regions of the UK and one exogenous region representing the rest of the world (ROW). The index r in R is used to refer to a specific region. The model includes the following 3 NACE Rev.2 sectors: $J = \{1, 2, 3\}$, representing the primary, manufacturing and services sectors. The indices $j = i$ in J are used to refer to a specific industry. In the model economy, firms operate under monopolistic competition à la (Dixit and Stiglitz, 1977) in all sectors except the primary sector, where perfect competition is assumed. Therefore, the number of firms N is endogenous in manufacturing and services, while it is kept exogenous and normalised to 1 for agriculture.

In each region, a representative firm produces a single variety, which is assumed to be an imperfect substitute for the variety produced in other regions. Regional goods are produced by combining value added with domestic and imported intermediate goods, while final goods are consumed by households and governments and investment goods are consumed by investors.

The regional heterogeneity in our model is due to the calibration of regional economic structures using input–output data that reflect differences in capital intensity, labour market dynamics and sectoral composition. Each region in our model is characterised by an initial (pre-shock) equilibrium, characterised by different endowments of capital and labour, as well as region-specific saving rates and consumption patterns. As a result, identical policy interventions can generate asymmetric responses across regions, as regional characteristics influence the magnitude and persistence of policy effects.

A distinctive feature of the model is that it fully accounts for bilateral final and intermediate shipments, where firms and consumers purchase goods from local or foreign producers through a composite Armington sector. In addition, the model takes into account congestion effects due to the non-public nature of public goods and the imperfect labour market in each region. In all endogenous regions we allow for involuntary unemployment, which means that workers cannot freely choose whether or not to work and that unemployed workers are always able to accept a job at the prevailing real wage.

[1] Partial equilibrium and reduced-form approaches do not usually distinguish between the different categories of policy expenditure, but may take into account specific factors that may affect the economic impact of the policy, such as the quality of institutions (Rodríguez-Pose and Garcilazo, 2015; Ederveen et al., 2006), regional absorptive capacity (Becker et al., 2013) and capital endowments (Fratesi and Perucca, 2014).

[2] The Nomenclature of Territorial Units for Statistics (NUTS) is a standard classification system for the administrative divisions of EU countries. Eurostat establishes a hierarchy of three NUTS levels for each EU Member State in agreement with the Member State concerned.

Agents have perfect foresight and make no systematic forecasting errors in solving the intertemporal investment and consumption decision.[3] Both investors and consumers take into account all available information when making decisions. Our model is inspired by the intertemporal model of Abel and Blanchard (1983), where saving decisions are separated from investment decisions, and has similar features to other numerical general equilibrium models (e.g. Go, 1994; Devarajan S., 1994; Lecca et al., 2013; Bröcker and Korzhenevych, 2013; Korzhenevych and Bröcker, 2020). Moreover, our model incorporates a number of building blocks of quantitative spatial models (see, for example, Redding and Rossi-Hansberg, 2017) such as product differentiation, increasing returns, input–output linkages, and asymmetric transport costs.

While the full perfect foresight model is fully described in the next section, the myopic version of the model is reported in the Appendix, where we report alternative behaviour for consumers and investors. Both specifications belong to the infinite-lived agent model, so the long-run steady state equilibrium is identical (this would be different if an overlapping generation model were considered).

In the next subsections we describe the model in detail, omitting the time index t in non-dynamic equations unless absolutely necessary.

2.2. Household

Each region is inhabited by a representative household that receives income from four sources: labour, rent of capital, profits rebated by firms competing in the monopolistic sector, and government transfers. The decision problem of the representative consumer is to choose a sequence of consumption that maximises the present value of utility, $U(C_{r,t})$, subject to an intertemporal budget constraint:

$$\begin{aligned} &\max && \int_0^\infty e^{-\rho t} U(C_{r,t}) dt \\ &\text{subject to} && \dot{W}_{r,t+1} = \chi_t W_t - P^c_{r,t} C_{r,t} \end{aligned} \tag{1}$$

where $U(C_{r,t})$ is the instantaneous utility function and represents the utility from consumption $C_{r,t}$ at period t and is defined as a constant intertemporal elasticity of substitution, $U(C_{r,t}) = \frac{C_{r,t}^{1-\sigma_u}}{1-\sigma_u}$. ρ is the household discount rate and σ_u is the intertemporal elasticity of substitution. The smaller is σ_u the more willing the household is to vary its consumption over time. $P^c_{r,t}$ is the consumer price index and χ_t is the interest rate. In the model, χ_t is an exogenous variable. All regions of the EU+UK are assumed to be price takers on the world financial market, which determines the actual level of the interest rate. $W_{r,t} = NFW_{r,t} + FW_{r,t}$ is the total wealth of households, which is given by the sum of non-financial wealth $NFW_{r,t}$ and financial wealth $FW_{r,t}$. The law of motion of the non-financial wealth of households is:

$$\begin{aligned} NFW_{r,t}\left(1+\chi_t\right) = & NFW_{r,t+1} + (1-\tau^w_r) w_{r,t}\left(1-u_{r,t}\right) L^s_{r,t} + \\ & TR_{r,t} - TR^{ROW}_r \end{aligned} \tag{2}$$

L^s_r is the labour supply and u_r is the unemployment rate, which is defined in equilibrium later in this section. w_r is the equilibrium wage rate and τ^w_r is the tax rate on labour income. TR_r is an exogenous variable representing the net transfer from the government to the household, while TR^{RoW}_r is the net transfer from the region to the ROW (remittances) and is considered fixed throughout the simulations. The law of motion of household financial wealth is:

$$FW_{r,t}\left(1+\chi_t\right) = FW_{r,t+1} + \sum_i \psi^k_r N_{r,i,t} K_{r,i,t} rk_{r,i,t} - S_{r,t} \tag{3}$$

In Eq. (3), ψ^k_r is the fraction of capital rents paid by firms to households, the remaining fraction, $1-\psi^k_r$, is paid to the government. $rk_{r,i}$ is the return to capital in region r, sector i, $K_{r,i}$ is the private capital stock in the sector i at the firm level, while $N_{r,i}$ is the number of firms. Finally, S_r is the total saving of the household.

The optimal consumption path of the household is given by Eq. (4).

$$C_{r,t+1} = C_{r,t}\left(\frac{P^c_{r,t+1}}{P^c_{r,t}}\frac{1+\rho_r}{1+\chi_t}\right)^{-\frac{1}{\sigma_u}} \tag{4}$$

Total consumption C_r is defined as a constant elasticity of substitution (CES) aggregator across goods and services from different sectors. Consumption is then optimally allocated across sectors according to:

$$c_{r,i} = \zeta^c_{r,i}\left(\frac{P^c_r}{P_{r,i}}\right)^{\sigma^c} C_r \tag{5}$$

where $c_{r,i}$ is the amount of consumption produced by sector i, $\zeta^c_{r,i}$ is an expenditure share parameter and σ^c is the elasticity of substitution between sectors. The consumption price index P^c_r is obtained by a weighted CES index defined over the Armington

[3] In the perfect foresight framework, agents are assumed to have full knowledge of the entire policy trajectory, including its long-term effects, and to adjust their decisions accordingly. This assumption implies that information acquisition is costless and instantaneous, which simplifies the modelling of expectations but may not entirely reflect real-world constraints where agents face information frictions, uncertainty, and learning dynamics.

price, $P_{r,i}$.

$$P^c_r = \left(\sum_i \zeta^c_{r,i} P_{r,i}^{1-\sigma^c}\right)^{\frac{1}{1-\sigma^c}} \tag{6}$$

2.3. Firms

Firms consume intermediate inputs, capital and labour in each region r and sector j. To start a business, firms face an additional fixed cost, $\phi^F_{r,j}$. Operationally, firms are forced to generate sufficient revenue to cover the fixed cost of producing an additional variety. In equilibrium, the number of varieties is determined by the zero profit equilibrium condition, where profits must equal fixed costs. Firms solve a multi-stage problem to determine the optimal combination of inputs subject to a nested CES production function. In the first stage, firms solve the following problem:

$$\max P^Z_{r,i} Z_{r,i} - \left(P^V_{r,i} V_{r,i} + P^Q_{r,i} Q_{r,i}\right) - \phi^F_{r,i} P^*_{r,i}$$

s.t.

$$Z_{r,i} = \left[\zeta^V_{r,i} V_{r,i}^{\frac{\sigma^Z-1}{\sigma^Z}} + \zeta^Q_{r,i} Q_{r,i}^{\frac{\sigma^Z-1}{\sigma^Z}}\right]^{\frac{\sigma^Z}{\sigma^Z-1}} \tag{7}$$

$Z_{r,i}$ is the total output defined as a CES combination between $Q_{r,i}$ and $V_{r,i}$, the value added and the intermediate goods composites, respectively. $\zeta^Q_{r,i}$ and $\zeta^V_{r,i}$ are the calibrated shares of the value added and the intermediate inputs, respectively, in total output, while σ^Z is the elasticity of substitution between the two inputs. $P^Z_{r,i}$, $P^V_{r,i}$ and $P^Q_{r,i}$ are the prices associated with total output Z, intermediate inputs V and value added Q respectively, while $P^*_{r,i}$ is the marginal cost. The first-order conditions of the firm's profit maximisation problem give the optimal demand for V and Q:

$$V_{r,i} = \zeta^V_{r,i} \left(\frac{P^V_{r,i}}{P^Z_{r,i}}\right)^{-\sigma^Z} Z_{r,i} \tag{8}$$

$$Q_{r,i} = \zeta^Q_{r,i} \left(\frac{P^Q_{r,i}}{P^Z_{r,i}}\right)^{-\sigma^Z} Z_{r,i} \tag{9}$$

The composite intermediate $V_{r,i}$, in turn, is a CES combination of input–output relations between all sectors of the economy, $v_{r,i,j}$, that is, the demand from sector j for the intermediate produced in sector i:

$$V_{r,i} = \left[\sum_j \zeta^v_{r,i,j} v_{r,i,j}^{\frac{\sigma^V-1}{\sigma^V_{r,i}}}\right]^{\frac{\sigma^V}{\sigma^V-1}} \tag{10}$$

The parameters $\zeta^v_{r,i,j}$ and σ^V are respectively the share parameter and the elasticity of substitution between intermediate inputs. The CES composite price index for the intermediate inputs is determined as follows in Eq. (11):

$$P^{V\,1-\sigma^V}_{r,j} = \sum_i \zeta^v_{r,i,j} P_{r,i}^{1-\sigma^V} \tag{11}$$

Capital K and composite labour L are combined in a CES production function that gives form to the value added $Q_{r,j}$ as in Eq. (12):

$$Q_{r,i} = A_{r,i}\left(KG^d_r\right)^{\phi} \left[\zeta^K_{r,i} K_{r,i}^{\frac{\sigma^Q-1}{\sigma^Q}} + \zeta^L_{r,i} L_{r,i}^{\frac{\sigma^Q-1}{\sigma^Q}}\right]^{\frac{\sigma^Q}{\sigma^Q-1}} \tag{12}$$

where $A_{r,i}$ is the conventional Hicks neutral technical change in this production function. The effective public capital KG^d enters the production function as an unpaid factor of production (Glomm and Ravikumar, 1994, 1997), meaning that all firms in all sectors enjoy the same level of free public capital. The parameter ϕ is the elasticity of value added to public capital. In Eq. (12) the conditions are such that the production function of value added has positive marginal productivity and diminishing returns for each of the three factors. This function shows constant returns to scale between private primary factors of production (K, L), but increasing returns to scale when combined with public capital (K, LD, KG^d). The substitution between the two types of primary factors is governed by the elasticity of substitution σ^Q and the share parameters ζ^K and ζ^L. The optimal demand for private capital and labour are given by the Eqs. (13) and (14) respectively:

$$K_{r,i} = \left[A_{r,i}\left(KG^d_{r,i}\right)^{\phi}\right]^{\sigma^Q-1} \zeta^K_{r,i} \left(\frac{P^Q_{r,i}}{rk_{r,i}}\right)^{\sigma^Q} Q_{r,i} \tag{13}$$

$$L_{r,i} = \left[A_{r,i}(KG^d_{r,i})^{\phi}\right]^{\sigma^Q-1} \zeta^L_{r,i} \left(\frac{P^Q_{r,i}}{w_r}\right)^{\sigma^Q} Q_{r,i} \tag{14}$$

where $rk_{r,i}$ and w_r are respectively the rental price of capital and the wage rate for labour, which is the same across sectors. The wage rate is determined according to a simple long-run wage curve based on Blanchflower and Oswald (1995) so that the real wage is negatively related to the unemployment rate:

$$ln\left(\frac{w_r}{P_r^c}\right) = a_r - \beta ln(u_r) \tag{15}$$

The unemployment rate in this wage setting reflects the bargaining power of workers. The magnitude of this effect is determined by the elasticity β. Therefore, if the unemployment rate rises for any reason, the real wage will fall and vice versa.

2.4. Private investment

The dynamic investment path is the result of an intertemporal problem that seeks to maximise the present value of the firm's net income or cash flow $R(.)$, defined as gross profit less private investment expenditure subject to the law of motion of capital:

$$\int_0^\infty e^{-\chi t} Y_{r,i,t} dt \tag{16}$$

s.t.

$$K^S_{r,i,t+1} = K^S_{r,i,t}(1-\delta) + I_{r,i,t} \tag{17}$$

where δ is the depreciation rate and $Y_{r,i,t} = rk_{r,i,t}N_{r,i,t}K_{r,i,t} - uck_{r,i,t}I_{r,i,t}(1+\theta(q))$. In equilibrium, the capital stock K^S is equal to the demand for capital, so that $K^S_{r,i} = N_{r,i,t}K_{r,i,t}$. Investment is valued at the user cost of capital uck and subject to the existence of adjustment costs $\theta(q) = \frac{\beta^I}{2}\frac{(q-\alpha^I)^2}{q}$. The adjustment cost of investment is an increasing function of q, defined as the ratio of investment to the capital stock $\left(\frac{I}{K}\right)$ (see Abel, 1990; Go, 1994; Devarajan S., 1994). The optimal path[4] is then:

$$\frac{I_{r,i,t}}{K^S_{r,i,t}} = \alpha^I + \frac{1}{\beta^I_{r,i}}\left(\frac{\lambda_{r,i,t}}{uck_{r,i,t}}\right) \tag{18}$$

where λ it the shadow price of capital defined in Eq. (19):

$$\lambda_{r,i,t}(1+r_t) = rk_{r,i,t} - uck_{r,i,t}\frac{\beta^I_{r,i}}{2}\left(\frac{I_{r,i,t}}{K^S_{r,i,t}}\right)^2 + \lambda_{r,i,t+1}(1-\delta) \tag{19}$$

According to this formulation the investment capital ratio $(I_{r,i}/K^S_{r,i})$ is a function of the real shadow price of capital, defined as the ratio between λ, and uck, allowing the capital stock to reach its optimal level smoothly over time. The definition of the user cost of capital, uck, is taken from Hall and Jorgenson (1967):

$$uck_{r,i} = (\chi + \delta)P^k + \xi_{r,i} \tag{20}$$

where ξ_r is an exogenous risk premium, and P^k is the relative price of investment at the EU aggregate level. Note that by having a region-sector invariant investment price index, the expected changes in uck are the same in all regions, since ξ is exogenous. This also mimics a situation where capital is perfectly mobile across sectors and regions. The demand for investment $I_{r,i}$ in sector i is transformed into the production of investment goods through the capital matrix $KM_{j,i,r}$ whose construction is explained in Lecca et al. (2018). Thus, the demand for investment goods produced by sector j, $I^S_{j,r}$, is given by Eq. (21):

$$I^S_{r,j} = \sum_i KM_{r,j,i}I_{r,i} \tag{21}$$

In turn, the price index for investment goods P^k is defined over the Armington price weighted by the capital matrix KM:

$$P^k = \frac{\sum_i KM_{r,i,j}}{\sum_{r,j,i} KM_{r,j,i}}P_{r,j} \tag{22}$$

2.5. Trade

The unique dataset we use allows us to model bilateral trade flows between regions disaggregated at the sectoral level. The policy shock is then affected by trade linkages between regions, allowing the shock in one region to be transmitted directly to other regions through international trade relations. Trade is modelled using a single Armingtom CES nest, where final and intermediate goods can be sold from the region of origin to other regions in the EU, the UK (including its own region) or the ROW. Thus, each region r' in R imports goods produced in every other region r in R such that, in equilibrium, the output of sector i in region r, $Z_{r,i}$, must satisfy the total demand for variety i coming from region r', $x_{r,r',i}$, net of fixed costs of production ϕ^F and taxes on production at the rate τ^Z:

$$P^Z_{r,i}[Z_{r,i}(1-\tau^Z_{r,i}) - \phi^F_{r,i}] = \sum_{r'} \tilde{P}_{r,r',i}x_{r,r',i} \tag{23}$$

[4] More details on the dynamic solution can be found in Devarajan S. (1994) and Lecca et al. (2013).

The Armington aggregator $X_{r',i}$ in region r' for sector i is defined as a CES function over the demand for varieties $x_{r,r',i}$. The optimal demand for goods and services is then defined as follows:

$$x_{r,r',i}N_{r,i} = \zeta^{x}_{r,r',i}\left(\frac{P_{r',i}}{\tilde{P}_{r,r',i}}\right)^{\sigma^x} X_{r',i} \tag{24}$$

$P_{r,i}$ is obtained as a CES price index over the market prices of varieties $\tilde{P}_{r,r',i}$ as in Eq. (25):

$$P^{1-\sigma^x}_{r,i} = \sum_{r'} \zeta^{x}_{r,r',i} N_{r,i}\left(\tilde{P}_{r,r',i}\right)^{1-\sigma^x} \tag{25}$$

Firm-level product differentiation is governed by the elasticity of substitution σ^x, which we have constrained to be the same across firms and products.[5] Firms then sell to all destinations at the same fob price, even though the cif prices in the destination regions differ because of iceberg transport costs τ. Transport costs are identical across varieties but specific to sectors and trading partners (region pairs).

Under monopolistic competition, the price $\tilde{P}_{r,r',i}$ set by region r for destination region r' includes an ad valorem iceberg transport cost $\tau_{r,r'}$ and the optimal mark-up $\frac{\sigma^x}{\sigma^x-1}$ over marginal cost $P^*_{r,i}$:

$$\tilde{P}_{r,r',i} = \frac{\sigma^x}{\sigma^x - 1}\tau_{r,r'}P^*_{r,i} \tag{26}$$

The marginal cost $P^*_{r,i}$ reflects the structure of production, combining the cost of the factors of production P^Q and the price of the intermediate input P^V as in Eq. (27):

$$P^{*\,1-\sigma^Z}_{r,i} = a^Q_{r,i}P^{Q\,1-\sigma^Z}_{r,i} + a^V_{r,i}P^{V\,1-\sigma^Z}_{r,i} \tag{27}$$

where $a^Q_{r,i}$ and $a^V_{r,i}$ are the shares of value added and intermediate consumption respectively in total output.

2.6. Public sector

Government expenditure consists of current expenditure on goods and services G_r, capital expenditure I^G_r and net transfers to households TR_r. Revenue consists of taxes on labour income at the rate of τ^w_r, indirect taxes on the production of goods and services at the rate of τ^Z, and the residual share of capital income $\left(1-\psi^k_r\right)$ paid by firms to government. The government deficit (or surplus) B_r is given by:

$$\begin{aligned} B_r = {} & \tau^w_r w_r L^s_r(1-u_r) + \left(1-\psi^k_r\right)\sum_i N_{r,i}K_{r,i}rk_{r,i} \\ & + \sum_i \tau^Z_{r,i}P^Z_{r,i}Z_{r,i} - G_r - I^G_r - TR_r \end{aligned} \tag{28}$$

In our standard configuration, we assume exogenous government consumption and investment at the aggregate level and no variation in tax rates, which implies no binding constraints on the government budget. Across sectors, government demand for goods and services and the price consumption index associated with government are obtained using a CES function where substitution between goods is governed by the elasticity of substitution σ_g:

$$g_{r,i} = \zeta^G_{r,i}\left(\frac{P^G_r}{P_{r,i}}\right)^{\sigma_g} G_r \tag{29}$$

$$P^G_r = \left(\sum_i \zeta^G_{r,i}P^{1-\sigma_g}_{r,i}\right)^{\frac{1}{1-\sigma_g}} \tag{30}$$

where $\zeta^G_{r,i}$ is a share parameter. Similarly, government investment is distributed across sectors in fixed shares $\zeta^g_{r,i}$.

$$I^g_{r,i} = \zeta^g_{r,i}I^G_r \tag{31}$$

Government debt $D^G_{r,t}$ evolves as follows:

$$D^G_{r,t} = (1+\chi_{r,t-1})D^G_{r,t-1} - B_{r,t-1}; \tag{32}$$

[5] Note that, as in Armington (1969), the elasticity of substitution between any two goods competing in any markets is the same as that between any other pair of goods competing in the same market.

2.7. Public capital accumulation

The model accounts for congestion effects arising from the non-public nature of public goods (see, for example, Bergstrom and Goodman, 1973). Therefore, the public capital stock, KG^d, is adjusted according to the traditional formulation of decreasing marginal congestion by Edwards (1990) and Fisher and Turnovsky (1998). The aggregate public capital service in Eq. (12) is adjusted for congestion by aggregate value added:

$$KG_r^d = KG_r^s \left(\sum_i N_{r,i} Q_{r,i} \right)^{\gamma} \quad \gamma = \frac{\eta - 1}{\eta}, \gamma \in (0, -\infty) \quad \eta \in (0,1) \tag{33}$$

where γ is the congestion parameter. The increase in production reduces the effective amount of public capital stock available to all firms, and the magnitude of this effect depends on the value of η. If $\eta = 1$ ($\gamma = 0$), we have the case of a pure public good that is equally available to each firm and its use would not reduce its usefulness to others and firms will enjoy full benefits from its use (non-rival and non-excludable). If $\eta = 0.5$ ($\gamma = -1$), public capital remains non-excludable but loses the property of being non-rival. The quantity of public services available to a producer decreases as the value added in the region increases.

The public capital stock is built up by public investment I_r^G, starting from a positive initial capital stock and adjusted for depreciation δ^g:

$$KG_{r,t+1}^s = (1 - \delta^g) KG_{r,t}^s + I_r^G \tag{34}$$

2.8. Equilibrium

Aggregate demand for region r' and sector i is made up of the sum of household and government consumption, private and public investment and the demand for goods used as intermediate inputs:

$$X_{r',i} = \sum_j N_{r',j} v_{r',i,j} + c_{r',i} + g_{r',i} + I_{r',i}^S + I_{r',i}^g \tag{35}$$

Given factor endowments $\left[L_r^s, K_{r,i}^S, KG_r^s\right]$, the equilibrium of the economy for each region r and each sector i is defined as a set of firm decisions $[Z_{r,i}, Q_{r,i}, V_{r,i}, v_{r,i,j}, L_{r,i}, K_{r,i}, X_{r,i}, x_{r,r',i}, N_{r,i}]$, consumer decisions $[C_r, c_{r,i}, S_r]$, private investor decisions $\left[I_{r,i}, I_{r,j}^S\right]$, exogenous government decisions $\left[g_{r,i}, KG_r^d, I_{r,i}^g\right]$ a set of prices $[P_{r,i}, P_{r,i}^c, P_{r,i}^Z, P_{r,i}^Q, P_{r,i}^V, rk_{r,i}, w_r, \lambda_{r,i}, uck_{r,i}, P^I, \tilde{P}_{r,r',i}, P_{r,i}^*, P_r^G]$ and a value for the unemployment rate u_r and a set of exogenous/policy variables $[G_r, I_r^G, TR_r^{ROW}]$ such that commodity markets, capital, labour and financial markets all clear:

- In the monopolistic sector i, the number of firms is determined by the zero profit condition, revenue equals cost of production minus fixed costs:

$$P_{r,i}^* \phi_{r,i}^F N_{r,i} = \sum_{r'} \tilde{P}_{r,r',i} N_{r,i} x_{r,r',i} - P_{r,i}^* N_{r,i} \sum_{r'} x_{r,r',i} \tag{36}$$

- In Eq. (37), market clearing conditions require that the demand for capital is equal to the capital stock. The rental rate of capital $rk_{r,i}$ adjusts in order to ensure such equilibrium:

$$K_{r,i}^S = N_{r,i} K_{r,i} \tag{37}$$

- The unemployment rate $u_{r,e}$ adjusts to clear the labour market, i.e. the labour demand for each skill level, aggregated across all sectors, equals the skill-specific labour supply:

$$\sum_i N_{r,i} L_{r,i} = \left(1 - u_r\right) L_r^s \tag{38}$$

- The total assets of the firms in region r are: $VF_{r,t} = \sum_i \lambda_{r,i,t} K_{r,i,t}^S$. The financial account is then in equilibrium if the following condition is satisfied:

$$FW_{r,t} = VF_{r,t} + D_{r,t}^G + D_{r,t}^F \tag{39}$$

where $D_{r,t}^F$ is foreign asset defined as: $D_{r,t}^F = \left(1 + \chi_t\right) D_{r,t-1}^F + S_{r,t-1}^F$ with $S^F = \sum_i \sum_r \tilde{P}_{r,r',i} N_{r,i} x_{r,r',i} - \sum_i \sum_{r'} \tilde{P}_{r,r',i} N_{r,i} x_{r,r',i}$ being the net saving to region r from other regions both defined as the regional net export to all the other regions.

Finally, the model ensures an unconstrained inflow (or outflow) of capital to support investment whenever needed to allow for greater openness of our small regions. This means that there are no constraints on the balance of payments. The balance of payments is therefore in equilibrium, with fully passive foreign savings, S^F.

Table 1
Estimated parameters. Year 2013.

Parameter	Description	Average	Median
ξ_r	Risk premium	0.27	0.13
τ_r^w	Labour income tax rate	0.16	0.13
$\tau_{r,PRY}^Z$	Production tax rate	−0.02	−0.01
$\tau_{r,MAN}^Z$	Production tax rate	0.01	0.01
$\tau_{r,SER}^Z$	Production tax rate	0.005	0.003
$\tau_{r,r'}$	Transport cost rate	0.14	0.13
$\beta_{r,i}^I$	Adjustment cost	2	1.29
u_r	Unemployment rate	0.09	0.07
$\zeta_{r,PRY}^c$	Sectoral share of household's consumption exp.	0.08	0.07
$\zeta_{r,MAN}^c$	Sectoral share of household's consumption exp.	0.38	0.38
$\zeta_{r,SER}^c$	Sectoral share of household's consumption exp.	0.56	0.54
$\zeta_{r,PRY}^G$	Sectoral share of government's current exp.	0.01	0.00
$\zeta_{r,MAN}^G$	Sectoral share of government's current exp.	0.01	0.01
$\zeta_{r,SER}^G$	Sectoral share of government's current exp.	0.98	0.99
$\zeta_{r,PRY}^X$	Sectoral share of intermediate composite in prod. func.	0.64	0.65
$\zeta_{r,MAN}^X$	Sectoral share of intermediate composite in prod. func.	0.59	0.59
$\zeta_{r,SER}^X$	Sectoral share of intermediate composite in prod. func.	0.45	0.45
$\zeta_{r,PRY}^Q$	Sectoral share of value added in the prod. func.	0.36	0.35
$\zeta_{r,MAN}^Q$	Sectoral share of value added in the prod. func.	0.21	0.21
$\zeta_{r,SEC}^Q$	Sectoral share of value added in the prod. func.	0.35	0.35
$\zeta_{r,i,j}^{xs}$	Sectoral share of intermediate input j in the prod. func.	0.1	0.03
$\zeta_{r,PRY}^L$	Sectoral share of labour in value added	0.27	0.27
$\zeta_{r,MAN}^L$	Sectoral share of labour in value added	0.50	0.51
$\zeta_{r,SER}^L$	Sectoral share of labour in value added	0.62	0.64
$\zeta_{r,PRY}^K$	Sectoral share of capital in value added	0.73	0.73
$\zeta_{r,MAN}^K$	Sectoral share of capital in value added	0.50	0.48
$\zeta_{r,SER}^K$	Sectoral share of capital in value added	0.37	0.35
$\zeta_{r,i,r'}^y$	Bilateral preference parameter in traded good and service	0.02	0.18

3. Calibration

The steady-state values for value added, bilateral final and intermediate inputs are calibrated to exactly match the 2013 data for country regions/sectors. The main data used for the calibration come from the interregional input–output (IO) matrix for the year 2013 constructed by Thissen et al. (2019). To our knowledge, this is the only existing source that fully accounts for bilateral final and intermediate shipments in line with the national accounts system at EU NUTS 1 level. The IO matrix contains data on domestic purchases, sectoral linkages, and trade flows between regions. The latter include data on traded goods used as intermediate inputs as well as for final consumption. The model fully reproduces the interregional flows of the IO table, i.e. we allow for unbalanced trade in the steady state (as e.g., in Kleinman et al., 2023) to match exactly observed bilateral trade and thus observed trade imbalances.

The distribution of income among economic agents (e.g. household income accounts) is taken from Eurostat's regional economic accounts. Tax rates on income and output are calibrated to be consistent with the household income accounts and the interregional IO table. In the initial steady state, the unemployment rates and the distribution of employment across sectors are obtained for each region from the European Labour Force Survey, while the initial steady-state level of N is set according to the European Structural Business Statistics.

Using trade and production data, fixed costs are calibrated to ensure zero profit under monopolistic firms according to Eq. (36) while the market risk premium parameter is calibrated in the model as the difference between the market return rk and the risk-free rate ($\chi + \delta$). The adjustment cost parameter β^I in Eqs. (18) and (19) is initially set to 2, then by trial and error we adjust this parameter for each region/sector to allow it to fall in the range $0.8 - 2.5$ (Cao et al., 2019; Belo et al., 2010). Bilateral iceberg transport costs τ are taken from Persyn et al. (2023) and measure the cost of transporting a good from origin to destination.

Selected calibrated parameters are presented in Table 1. The model also includes another class of parameters that we assume to be homogeneous across sectors and regions, mainly the elasticities of substitution, the depreciation rates of capital and the elasticity related to public investment.

Following standard practice in the literature, we set the elasticity of substitution in final consumption (households and government), σ_c and σ_g, to 0.3 (Johnson, 2014). For trade, we assume an Armington trade elasticity of substitution of 4, based on empirical estimates on European data by Németh et al. (2011) and Olekseyuk and Schürenberg-Frosch (2016). For production, the capital–labour elasticity of substitution, σ^Q, is 0.4. This is within the usual ranges reported in the literature (see e.g. Krusell et al., 2000; Acemoglu, 2003; Chirinko, 2008; León-Ledesma et al., 2010). We set the congestion parameter of public capital, γ, to

Table 2
Assigned parameters.

Parameter	Description	Value
σ_u	Intert. elast. of sub. utility.	1.2
ρ	Household's discount factor	0.04
σ_c, σ_g	Elast. of sub. consumption exp.	0.3
σ^Q	Elast. of sub. value added	0.4
σ^V	Elast. of sub. intermediate composite	0.3
σ^Z	Elast. of sub. production function	0.3
σ^x	Elast. of sub. trade	4
δ	Dep. rate private capital	0.15
δ^g	Dep. rate public capital	0.05
χ	Interest rate	0.04
ϕ	Value added elasticity to public capital	0.1
γ	Congestion parameter	0.5
α_e	Constant term wage setting	0.1
β	Sensitivity of wage to current unemp. rate	0.1

0.5, which represents a medium level of congestion and is close to the values reported in similar regional general equilibrium models (e.g. Alonso-Carrera et al., 2009). In line with Ramey (2020), we assume a homogeneous value of 0.1 for the output elasticity of public capital across EU regions. These parameters are shown in Table 2.

The depreciation rates of private capital, δ, and public capital, δ^g, are set at 0.15 and 0.05 respectively. With regard to the parameters governing the labour market, the model assumes a long-run wage curve with $\beta = 0.1$ (Blanchflower and Oswald, 1995).[6]

4. Modelling cohesion policy investments

We focus on the 2014–2020 programming period, whose ERDF and CF interventions are deployed over ten years until 2023 due to the N+3 rule, which allows policy allocations to be spent within three years of their allocation. Cohesion interventions are allocated asymmetrically by the policymakers, which allows us to consider them as an exogenous shock perturbing the initial equilibrium in the model. By using the information on the spatial distribution of the policy investments, the simulated impact of the policy reflects not only the heterogeneity resulting from the data used to calibrate the model, but also the heterogeneous distribution of the EU funds, which in this case are mainly targeted at the less developed regions.

The investments simulated in the analysis amount to almost €260 billion, mostly concentrated in the middle of the implementation period (on average, 75% of the investments take place between 2016 and 2021, according to data provided by the European Commission). Table 3 shows the amount of cohesion investment (both total and per capita), as well as the annual average over the implementation period in % of 2013 GDP, for each EU NUTS 1 region.[7]

Cohesion policy is financed by the EU budget, to which Member States contribute according to their economic size. We model the financing side of the policy with a lump sum contribution proportional to the weight of the region in the EU GDP. This results in the classification of regions as either net contributors to the policy (47 in total, marked with a (c) in Table 3) or net beneficiaries (42 in total, marked with a (r) in Table 3). Regarding the financing of the policies, we prefer to avoid the negative supply-side effects associated with an increase in the income tax rate, which, in combination with the variety of shocks implemented, can make the interpretation of the results unnecessarily complex. Therefore, the policy shocks are financed by a non-distortionary tax, which implies a reduction in household income in all regions relative to their GDP.

As Table 3 shows, ERDF and CF resources tend to be invested in the low-income regions of the EU (see also Figure A1 in the Appendix) and can be substantial for some countries and regions, reaching up to 3.4% of annual GDP.[8] On average, regions receive funding equivalent to 0.58% of their GDP over the period of implementation, with a median value of 0.10%. This reflects the fact that the more developed regions of the EU receive less funding (although they contribute more to the financing of the interventions — and are therefore net contributors), while most of the expenditure is concentrated in the less developed regions (which are also net beneficiaries, since they only finance the policy in proportion to their weight in GDP in the EU).

For monitoring purposes, cohesion policy interventions are classified into 123 expenditure categories (European-Union, 2014). To introduce ERDF and CF interventions into the model, the different expenditure categories are associated with specific shocks that trigger the relevant economic mechanisms behind the effects of ERDF and CF interventions. These can be broadly classified into three policy channels: public infrastructure investment, direct subsidies to private investment and current government expenditure.

Expenditure categories related to infrastructure investments that have the nature of public goods, such as transport infrastructure, electricity network improvements, water treatment or waste management, are modelled as public investment ($Publ\_Inv$). These

[6] We acknowledge that different sectors and regions may have different levels of product differentiation and elasticities, but estimating industry-region specific parameters for each sector in our analysis would be challenging and beyond the scope of our study.

[7] Outermost regions are not included in the model due to lack of data for these regions.

[8] The national shares of the ERDF and CF have been regionalised in proportion to the regional population.

Table 3
EU Cohesion Policy expenditure 2014–2020, EU NUTS1 regions.

Region	Yearly cohesion policy expenditure	2014–2020 cohesion policy expenditure		Region	Yearly cohesion policy expenditure	2014–2020 cohesion policy expenditure	
	per capita (Euro)	Million (Euro)	% GDP yearly average		per capita (Euro)	Million (Euro)	% GDP yearly average
AT1 (c)	10.65	388	0.03%	FR5 (c)	10.73	934	0.04%
AT2 (c)	9.21	163	0.03%	FR6 (c)	13.86	972	0.05%
AT3 (c)	8.82	268	0.02%	FR7 (c)	9.79	759	0.03%
BE1 (c)	9.18	107	0.02%	FR8 (c)	11.48	919	0.04%
BE2 (c)	5.77	369	0.02%	HR0 (r)	165.82	7068	1.66%
BE3 (c)	21.45	767	0.09%	HU1 (r)	69.55	2055	0.44%
BG3 (r)	83.06	3068	1.90%	HU2 (r)	216.36	6459	2.48%
BG4 (r)	81.64	2932	1.17%	HU3 (r)	214.05	8497	3.44%
CY0 (r)	67.69	586	0.34%	IE0 (c)	12.18	561	0.03%
CZ0 (r)	176.21	18 531	1.21%	ITC (c)	10.42	1652	0.03%
DE1 (c)	3.90	412	0.01%	ITF (r)	85.83	11 999	0.52%
DE2 (c)	5.28	661	0.01%	ITG (r)	85.11	5652	0.51%
DE3 (c)	19.71	665	0.06%	ITH (c)	9.83	1132	0.03%
DE4 (c)	37.79	926	0.14%	ITI (c)	12.19	1424	0.04%
DE5 (c)	16.95	111	0.04%	LT0 (r)	189.61	5635	1.67%
DE6 (c)	4.14	72	0.01%	LU0 (c)	5.64	30	0.01%
DE7 (c)	4.52	272	0.01%	LV0 (r)	189.55	3836	1.69%
DE8 (r)	64.47	1032	0.30%	MT0 (r)	141.48	598	0.81%
DE9 (c)	9.98	776	0.03%	NL1 (c)	7.70	132	0.02%
DEA (c)	7.89	1385	0.02%	NL2 (c)	4.80	171	0.02%
DEB (c)	6.45	257	0.02%	NL3 (c)	3.56	282	0.01%
DEC (c)	16.71	166	0.05%	NL4 (c)	5.87	211	0.02%
DED (r)	54.56	2210	0.22%	PL1 (r)	55.91	4354	1.82%
DEE (r)	64.75	1463	0.28%	PL2 (r)	243.94	19 214	1.14%
DEF (c)	11.51	323	0.04%	PL3 (r)	210.48	14 012	2.93%
DEG (r)	55.26	1199	0.24%	PL4 (r)	169.00	10 382	1.70%
DK0 (c)	6.38	357	0.01%	PL5 (r)	172.29	6618	1.58%
EE0 (r)	225.32	2975	1.57%	PL6 (r)	184.60	10 629	2.12%
EL3 (r)	126.80	4961	1.14%	PT1 (r)	125.86	12 556	0.78%
EL4 (r)	236.91	2758	0.91%	PT2 (r)	388.62	962	2.60%
EL5 (r)	87.50	2754	0.31%	PT3 (r)	112.99	297	0.69%
EL6 (r)	44.73	1243	0.75%	RO1 (r)	92.15	4565	1.50%
ES1 (r)	39.70	1755	0.21%	RO2 (r)	97.46	5655	1.87%
ES2 (c)	21.06	942	0.08%	RO3 (r)	78.11	4210	0.77%
ES3 (c)	15.50	994	0.05%	RO4 (r)	95.01	3680	1.55%
ES4 (r)	59.19	3382	0.33%	SE1 (c)	6.06	225	0.01%
ES5 (c)	23.51	3192	0.10%	SE2 (c)	8.99	372	0.02%
ES6 (r)	71.45	7161	0.45%	SE3 (c)	36.73	626	0.10%
ES7 (r)	67.63	1424	0.37%	SI0 (r)	115.79	2384	0.67%
FI1 (c)	8.38	227	0.04%	SK0 (r)	217.70	11 780	1.61%
FI2 (c)	24.77	672	0.05%	UKC-K (c)	2.49	4245	0.03%
FR1 (c)	1.64	197	0.00%	UKL (r)	47.72	1467	0.23%
FR2 (c)	13.00	1405	0.05%	UKM (c)	10.63	564	0.04%
FR3 (c)	19.62	797	0.08%	UKN (c)	26.90	490	0.12%
FR4 (c)	13.31	717	0.05%				

categories of expenditure directly increase the stock of public capital, which enters the production function as an unpaid factor subject to congestion. At the aggregate level, about 60% of ERDF and CF expenditure is modelled as public investment.

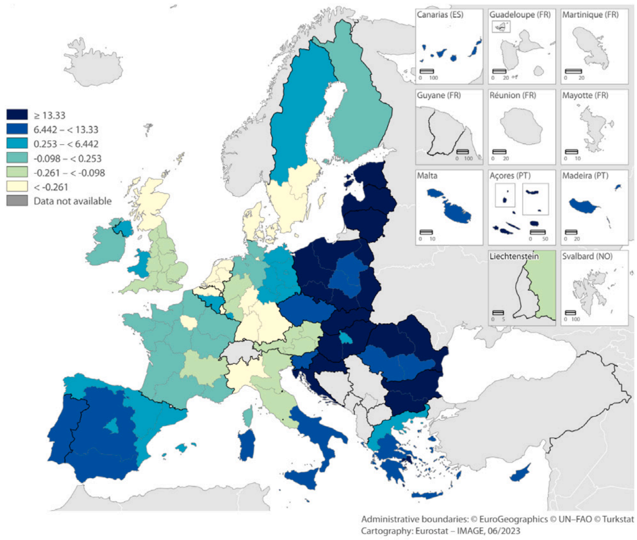
The categories related to aid to the private sector ($Priv\_Inv$) directly increase private investment, thereby adding to the stock of private capital. These categories account for more than 20% of the aid considered here. All other expenditure not related to infrastructure or industrial processes is modelled as an increase in current public expenditure to take account of the purchase of goods and services associated with the interventions, with no supply side effects. About 20% of ERDF and CF expenditure is modelled as a shock to public current expenditure (Gov_Cons), with purely short-lived demand-side effects.

The mapping of ERDF and CF expenditure categories to the model shocks reported in Table A1 of the Appendix determines the policy mix applied to the NUTS 1 regions of the model. In addition, Figure A2 in the Appendix shows the time profile of these exogenous shocks that generate the response of the endogenous variables described here in the main text.

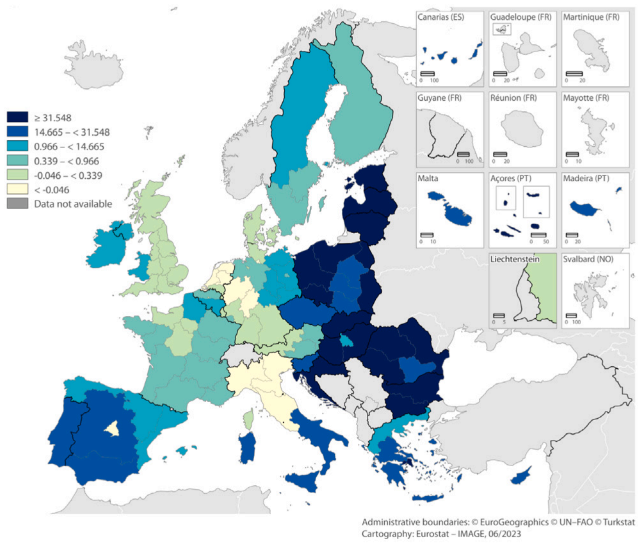
5. The system-wide impact of the European regional policy

5.1. The general equilibrium impact of European regional policy

In this section, we report the results of the simulation of the ERDF and CF interventions using the policy channels identified above. Unless otherwise stated, the results are expressed in terms of deviations from the baseline scenario in which no exogenous



(a) 2023



(b) 2033

Fig. 1. Cumulative GDP changes – Forward-looking agents – Notice that the scale (and colour coding) of the positive values of panel (b) differs from that of panel (a). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

growth or other exogenous factors are at work. This allows us to interpret the results as being solely due to the policy injections. All shocks are temporary and the model is run forward for 60 periods to ensure a full adjustment to the new steady state and to capture potential long-run effects.[9]

[9] Choosing either 50, 70 or 80 periods instead does not affect the results (results available upon request and not reported for the sake of brevity).

We focus first on the system-wide economic impact, summarised by the cumulative changes in GDP at horizon T, calculated as the percentage deviation between the cumulative change in GDP and the base year GDP as in Eq. (40):

$$M_1 = \sum_{t=0}^{T} \frac{GDP_t}{GDP_{t=0}} - 1 \tag{40}$$

The changes in cumulative GDP are calculated for two different time horizons T, until $T = 2023$ and until $T = 2033$. i.e. 10 years after the start of the implementation period and 10 years after the end of the policy injection, in order to measure the impact of the policy in the long run and its corresponding legacy effects.

Fig. 1 shows the percentage deviation in GDP, calculated according to Eq. (40), for each region in 2023 (panel a) and ten years later, in 2033 (panel b). Eastern European regions (all net beneficiaries) experience positive impacts on GDP from the ERDF and CF investments. The cumulative changes in GDP by 2023 are as high as 20%, as for example in some regions of Poland and Hungary. The impact is also particularly large in southern Europe, especially in some regions of southern Spain, southern Italy and Portugal. Net contributor regions benefit less than net beneficiaries due to the fact that in the short term these regions bear a large share of the costs of the policy while receiving little funding. In 2023, there are 33 regions with negative cumulative changes in GDP out of the 47 net contributors. However, the largest negative impact is recorded for the region Île-de-France, with only −0.47%. In 2033, most of the regions end up benefiting from the policy (the cumulative change in GDP up to that year is negative in only 12 regions). This is explained both by the impact of the interventions there, which gradually offset the negative impact of the contribution needed to finance the policy, and by the positive spill-over effects of the interventions in the main beneficiary regions, where investments stimulate imports from the other regions of the EU (as suggested by the analysis of Crucitti et al., 2023).

The combination of the supply-side effects in the beneficiary regions and the lower household demand due to the lump-sum contribution exerts downward pressure on prices. The fall in prices is then transmitted to the net contributors through lower import prices. It is therefore not surprising that clusters of net contributor regions with strong trade links to some of the main beneficiaries ultimately benefit from the policy. These are mainly German regions that benefit from spillovers from eastern regions, where a large share of cohesion policy investment takes place.[10]

In contrast, some western European regions distant from the main beneficiaries (in the Netherlands, Germany, northern Italy and France) show negative cumulative effects even 10 years after the end of the policy shock. These regions contribute significantly to the financing of the policy, with a negative net injection that is not fully offset by positive spillovers and the impact of their own programmes.

The changes in GDP shown in Fig. 1 suggest that the impact of ERDF and CF interventions is beneficial for regional economic convergence. The change in the Theil index, calculated with the regional GDP per capita obtained in the simulation, confirms this intuition. Our results indicate that this measure of regional disparities decreases by 1% in 2023 thanks to the policy interventions. The existence of spillovers from the targeted less developed regions to the more developed ones prevents the reduction from being greater. As cohesion policy investments – notably in infrastructure and business support – improve overall economic connectivity and market integration, some of the benefits spill over beyond the targeted beneficiary regions. This highlights the need for complementary policies to further enhance the redistribution of economic gains and ensure that spillovers do not counteract the intended objective of reducing disparities.

5.2. Regional adjustment

The response and adjustment to policy shocks vary across regions, particularly between net contributor and net beneficiary regions. To improve our understanding of the main mechanisms at work in individual regions, we report in Table 4 the behaviour of some key variables at three critical points in time (the beginning and end of the implementation period, i.e. 2014 and 2023, and ten years thereafter) for a Polish region targeted by cohesion policy (Południowy - PL2), and for a Belgian region that is a net contributor to the policy (Flanders - BE2). Południowy receives a substantial amount of net investment relative to its GDP, on average around 1.14% per year, while Flanders receives little transfer from the EU, 0.16%, despite contributing to the overall policy package in the order of 0.17% per year of its GDP.

The responses of GDP and employment differ between the two regions not only in terms of magnitude but also in terms of the dynamic response to the shock. Given the size of the policy intervention and the relatively low contribution of the region to the financing of the policy, the economic impact is particularly large in Południowy throughout the implementation period. At the end of the period, GDP and employment are 2.35% and 0.64% above their steady state values, respectively. On the contrary, the economic impact in Flanders is almost zero in the first period, while GDP and employment in 2023 remain about 0.02% and 0.01% lower than in the base year. This reflects the large share of costs borne by Flanders for the benefit of other EU regions. When the excess costs of the policy outweigh its benefits in 2023, ten years after the end of the interventions, the impact of the policy in Flanders becomes positive. This positive impact in Flanders results from the positive spillovers generated by the positive long-term effects in the main beneficiary countries. In these regions, production is still higher than in the initial steady state after the shocks have ended, which increases the demand for inputs that have to be purchased from other regions. In Południowy, imports from the rest of the EU increase, as imports from the ROW fall by more than the total change in imports (including the ROW), thus

[10] These findings are consistent with those of Persyn et al. (2023), who find that cohesion policy investment in transport infrastructure benefits German regions close to the borders of the targeted regions.

Table 4
Key macroeconomic variables deviations from baseline in PL2 and BE2.

Key variables	PL2			BE2		
	2014	2023	2033	2014	2023	2033
GDP	0.06	2.35	1.34	0.00	−0.02	0.11
Employment	0.16	0.64	0.34	0.0	−0.01	0.05
Output price	0.54	−2.08	−1.17	0.07	−0.36	−0.33
Exports Tot.	−0.51	4.07	2.43	−0.04	0.23	0.36
Exports ROW.	−2.13	9.17	5.50	−0.28	1.43	1.34
Imports Tot.	0.76	−0.58	−0.33	0.01	−0.04	−0.06
Imports ROW.	1.48	−4.45	−2.90	0.27	−1.49	−1.23
Investment	0.97	0.47	0.31	−0.11	0.30	0.25
Hh. cons.	0.45	−1.73	−0.97	0.06	−0.30	−0.28
Fin. W	0.45	−0.08	0.05	0.84	−1.99	−2.34
Non-Fin. W.	−0.03	−0.43	−0.22	−0.21	−0.17	−0.09

stimulating production in the non-beneficiary regions.[11] The other source of spillovers to non-beneficiary regions is cheaper imports from regions where supply-side effects are stronger.

At the beginning of the implementation period, prices rise in both regions due to capacity constraints, reflecting the delayed adjustment response of firms to the shock. By the final disbursement, prices are below baseline levels, leading to increased competitiveness in both regions and an improved trade balance. Private investment decreases in the short run in the Flemish region, while in Południowy it increases throughout the implementation period and beyond thanks to the substantial policy injection.

The decline in household consumption is larger in the Polish regions than in the Flemish region in 2023 and 2033. This is due to the forward-looking behaviour of consumers and thus to the different intertemporal substitutions induced by the shock in these regions. In Flanders, households use part of their wealth to maintain a certain level of consumption, especially after 2023, more than in the Polish region. This effect would disappear if household consumption responded only to current income levels, neglecting the possibility of using previously accumulated wealth.

5.3. Disaggregating the policy shock: demand-side vs. supply-side effects

The results presented so far are those from the simulation of the full policy package. We now examine the results obtained for each shock separately, as the extent to which each type of policy intervention contributes to the overall impact is likely to differ not only in magnitude but also in terms of transmission mechanisms and adjustments. Typically, we would expect a larger and more long-lasting impact from policies with a strong and direct supply-side effect.

We report the results obtained by simulating the three categories of shocks separately in Table 5 by showing the main distributional characteristics of the regional cumulative GDP multipliers at $T = 2023$ and $T = 2033$ (10 and 20 years after the start of the implementation period, respectively), calculated as the ratio between the cumulative change in GDP and the cumulative policy expenditure shock ExS, as in Eq. (41):

$$M_2 = \frac{\sum_{t=0}^{T} \Delta GDP_t}{\sum_{t=0}^{T} \Delta ExS_t} \tag{41}$$

The private and public investment shocks generate the largest average and median multipliers in the short and long run. This is not a surprising result given that both shocks directly increase the capital stock. Private investment shocks generate larger multiplier effects than public investment shocks on average due to the congestion effect associated with the public capital stock. The congestion parameter is set at 0.5, which is sufficient to dampen the impact of public investment, but not so high as to completely offset its positive effect on the productivity of the factors of production.

The small impact of a temporary increase in government consumption reflects the demand-side nature of this shock. The moments reported in Table 5 suggest that the multiplier at the 25th percentile is negative until 2033. This implies that there is a group of a few regions that experience negative multipliers 10 years after the end of the shock, putting downward pressure on the overall EU multiplier. Forward-looking investors anticipate the temporary nature of the shock and immediately internalise the full cost of the policy, especially in the net contributor regions, which have to pay more to finance the overall investment. This mitigates the legacy effects of a purely demand-side shock, such as an increase in government current expenditure.

The Appendix provides additional results on the full dynamics of the responses of some key macroeconomic variables at the EU level to the individual shocks, highlighting the short-lived nature of demand-side interventions (e.g. public current expenditure) and the more persistent impact of supply-side measures (e.g. public infrastructure investment and private sector support).

[11] EU firms are more competitive than ROW firms after the shock — the assumption is that there is no policy response in the ROW.

Table 5
Distribution of cumulative GDP multipliers in 2023 and 2033, shock by shock.

Key moments	Gov_Cons		Publ_Inv.		Priv_Inv	
	2023	2033	2023	2033	2023	2033
Average	0.35	0.42	1.36	3.66	1.67	3.71
Std. dev.	0.57	1.14	1.58	2.73	1.61	3.26
25th perc.	0.01	−0.17	0.06	2.59	0.84	2.17
Median	0.18	0.19	1.08	3.08	1.12	2.69
75th perc.	0.33	0.37	1.45	4.64	1.40	3.24

6. Do expectations matter?

6.1. The myopic variant

So far, we have assumed that consumers and investors are rational and have perfect foresight. In this section, we examine whether an alternative model of agents' expectations changes the responses to the same policy shocks. We assume that myopic agents form their expectations about future events based on what has happened in the past (have adaptive expectations). This implies that consumers respond only to changes in current income and that they do not smooth consumption using part of their accumulated wealth. Investors are modelled using a flexible accelerator model in which the level of investment from period to period is determined by the gap between the desired and the actual levels of capital. Thus, while forward-looking agents know that the shock is temporary and react accordingly from the beginning of the period, myopic agents, perceive the shock as permanent until the period after it has ended, forcing them to adjust from then on. They also react to the shock only when it occurs. The mathematical description of this alternative version of the model is given in the Appendix.

The purpose of this section is then to test whether different agents' expectations have an impact on the results. A model with myopic agents is less computationally demanding because it can be solved using recursive dynamic programming, whereas a full forward-looking model must be solved simultaneously for all periods considered in the simulation. We therefore assess the extent to which investment in greater computational capacity is worthwhile and leads to significant improvements in modelling results. This analysis is related to the literature on the role of rational versus adaptive expectations in policy assessment (e.g., Mankiw and Reis, 2002). The existing evidence suggests that rational expectations allow agents to efficiently anticipate policy effects, while adaptive expectations often lead to delayed responses and different adjustment dynamics (Gali and Gertler, 1999). Using both expectation mechanisms in our analysis contributes to the existing research on the implications of expectation formation in macroeconomic models (Branch and Evans, 2006).

6.2. Differences between the results of the two models

Fig. 2 shows the behaviour of key macroeconomic variables at the aggregate EU and UK level obtained with the perfect foresight (red lines) and myopic (blue lines) versions of the model. The top panel shows changes in GDP, imports and exports, while the bottom panel shows changes in private consumption, private investment and employment. The bars in the GDP impact panel represent the full monetary injection as a share of baseline GDP.

With perfect foresight agents, GDP rises steadily over the policy implementation period, reaching a peak of around +0.36% in 2023, close to the end of the implementation period, with a corresponding cumulative change over the first ten years of +2%. In 2033, ten years after the end of the interventions, GDP is still above its baseline value, indicating significant legacy effects that persist beyond the end of the programming period. This reflects the supply-side effects of the policy associated with the increase in private and public capital stocks. In the early years of the implementation period, employment increases more than GDP, suggesting that, at least during this period, there is greater substitution in favour of labour. This is reflected in the change in private investment, which is smaller than that of GDP during the implementation period. This is a feature of the perfect foresight model where investors fully anticipate the shock and start adjusting immediately, thereby limiting the size of their response.

Policy interventions put upward pressure on prices in the first years of implementation due to increased demand. This is accompanied by a loss of competitiveness, reflected in a rise in imports and a fall in exports of goods and services. In the medium and long term, however, the situation is soon reversed as prices fall below their base year value due to the policy-induced supply-side effects. As a result, the EU economy becomes more competitive and exports and imports adjust, leading to an improvement in the trade balance. This in turn drives the long-term impact on GDP, which is still above baseline in 2050.

In the short run, the impact on GDP is larger in the perfect foresight model than in the myopic model because rational agents anticipate the coming policy injections. In the medium to long run, however, the impact is larger in the myopic version because agents do not anticipate the end of the programmes until they actually end. This leads to a greater degree of persistence of the shock on economic activity and hence to larger long-run effects. In the myopic model the shocks implemented in period t are expected by agents to remain in place in period $t + 1$. This amounts to assuming that agents believe that the intervention programmed for a given period will never end until it actually does. On the contrary, forward-looking agents correctly anticipate not only the duration and content of the programmes, but also the nature and magnitude of their impact on the economy. This anticipation effect thus mitigates the legacy effects of cohesion policy.

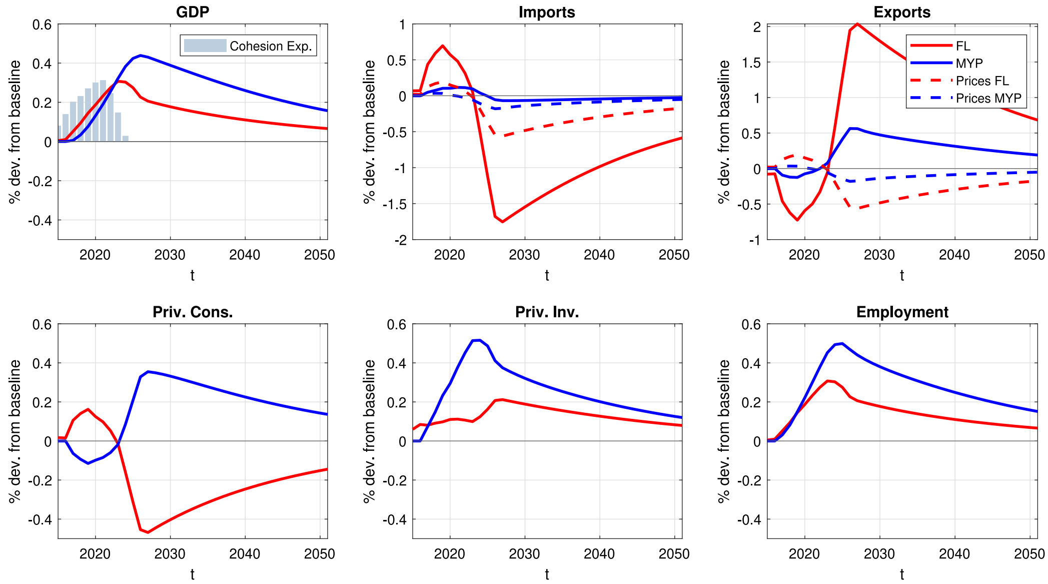


Fig. 2. Selected macroeconomic variables over time, EU+UK level, Forward-looking (red) and Myopic model (blue). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

In the myopic case, the peak impact on GDP is reached one year after the end of the implementation of the shock. Moreover, the GDP curve is already above the lighter blue bars (indicating the policy injections) five years before the end of the shock. This suggests that a break-even point of positive net benefits is reached some time before the end of the policy. However, the multipliers are positive from the start, albeit initially below 1.

The gap between the two GDP responses widens as the policy injection builds up over time. As a result, the transition to the new steady state takes longer, and the knock-on effects of the myopic agents' protracted adjustments generate larger cumulative changes in GDP than the forward-looking counterpart.

There are substantial differences in the responses of household consumption and of the trade balance between the two versions of the model. With perfect foresight, consumption increases in the early years of the policy implementation periods, while myopic households reduce consumption immediately due to the negative impact of lump-sum contributions to finance the policy on disposable income. As for the trade balance, with perfect foresight agents, there is a large reaction on exports and imports, leading to an initial deterioration of the EU trade balance, which then improves from the end of the implementation period. In the myopic case, this is less clear as there is less upward and subsequent downward pressure on prices in these two different periods, and therefore the impact on the trade balance is not as pronounced.[12]

Thus, the way in which agents form expectations about the future can have a significant impact on the size and timing of policy effects and have strong implications for policy evaluation.[13] Of course, the assumptions of myopic versus perfect agents are stylised representations of reality. Most likely, the results obtained under the two alternatives represent the lower and upper bounds of reality where agents are neither completely myopic nor perfectly rational with respect to the nature of the policy and its implications for the future. In a slightly different setting, this has also been observed by Allan et al. (2021) who made different assumptions about how investment decisions are made. Modelling investors with either myopic or heuristically imperfect foresight has a major impact on the simulated results, particularly under temporary shocks.

The aggregate macroeconomic impact of cohesion policy is greater when simulated with myopic agents as opposed to forward-looking agents. Fig. 3 shows the distribution of the differences in the cumulative GDP impact in 2033 obtained with the myopic version of the model compared to the forward-looking one. The map shows that the largest differences are recorded in the net beneficiary regions where the policy injection is significant, i.e. in Eastern and Southern Europe. In these regions, the difference in GDP impact between the two settings can be significant, reaching more than 8% points. This means that the choice of model agents' expectations has a strong incidence on the evaluation of the policy, especially in the regions targeted by the policy.

[12] This implies that there is a different driving source of the legacy effects of the policy in the two model versions. In the perfect foresight model, the legacy effects are driven by past competitiveness gains, while in the myopic case the long-run effects are mainly driven by domestic demand, in particular household consumption.

[13] Additional simulations, not reported here for the sake of brevity, suggest that when an investment policy is simulated as permanent, the GDP impact obtained with forward-looking agents is consistently higher than that obtained with myopic agents, since forward-looking agents understand the full benefits of the policy from the outset.

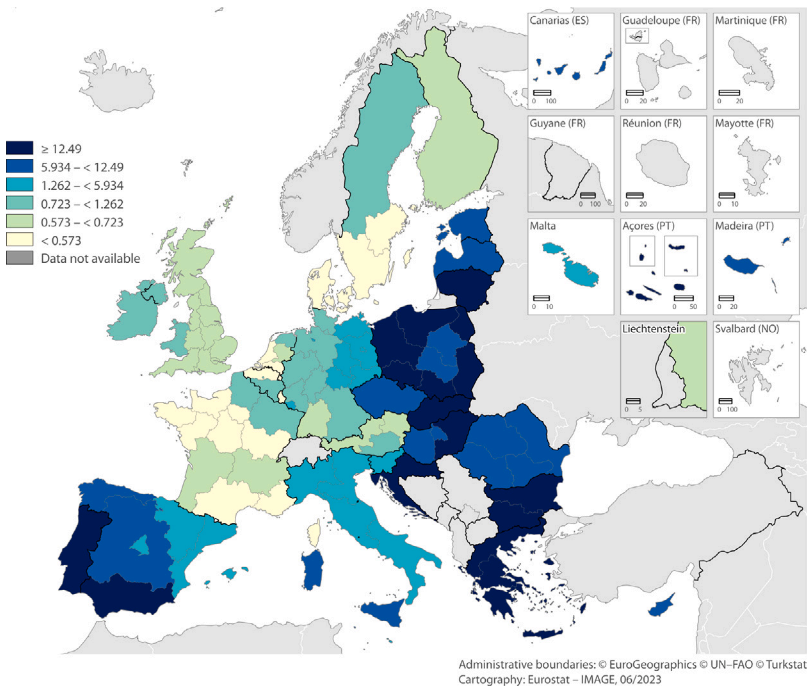


Fig. 3. Myopic vs. forward-looking differences in cumulative GDP impact in 2033 (expressed in percentage points).

7. Conclusion

We develop a spatial dynamic computable general equilibrium model defined over nearly 89 NUTS 1 regions of the EU+UK to analyse the macroeconomic impact of regional investments made through the ERDF and the CF over the period 2014–2020. We quantify the magnitude of the redistributive capacity of place-based policies and their ability to generate spatial spillovers related to trade and capital mobility. Contrary to the standard approach in the literature, we have attempted to identify distinct channels for the different categories of cohesion policy expenditure and to examine the likely long-term effects of the policy in addition to its short-term effects.

We show the results of the counterfactual analysis under two variants of the model. A model that includes forward-looking agents capable of forming expectations about future economic outcomes and a version in which agents are backward-looking and form expectations based only on current and past economic states. We find significant differences between the two settings, demonstrating the usefulness of devoting computational resources to the construction of large-scale spatial models with perfect-foresight agents. The system-wide impact under perfect-foresight agents is typically lower than that predicted by the model with myopic agents. Moreover, the differences between the two types of model are particularly large in regions that are net beneficiaries rather than net contributors.

We disentangle a number of demand-side and supply-side channels in relation to the diversity of expenditure associated with cohesion policy. The analysis shows that supply-side shocks have larger multipliers than pure demand-side shocks, as well as larger and more long-lasting effects than demand-side shocks. The model shows a rapid adjustment to the post-policy equilibrium in the case of demand-side shocks, which limits the legacy effects of the interventions. Our modelling analysis provides valuable insights into the potential macroeconomic impact of regional investment and the effectiveness of cohesion policy, but it is important to interpret the results with caution due to the assumptions and limitations inherent in the models, as shown by the significant impact of the key modelling choice on agents' expectations.

CRediT authorship contribution statement

Francesca Crucitti: Conceptualization, Data curation, Formal analysis, Investigation, Visualization, Writing – original draft, Writing – review & editing. **Patrizio Lecca:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Philippe Monfort:** Conceptualization, Formal analysis, Investigation, Supervision, Validation, Writing – original draft, Writing – review & editing. **Simone Salotti:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing.

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Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.eap.2025.04.036.

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