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Regional general equilibrium modelling with forward-looking agents: an application to the 2014-2020 European structural regional investments

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Abstract

We investigate the effects of the 2014-20 European structural funds with a general equilibrium model calibrated on the NUTS 1 regions of the EU. We assume forward-looking agents to account for expectations and long-lasting effects of the policy. The almost €260 billion of investments lead the European GDP to be 0.3% higher in 2022 than it would be in the absence of the policy. Interestingly, this effect is lower than what a model with myopic agents would suggest. The regional distribution of the differences in the GDP impacts between the two settings indicates that the largest deviations are recorded for the net recipient regions, with interesting implications regarding the policy credibility, the nature of the interventions and their duration.

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1 Introduction

Cohesion policy is the second largest item in the budget of the European Union (EU). The bulk of the policy, about 75% of the funds (almost €260 billion), are channelled through the European Regional Development Fund (ERDF) and the Cohesion Fund (CF), which aim to reduce the disparities in the levels of development between the regions of the Union (European-Commission (2021)). The ERDF focuses on four priority areas: research and innovation (R&I), digital economy, small and medium enterprises (SMEs) competitiveness, and low carbon economy. The CF concentrates on the Member States whose per capita Gross National Income is below 90% of the EU average, and focuses on transport networks and projects falling under EU environmental priorities.

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 evaluations (see, for instance, Fratesi and Wishlade (2017)). The existing, and sometimes contradictory, evidence demonstrates that quantifying the impact of cohesion policy is not a simple task.

Partial equilibrium and reduced form tools like econometric analysis and case studies can shed light on particular aspects of what can be expected from the deployment of these EU structural funds. On the other hand, general equilibrium models, which account for the structural linkages of the economy, are capable of capturing both the direct and indirect impact of the investments. The latter may materialise through, for instance, competitiveness effects and trade, mobility of factors of production, and other economic spillovers. Studies based on general equilibrium modelling can also differentiate the channels through which the various types of interventions included in the cohesion policy package produce their impact.

In general, model-based simulations tend to support a sizable impact of the policy on key macroeconomic variables, especially in the main beneficiary territories. However, due the complexity of this type of analysis, the literature only offers limited contributions, and most of them are based on models calibrated with country-level data (see, for instance, Monfort et al. (2017)), limiting the possibilities to understand fully the impact of cohesion policy, which has a marked regional dimension. An exception is Crucitti et al. (2022a) who use the regional dynamic model RHOMOLO to assess the impact of the 2014-2020 cohesion policy programmes on the EU NUTS 2 regions. The potential impact of the ERDF and the CF has also been assessed by the European-Commission (2018) using both RHOMOLO and a national-level dynamic stochastic general equilibrium (DSGE) model called QUEST. The main behavioral differences between the two models rest on the dynamic properties and the different assumptions behind the agents' expectations. QUEST adopts forward-looking rational expectations, while in RHOMOLO agents are myopic (backward-looking).

The lack of intertemporal substitution in regional economic models used to evaluate regional policies has often been subject to criticism as myopic models may fail to capture dynamic policy gains and, consequently, they could produce inaccurate and possibly incorrect results.

In this paper, we use a spatial dynamic computable general equilibrium model defined over more than 80 NUTS 1 regions of the EU to analyse the macroeconomic impact of the investments financed over the 2014-2020 period by the ERDF and the CF. We compare the results obtained under the assumption of forward-looking agents capable of forming rational expectations, with an alternative version in which agents are myopic and form expectations solely based on current and past states of the economy.

To the best of our knowledge, this analysis constitutes the first evaluation of cohesion policy in an intertemporal spatial general equilibrium modelling framework of this type. We argue that the role played by anticipation is central for assessing the impact of such a policy. The EU cohesion policy is enshrined in a multi-annual financial framework which in practice covers a period of ten years so that the interventions can be credibly anticipated by the economic agents. Consequently, using a model with rational expectations seems well suited to analyse the macroeconomic impact of the policy. Nevertheless, constructing a regional model with forward-looking agents is computationally intensive, and this paper is an attempt to verify whether investing in such development is worthwhile in terms of the quality of the results.

The influence of expectations on the results is a priori unknown. On the one hand, while myopic agents only react to the policy when it is actually implemented, forward-looking agents anticipate the interventions to come. This would lead the impact of the policy to be frontloaded in the response function of the forward-looking agents compared to that of the myopic ones. On the other hand, assuming that agents are myopic implies that the policy is perceived as permanent, rather than temporary. Therefore, the response to the shock may be larger than that of agents who correctly anticipate the duration of the interventions. The difference between the two settings is therefore likely to depend on the parameters affecting expectations, on the magnitude and nature of the policy shock (for example, some types of interventions produce their impact in the long run which is anticipated by forward-looking agents), as well as on the period at which the policy impact is analysed.

The results of the model simulations suggest that, following a policy injection of €260 billion of investments spread across EU regions, the European GDP would be about 0.3% higher in 2022 than it would be in the absence of the policy. Interestingly, the impact of the policy is lower with forward-looking than with myopic agents, unless the intertemporal elasticity of substitution is set at unrealistically high values. The regional distribution of the differences in the results between the two versions of the model suggests that assuming myopic agents lead to especially higher impacts of the policy in the regions which are the main targets of the policy, while differences are smaller in the net contributor regions.

This suggests interesting implications regarding policy credibility and the effects of announcements about the nature of the policy interventions and their duration. Investigating the various types of shocks used to simulate the full policy package yields additional insights on the reaction of the economic agents to demand-side versus supply-side interventions.

The remainder of the paper is organised as follows. Section 2 contains a review of the relevant literature on the assessment of the macroeconomic impact of cohesion policy. Section 3 presents the regional forward-looking model used in the present study, and 4 the model with myopic agents. Section 5 illustrates the data and the modelling strategy adopted for the analysis. Section 6 illustrates the results, and Section 7 concludes.

2 Literature Review

A large and growing body of literature has investigated the cohesion policy's contribution to economic growth and convergence. However, after more than 30 years of policy intervention (in its current form), there is no consensus yet on its economic impact.

The empirical literature has resorted to a number of econometric approaches to estimate the impact of cohesion policy on EU regions and countries, resulting in conflicting evidence depending on the data and methods used. For instance, Cappelen et al. (2003), Beugelsdijk and Eijffinger (2005), and Mohl and Hagen (2010) find a positive impact of regional policy on growth and convergence, while Boldrin and Canova (2001) and Dall'Erba and Le Gallo (2008) suggest that the policy effects on economic growth may be negative, if existing at all. In fact, Mohl and Hagen (2010) conclude that the existing empirical evidence at the time had provided mixed, if not contradictory, results.

A further strand of econometric studies finds that the evidence on the effects of cohesion policy depends on the investigation of specific factors which could affect the relationship between the policy and economic growth, such as the quality of institutions (Rodríguez-Pose and Garcilazo (2015); Bähr (2008); Ederveen et al. (2006)), the regional absorptive capacity (Becker et al. (2013)), and capital endowments (Fratesi and Perucca (2014)). The lack of consensus over the econometric assessment of cohesion policy may be partially due to the approach adopted by most studies on the subject, with Berkowitz et al. (2020) criticising the use of growth regressions which may suffer from potential endogeneity issues. This would be due to the cohesion investments mostly targeting the least developed regions of the EU, and therefore possibly being inversely related to economic growth by policy design.

Recent studies adopting regression discontinuity set ups mostly find positive effects of the policy on GDP, employment and growth, although in many cases they seem short lived. Some notable examples at the EU level include Pellegrini et al. (2013) and Giua (2017), and there exists also additional evidence on specific regions and countries (see, for example, Albanese et al. (2021), and Ciani and De Blasio (2015), on the Southern Italian regions). However, regression discontinuity analyses lack the amount of granularity needed in order to account for the nature of the policy interventions and the economic mechanisms they are likely to trigger.

A major disadvantage of the empirical investigation on this topic is that the results strongly depend on the adopted model specifications and econometric techniques, as well as the underlying data. Despite the lack of consensus on the effectiveness of cohesion policy in terms of GDP and employment impacts, it is still possible to derive an important conclusion from the existing literature: the macroeconomic impact of the policy intervention is territorially heterogeneous and depends on region-specific characteristics.

More consistent results on the potential impact of the European regional policy are offered by the literature based on macroeconomic models. General equilibrium modelling generally assumes that the funds are spent efficiently on all projects, which may not be the case in all countries and regions (a notable exception is constituted by Gianelle et al. (2022)). Moreover, the policy injection is usually measured with the ex-ante allocation of funding across regions and fields of interventions which can depart from the actual expenditure resulting from the programme implementation. Hence, model simulations are to be taken as estimates of the potential impact of the policy provided that the latter is implemented as planned. On the other hand, general equilibrium settings can account for the various transmission mechanisms activated by the multiple types of investments of the policy programmes. Modelling analyses permit to investigate both the direct and the indirect effects of these investments, including spatial spillovers and other induced effects of the policy interventions.

Despite the appeal of modelling-based policy impact assessments, the existing contributions are not numerous. Moreover, macroeconomic models integrating geography elements could be a suitable tool to produce credible estimates of the impact of cohesion policy, but building up a regional general equilibrium model is challenging, mainly due to data availability and computational complexity. That is why most of the existing contributions are based on models which are defined at best at the national level such as GIMF (Allard et al. (2008)), GMR-Europe (Varga et al. (2011)), or QUEST (Varga and in't Veld (2011); and Monfort et al. (2017)). This limits the possibilities to fully understand the impact of a regional policy such as cohesion policy.

Varga and in't Veld (2011) use the QUEST model, which features semi-endogenous growth and endogenous human capital accumulation, to simulate cohesion investments for the programming period 2000–06. The results show significant benefits arising from the implementation of the policy, with important output gains in the long-run mainly driven by productivity increases. The main shortcoming of this analysis lies in the territorial aggregation of the model, as it is defined and calibrated at the level of EU member states (or groups of member states), making it a less than ideal tool for a regional investigation.

The regional dimension of any analysis on cohesion policy is of paramount importance. Even within the same country, EU regions are characterized by high degree of heterogeneity in terms of economic conditions, institutions, and geographical characteristics. Furthermore, there is significant within-country heterogeneity in the distribution of cohesion investments, especially in countries like Italy, Spain or France which are characterised by varying levels of economic development. Obviously, this is reflected in the actual distribution of the cohesion investments: most of the projects financed by the ERDF and CF take place in the less developed regions of the EU, irrespective of the countries they are in. For these reasons, assessing the impact of cohesion policy by assuming homogeneity at the country level may lead to misleading results. Only a regional model calibrated with adequately disaggregated data would be able to take into account both the existing regional heterogeneity, and all the economic mechanisms that are likely to be triggered by place-based interventions such as those of cohesion policy.

As for the existing evidence based on models defined at the regional level, the literature mostly offers case studies and single region analyses. For instance, De la Fuente (2002) assesses the impact of the policy on growth and convergence in the Spanish regions using a supply oriented model estimated with regional panel data covering a period of 30 years. Sosvilla-Rivero et al. (2006) use the HERMIN model to analyse the impact of the structural funds in Castilla la Mancha, while Arcalean et al. (2012) calibrate a two-regions endogenous growth model for Portugal.

An exception is constituted by Crucitti et al. (2022a) who use the RHOMOLO model to assess the impact of the 2014-2020 cohesion policy programmes on all the EU NUTS 2 regions. Their findings suggest a positive impact on the aggregate EU GDP for the entire programming period and beyond, with evidence of long-lasting effects. That same model has been used for more specific cohesion-related analyses on specific countries (see Barbero and Salotti (2021) on Portugal, Crucitti et al. (2021) on Bulgaria, and Crucitti et al. (2022b) on Romania), with a focus on additional aspects such as the existence of interregional spillovers.

One important limitation of the RHOMOLO model lies in its assumption of myopic agents, in contrast with the forward-looking behaviour of DSGE models such as the aforementioned QUEST. The model used by Crucitti et al. (2022a) and Barbero and Salotti (2021) is dynamic, as the simulation periods are linked via capital accumulation through investments, but a myopic behaviour of both firms and households is assumed so that the models are solved recursively, mainly due to the computational complexity which would be implied by employing forward-looking agents capable of forming expectations on the future states of the economy. According to Partridge and Rickman (2010), assuming myopic agents could be considered as a serious shortcoming when analysing the potential impact of a multi-annual development policy. Key assumptions significantly affect the agents' expectations with consequences in terms of consumption smoothing and investments decisions in reaction to the policy implementation.

There are reasons to expect the results obtained with a regional model with forward-looking agents to differ substantially from those obtained with a model featuring myopic agents. For example, Lecca et al. (2013) used a stylized computational macroeconomic model applicable to a regional context to demonstrate that the assumption of myopic vs forward-looking agents yields differences in the dynamics generated by a shock perturbing the initial steady state, even though the alternative paths lead to the same long-run equilibrium.[1]

In this paper we show the importance of accounting for alternative types of agents' expectations when evaluating the impact of regional policies. Economic agents take their decisions using all the information available to them. Hence, when evaluating the impact of cohesion policy (or any other policy), it would be important for models to be flexible in the way economic agents form their expectations about future states of the economy.

We now turn to the illustration of the regional dynamic general equilibrium model with forward-looking agents that we propose here (inspired by the work of Lecca et al. (2013) and Bröcker and Korzhenevych (2013)), and that we use for an assessment of the macroeconomic impact of the European regional structural investments of the ERDF and CF.

3 The dynamic spatial general equilibrium model with forward-looking agents

The model represents a decentralised market economy based on the assumption that producers maximize their profits and consumers maximize the utility derived from their consumption, with market prices adjusting endogenously so to keep supply and demand balanced in all markets.

[1]These results might be driven by the assumption about the households saving decisions of the model. Though agents are fully forward-looking expectation and total saving is endogenous, the households saving rate is exogenous in both specifications of the model.

The domestic economy consists of the $R = 85$ endogenous NUTS 1 regions forming the EU-27 Member States, plus the UK. The set of regions is $R = \{1, 2, \ldots R\}$. Index $r \in R$ is used to refer to a particular region. The rest of the world (ROW) is an exogenous external region.

The model includes the following $I = 3$ NACE rev.2 economic sectors. The set of sectors is $I = \{1, 2, 3\}$, standing for primary, secondary and tertiary. Indices i or $j \in I$ are used to refer to a particular industry.

There are $E = 3$ types of labour skills. The set of skills is $E = \{1, 2, 3\}$, standing for low, medium and high, based on educational attainment. Index $e \in E$ is used to refer to a particular labour skill.

In the model economy, firms operate under a monopolistic competition framework à la Dixit and Stiglitz (1977) in all sectors except for agriculture, in which perfect competition is assumed. [2] In the description of the model, time index t is omitted in non-dynamic equations where not strictly necessary.

3.1 Household

Each region is inhabited by a representative household that earns income from four sources: labour, rental 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, subject to the intertemporal budget constraint.

$$Max \sum_{t=0}^{\infty} (1+\rho)^{-t} \frac{C_{r,t}^{1-\sigma_u} - 1}{1-\sigma_u} \tag{1}$$

s.t.

$$\sum_{t=0}^{\infty} \left(\frac{1}{1+r_t} \right)^t P_{r,t}^c C_{r,t} \leq FW_{r,t} + NFW_{r,t} \tag{2}$$

where ρ is the household's discount factor and σ_u is the intertemporal elasticity of substitution. $P_{r,t}^c$ is the consumer price index and r_t is the interest rate. In the model, r_t is an exogenous variable, the EU is assumed to be a price-taker on the world financial market, which determines the actual level of the interest rate. $FW_{r,t} + NFW_{r,t}$ is household's total wealth, which is given by the sum of non-financial wealth $NFW_{r,t}$ plus financial wealth $FW_{r,t}$. The law of motion of household's non financial wealth is:

[2] The number of firms per sector, a variable needed to model the markets as imperfectly competitive, is taken from the Structural Business Statistics of Eurostat, and it is not available for the agricultural sector.

$$NFW_{r,t}\,(1+r_t) = NFW_{r,t+1} + \sum_e (1-\tau^w_{r,t}) W_{r,e,t} L_{r,e,t} + \Pi_{r,t} + TR_{r,t} - TR^{CF}_{r,t} \tag{3}$$

In each region, the representative household is endowed with a certain amount of each labor skill. $L_{r,e} = (1 - u_{r,e})\,\overline{L}_{r,e}$ is the labor supply, where $\overline{L}_{r,e}$ is the exogenous household labour endowment of skill type e and $u_{r,e}$ is the unemployment rate, which is defined in equilibrium. $W_{r,e}$ is the equilibrium wage, which is region and skill specific and τ^w_r is the tax rate on labor income. The household is also the owner of the firm producing the final good, and Π_r is the profit derived from running the business. TR_r is transfer from the government to the household. $TR^{CF}_{r,t}$ is a negative transfer directly imposed on households, used in the model to take into account the fact that the ERDF and CF expenditures are financed by contributions of each Member State. This specific contribution are proportional to Member States' contributions to the overall EU budget. Hence, each Member State's contribution is assumed to be proportional to its GDP and is introduced in the model as a lump-sum tax. The effect is a decrease in household disposable income, which adversely affects the economic performance and partly offsets the positive impact of the programs.

The law of motion of household financial wealth is:

$$FW_{r,t}\,(1+r_t) = FW_{r,t+1} + \sum_i \psi^k_r N_{r,i,t} K_{r,i,t} rk_{r,i,t} - S_{r,t} \tag{4}$$

In the equation, ψ^k_r is the share of capital rents paid by firms to household, the share and $1-\psi^k_r$ is paid to the government. $rk_{r,i}$ is the return to capital on region r, sector i, $K_{r,i}$ is the private capital stock in the sector. $N_{r,i}$ is the number of firms. In the primary sector, where firms operate in perfect competition $N_{r,i}$ is equal to 1. Finally, S_r is total household's saving. We assume that every period households save a fix rate s_r of their disposable income, such that:

$$S_{r,t} = s_r \left(\sum_i \psi^k_r N_{r,i,t} K_{r,i,t} rk_{r,i,t} + \sum_e (1-\tau^w_{r,t}) W_{r,e,t} L_{r,e,t} + \Pi_{r,t} + TR_{r,t} - TR^{CF}_{r,t} - P^c_{r,t} TR^{RoW}_{r,t} \right) \tag{5}$$

s_r is the exogenous saving rate, and $P^c_{r,t} TR^{RoW}_{r,t}$ are transfer from the region to the ROW.

The following equation is the first order condition of the utility maximization problem, and it gives the household's optimal consumption path.

$$C_{r,t+1} = C_{r,t} \left(\frac{P^c_{r,t+1}}{P^c_{r,t}} \frac{1+\rho_r}{1+r_t} \right)^{-\frac{1}{\sigma_u}} \tag{6}$$

Total consumption C_r is a Constant Elasticity of Substitution (CES) aggregator over good and services from different sectors:

$$C_r = \left(\sum_i \zeta^c_{r,i} c_{r,i}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{7}$$

where $c_{r,i}$ is the amount of consumption of item i, $\zeta^c_{r,i}$ is a share of expenditure parameter and σ^c is the elasticity of substitution across items. Then, consumption is optimally allocated across sectors according to:

$$c_{r,i} = \zeta^c_{r,i} \left(\frac{P^c_r}{P_{r,i}} \right)^{\sigma} C_r \tag{8}$$

The consumption price index P^c_r is obtained through a weighted CES index defined over the Armington price, $P_{r,i}$.

$$P^c_r = \left(\sum_i \zeta^c_{r,i} P_{r,i}^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \tag{9}$$

3.2 Regional Producer

In each sector i, and region r, regional producers choose production inputs in order to maximize profits, subject to the production function. They solve the following problem:

$$\max \Pi_{r,i} = P^Z_{r,i} Z_{r,i} - P^X_{r,i} X_{r,i} - P^Q_{r,i} Q_{r,i}$$

s.t.

$$Z_{r,i} = \left[(\zeta^X_{r,i})^{\frac{1}{\sigma^Z}} (X_{r,i})^{\frac{\sigma^Z-1}{\sigma^Z}} + (\zeta^Q_{r,i})^{\frac{1}{\sigma^Z}} (Q_{r,i})^{\frac{\sigma^Z-1}{\sigma^Z}} \right]^{\frac{\sigma^Z}{\sigma^Z-1}} \tag{10}$$

Total production $Z_{r,i}$ is a CES combination of the value added $Q_{r,i}$ and intermediate inputs $X_{r,i}$, $\zeta^X_{r,i}$ $\zeta^Q_{r,i}$ and are the calibrated shares of intermediate inputs and value added in total production, while σ^Z is the elasticity of substitution.

The composite of intermediate inputs is produced from intermediate inputs from all sectors in the economy, $xs_{r,i,j}$, from the CES combination:

$$X_{r,i} = \left[\sum_j (\zeta^{xs}_{r,i,j})^{\frac{1}{\sigma^X}} (xs_{r,i,j})^{\frac{\sigma^X-1}{\sigma^X_{r,i}}} \right]^{\frac{\sigma^X}{\sigma^X-1}} \tag{11}$$

The parameters $\zeta^{xs}_{r,i,j}$ and σ^X are respectively a share parameter and the elasticity of substitution between intermediate goods.

Value added is obtained by combining capital K with a composite of labour, LD in a CES function, net of fixed costs $\phi_{r,i}^{FC}$. The production of value added is given by:

$$Q_{r,i} = TFP_{r,i} \left(KG_r^d\right)^{\phi} \left[(\zeta_{r,i}^K)^{\frac{1}{\sigma^Q}} (K_{r,i})^{\frac{\sigma^Q - 1}{\sigma^Q}} + (\zeta_{r,i}^L)^{\frac{1}{\sigma^Q}} (LD_{r,i})^{\frac{\sigma^Q - 1}{\sigma^Q}} \right]^{\frac{\sigma^Q}{\sigma^Q - 1}} - \phi_{r,i}^{FC} \quad (12)$$

where $TFP_{r,i}$ represents the conventional Hicks neutral technical change in this production function. $TFP_{r,i}$ follows an AR(1) process, such as:

$$TFP_{r,i,t} = (1 - \theta_r) TFP_{r,i,t=0} + \theta_r TFP_{r,i,t-1} + RD_{r,t} \quad (13)$$

where ψ is the parameter governing the persistence of the AR(1) process and $RD_{r,t}$ is a function of variation of the aggregate capital in the economy, relative to its initial steady state level. Formally, it follows:

$$RD_{r,t} = \varkappa_r \sum_i \left(\frac{K_{r,i,t}}{K_{r,i,t=0}} - 1 \right) \quad (14)$$

where $\varkappa$ is the elasticity of TFP to the variation of capital stock and it captures the region specific propensity to research and development.

Effective public capital, KG^d enters the production function as an unpaid factor of production (Glomm and Ravikumar (1994) and Glomm and Ravikumar (1997)) meaning that all firms, in all sectors, enjoy the same level of public capital at no cost. The parameter ϕ is the value added elasticity to public capital. In Equation 12 the conditions are such that the production function of value added exhibits positive marginal productivity and diminishing returns for all three factors. This function exhibits constant return to scale between private-primary factors of production (K, LD), however, combining them with public capital (K, LD, KG^d) it generates increasing return to scale. Substitution between the two types of primary factors is governed by the elasticity of substitution σ^Q and the share parameter ζ^K and ζ^L.

Labour input is further disaggregated by skills. We distinguish between three types of skills: low, medium and high. The labour composite is produced combining labour of the various skills types in a CES function

$$LD_{r,i} = \left[\sum_e (\zeta_{r,i,e}^{le})^{\frac{1}{\sigma^l}} \left(\Omega_{r,i,e}^l l_{r,i,e} \right)^{\frac{\sigma^l - 1}{\sigma^l}} \right]^{\frac{\sigma^l}{\sigma^l - 1}} \quad (15)$$

where $\Omega_{r,i,e}^l$ is a scale parameter that is used in the model for skills specific labour augmenting technology shocks and $\zeta_{r,i,e}^{le}$ is the share parameter, while σ^l is the elasticity of substitution.

The first order conditions of firm's profit maximization problem give the optimal demand for the X and Q:

$$X_{r,i} = \zeta^X_{r,i} \left(\frac{P^X_{r,i}}{P^Z_{r,i}} \right)^{-\sigma^Z} Z_{r,i} \tag{16}$$

$$Q_{r,i} = \zeta^Q_{r,i} \left(\frac{P^Q_{r,i}}{P^Z_{r,i}} \right)^{-\sigma^Z} Z_{r,i} \tag{17}$$

The optimal demand from sector i for the intermediate good produced in sector j is given by

$$xs_{r,i,j} = \zeta^{xs}_{r,i,j} \left(\frac{P^X_{r,j}}{P_{r,i}} \right)^{-\sigma^X} X_{r,i} \tag{18}$$

Optimal demand for capital and the labour composite is respectively given by

$$K_{r,i} = \frac{\zeta^K_{r,i}}{\left(TFP_{r,i}(KG^d_{r,i})^\phi\right)^{1-\sigma^Q}} \left(\frac{rk_{r,i}}{P^Q_{r,i}} \right)^{-\sigma^Q} Q_{r,i} \tag{19}$$

$$LD_{r,i} = \frac{\zeta^L_{r,i}}{\left(TFP_{r,i}(KG^d_{r,i})^\phi\right)^{1-\sigma^Q}} \left(\frac{W_{r,i}}{P^Q_{r,i}} \right)^{-\sigma^Q} Q_{r,i} \tag{20}$$

where $rk_{r,i}$ and $W_{r,i}$ are respectively the rental price of capital and the wage index for the labour composite.

The demand for labour of skills type e is given by

$$l_{r,i,e} = \frac{\zeta^{le}_{r,i,e}}{\left(\Omega^l_{r,i,e}\right)^{1-\sigma^l}} \left(\frac{W^e_{r,e}}{W_{r,i}} \right)^{-\sigma^l} LD_{r,i} \tag{21}$$

where $W^e_{r,e}$ is the wage rate for each skills type, its dynamic follows the one of the unemployment rate, according to the wage setting equation:

$$W^e_{r,e,t} = a_e - \beta u_{r,e,t} \tag{22}$$

It aggregates over sector according to:

$$W^{1-\sigma^l}_{r,i} = \sum_e \zeta^{le}_{r,i,e} \left(\frac{W^e_{r,e}}{\Omega^l_{r,i,e}} \right)^{1-\sigma^l} \tag{23}$$

3.3 Private investment

In the model, the dynamic path of investment is the result of an inter-temporal program that seeks to maximize the present value of the firms cash flow, subject to the capital low of motion.

$$max \sum_{t=0}^{\infty} \left(\frac{1}{1+r_t}\right)^t \left[rk_{r,i,t}K_{r,i,t} - uck_{r,i,t}I^p_{r,i,t}\left(1+f\left(\frac{I^p_{r,i,t}}{K^p_{r,i,t}}\right)\right)\right] \tag{24}$$

s.t.

$$K^p_{r,i,t+1} = K^p_{r,i,t}\left(1-\delta\right) + I^p_{r,i,t} \tag{25}$$

where $f\left(x\right)$ is the adjustment costs function.

The optimal path [3] is then:

$$\frac{I^p_{r,i,t}}{K^p_{r,i,t}} = \alpha^I + \frac{1}{\beta^I_{r,i,t}}\left(\frac{\lambda_{r,i,t}}{uck_{r,i,t}}\right) \tag{26}$$

where λ it the shadow price of capital:

$$\lambda_{r,i,t}(1+r_t) = rk_{r,i,t} - uck_{r,i,t}\frac{\beta^I_{r,i,t}}{2}\left(\frac{I^p_{r,i,t}}{K^p_{r,i,t}}\right)^2 + \lambda_{r,i,t+1}(1-\delta) \tag{27}$$

where δ is the depreciation rate. According to this formulation the investment capital ration ($\varphi = I^p_{r,i}/K^p_{r,i}$) is a function of the equilibrium rate of return of capital, rk, and the user cost of capital, uck, allowing the capital stock to reach its desired level in a smooth fashion over time.

The user cost of capital, uck, is defined as in Hall and Jorgenson (1967) as a typical no arbitrage condition. Thus, uck is given by

$$uck_{r,i} = \left(r_t + \delta\right)P^I_{EU} + \xi_{r,i} \tag{28}$$

where ξ_r is an exogenous risk premium, and P^I_{EU} the relative price of investment at the EU level. Note that, by having a single investment price, we assume that capital is perfectly mobile across sector and region.

The demand for investments $I^p_{i,r}$ in sector i is transformed to the production of investment goods through the capital matrix $KM_{i,j,r}$.[4] Thus, the demand for investments goods produced by sector i, $I^s_{i,r}$, is given by

$$I^S_{r,i} = \frac{P^I_{EU}}{P_{r,i}}\sum_j KM_{r,i,j}I^p_{r,j} \tag{29}$$

[3] More detail about the dynamic solution can be found in Go (1994), Devarajan (1994), and Lecca et al. (2013)

[4] More details on the construction of the capital matrix can be found in the online Appendix 1.

In turns, the cost of capital in the whole EU P^I_{EU} is defined as the price index over the Armington price weighted by the capital matrix KM:

$$P^I_{EU} = \frac{\sum_j KM_{r,i,j}}{\sum_{r,i,j} KM_{r,i,j}} P_{r,i} \tag{30}$$

3.4 Trade

The specification of multi-regional trade is based on the approach proposed firstly by Armington (1969). Accordingly, in the model goods are distinguished not only by their kind but also by their place of production. Such goods are distinguished from one another in the sense that they are assumed to be imperfect substitutes in demand. Hence, each region $r' inR$ imports goods produced in any other region $rinR$ Such that, in equilibrium, the output of production of sector i in region r, $Z_{r,i}$, must cover the total demand of item i coming from each region, plus the fixed cost of production:

$$P^Z_{r,i} Z_{r,i} = \sum_{r'} P^y_{r,i,r'} y_{r,i,r'} - P^Z_{r,i} \phi^{FC}_{r,i} \tag{31}$$

where $y_{r,i,r'}$ is the optimal quantity of the item i demanded by region r' produced in region r. In turns, we define $Y_{r',i}$ as the market size of good i in region r' or, equivalently, the total regional demand. It is composed by household's and government consumption, private and public investment, and the demand for good used as intermediate input:

$$Y_{r',i} = \sum_r y_{r,i,r'} = \sum_j N_{r',j} xs_{r',i,j} + c_{r',i} + g_{r',i} + I^S_{r',i} + IG_{r',i} \tag{32}$$

The quantity $y_{r,i,r'}$ is the solution of the following problem:

$$\min_{y_{r',i,r}} \sum_r \sum_i \tilde{P}^y_{r',i,r} y_{r',i,r}$$

subject to:

$$Y_{r',i} = \left(\sum_r \sum_i \left[\zeta^y_{r',i,r} \left(1 + \tau^{TR}_{r',i,r}\right) \right]^{\frac{1}{\sigma^y}} y_{r',i,r}^{\frac{\sigma^y - 1}{\sigma^y}} \right)^{\frac{\sigma^y}{\sigma^y - 1}}$$

where $\tilde{P}^y_{r,i,r'} = P^y_{r,i} \left(1 + \tau^{TR}_{r,i,r'}\right) \left(1 + \tau^Z_{r,i}\right)$ is the price applied to the good sold in region r', and $\tau^Z_{r,i}$ is the tax rate paid on production in region r. σ^y is the elasticity of substitution. 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. where $\zeta^{y}_{r',i,r}$ is a bilateral preference parameter and $\tau^{TR}_{r',i,r}$ is the rate of transport cost faced to move the item i from region r to region r'. Transportation costs are modelled as iceberg costs. This means that in order from one unit of a good to arrive to destination r', destination r must ship $1+\tau^{TR}_{r',i,r}$ units.

The first order condition of the problem is:

$$y_{r',i,r} = \zeta^{y}_{r',i,r}\left(1+\tau^{TR}_{r',i,r}\right)\left(\frac{\tilde{P}^{y}_{r',i,r}}{P_{r,i}}\right)^{-\sigma^{y}} Y_{r,i} \tag{33}$$

The market price set by a firm in a monopolistic sector in region r is given by a markup over marginal costs

$$P^{y}_{r,i} = \frac{\sigma^{y}}{\sigma^{y}-1} MC_{r,i} \tag{34}$$

Differently, in perfectly competitive sectors, firms don't have any markup and price simply equals the marginal costs of production.

The price $P_{r,i}$ is defined as a CES price index over the market prices $\tilde{P}^{y}_{r,i,r'}$ (taking into account transport costs $\tau_{r,r',i}$, taxes on import $\tau^{IMP}_{r,r',i}$ and production taxes $\tau^{Z}_{r,r',i}$)

$$P^{1-\sigma^{y}}_{r,i} = \sum_{r'} \zeta^{y}_{r,i,r'}\left(\tilde{P}^{y}_{r,i,r'}\right)^{1-\sigma^{y}} \tag{35}$$

or, equivalently:

$$P^{1-\sigma^{y}}_{r,i} = \sum_{r'} \zeta^{y}_{r,i,r'}\left[\left(1+\tau^{TR}_{r,i,r'}\right)\left(1+\tau^{Z}_{i,r'}\right)\left(1+\tau^{IMP}_{i,r'}\right)P^{y}_{r,i}\right]^{1-\sigma^{y}} \tag{36}$$

3.5 Public sector

Government expenditure comprises of current spending on goods and services $g_{r,i}$, capital expenditures dedicated to the construction of public infrastructure $IG_{r,i}$ and net transfers to households TR_r. Revenues are generated by labour income taxes on household income at the rate of τ^{w}_{r}, indirect taxes on production of goods and services $Z_{r,j}$ and taxes on imports. The government deficit (or surplus) is given by

$$\begin{aligned} B_r = {} & \tau^{w}_{r}\sum_{e} W_{r,e}L_{r,e} + \left(1-\psi^{k}_{r}\right)\sum_{i} N_{r,i}K^{p}_{r,i}rk_{r,i} + \\ & + \sum_{i}\tau^{Z}_{r,i}P^{Z}_{r,i}\left(Z_{r,i}-\phi^{FC}_{r,i}\right) + \sum_{i}\sum_{r}^{\prime}\tau^{IMP}_{r,r',i}\,y_{r,r',i} + \\ & - \sum_{i}\left(g_{r,i}+I^{g}_{r,i}\right) \end{aligned} \tag{37}$$

In our default configuration we assume exogenous government consumption and investment, and no variations in tax rates. Therefore no binding constraint on government budget applies. Across sectors, government consumption is:

$$g_{r,i} = \zeta^G_{r,i} \left(\frac{P^G_r}{P_{r,i}} \right)^{\sigma} \overline{G_r} \tag{38}$$

Similarly, government investments is distributed among sectors as follows:

$$I^g_{r,i} = \zeta^{IG}_{r,i} {I^g}_r \tag{39}$$

Net transfer to households are fixed in real terms, therefore the base year value $\overline{TR}$ is simply augmented to reflect changes in prices

$$TR_r = \overline{TR}_r P^c_r \tag{40}$$

3.6 Public capital accumulation

The model takes into account congestion effects arising from non-publicness of public goods (see e.g., Bergstrom and Goodman (1973); Stiglitz and Rosengard (2015)). Therefore the public capital stock, KG^d is adjusted following a simple model of congestion (see e.g. Edwards (1990) and Fisher and Turnovsky (1998)). The congestion model we use follows the traditional formulation of decreasing marginal congestion. The aggregate public capital service appearing in equation 12 is adjusted for congestion by aggregated value added by the production sector

$$KG^d_r = KG^s_r \left(\sum_i N_{r,i} Q_{r,i} \right)^{\gamma} \quad \gamma = \frac{\eta - 1}{\eta}, \gamma \in (0, -\infty) \quad \eta \in (0, 1) \tag{41}$$

where γ is the congestion parameter. The increase in production reduces the effective quantity of public capital stock enjoyable by all firms and the magnitude of this effect depends on the value of η. When $\eta = 1$ $(\gamma = 0)$ we have the case of a pure public good, which is available equally 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-excludible). If $\eta = 0.5$ $(\gamma = 1)$ public capital still remains non-excludible but loses the property of non-rivalry. The quantity of public services available to a producer declines if value added in the region increases.

The public capital stock accumulates through public investment in infrastructure I^g_r starting from an initial positive capital stock:

$$KG^s_{r,t+1} = (1 - \delta^g) KG^s_{r,t} + I^g_r \tag{42}$$

3.7 Equilibrium

Given the initial factors' endowment $\left[\overline{L}_{r,e}, K^p_{r,i}, KG^s_r\right]$, the equilibrium of the economy is defined for each region r and each sector i, as a set of consumers' decision $[C, S]$, investors' decisions I^p, firms' decision $[Z, Q, X, xs, LD, K, l]$, price vector $[P, rk]$ and a value for unemployment rate $u_{r,e}$ such that:

- In the monopolistic sector $i \in SCI$ the number of firms is pinned down by zero profit condition, revenues equals costs of production:

$$\sum_{r'} P^y_{r,i,r'} y_{r,i,r'} = MC_{r,i} \sum_{r'} y_{r,i,r'} + MC_{r,i}\phi^{FC}_{r,i} \tag{43}$$

  where MC is the marginal cost of production

- The rental rate of capital $rk_{r,i}$ adjusts in order to guarantee private capital market clearing:

$$K^p_{r,i} = N_{r,i}K_{r,i} \tag{44}$$

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

$$\sum_{i} N_{r,i}l_{r,i,e} = (1 - u_{r,e})\,\overline{L}_{r,e} \tag{45}$$

In its default configuration, the model ensures an unconstrained inflow of capital to sustain investment whenever required (this is a typical regional macroeconomic closure), not imposing any constraints on the balance of payments. However, foreign savings from the ROW in the model are passive, hence maintaining equilibrium in the balance of payments.

The calibration of all the main parameters introduced above is presented in the online Appendix 1

4 The Myopic Model

In this section, we highlight the equations that need to be modified in order to obtain a version of the model where all agents, households and firms, are myopic. In this alternative environment, the equations that change are those governing household consumption and firms' investment. In fact, in a myopic world, the following two equations are not the solution of an intertemporal problem. More specifically:

- Eq. 6 becomes:

$$P_r^c C_r \leq (1 - s_r) YC_r \tag{46}$$

where YC_r is the household's disposable income:

$$YC_r = \sum_i \psi_r^k N_{r,i,t} K_{r,i,t} rk_{r,i,t} + \sum_e (1 - \tau_{r,t}^w) W_{r,e,t} L_{r,e,t} + \Pi_{r,t} + TR_{r,t} - TR_{r,t}^{CF} \tag{47}$$

- And eq. 26 becomes:

$$I_{r,i}^p = \delta K_{r,i}^p \left(\frac{rk_{r,i}}{uck_{r,i}} \right) \tag{48}$$

5 Modelling cohesion policy investments

5.1 Cohesion policy funding

We focus on the 2014-2020 programming period whose funds will be deployed over ten years (until 2023, due to the N+3 rule which allows the policy allocations to be spent within three years from the initial investment). The investments simulated in the analysis amount to almost €260 billion, mostly concentrated in the middle six years of the implementation period (on average, 75% of the investments take place between 2016 and 2021, according to the data provided by the European Commission). Table 1 shows the amount of cohesion investments (both total and in per capita terms), as well as the yearly average over the implementation period in % of the 2013 GDP, for each EU NUTS 1 regions[5].

As Table 1 shows, the ERDF and CF resources tend to be invested in the less developed parts of the EU (see also Figure 1 in the online Appendix 2), and for some countries and regions they may be substantial, reaching values as high as 3.4% of annual GDP.[6] On average, the NUTS 1 regions of the EU receive funding worth 0.58% of their GDP on average during the implementation period, with the median value in the distribution being equal to 0.10%. This reflects the fact that the more developed regions of the EU are allocated less of the funding, while most of the expenditures are concentrated in the less developed territories.

5.2 Translating actual expenditures into model shocks

The cohesion policy interventions are classified into 123 spending categories for monitoring purposes (European-Union (2014)). In order to introduce the ERDF and CF

[5]Outermost regions are not incorporated in the model due to the lack of data available for those regions

[6]The national parts of the ERDF and CF funds were regionalised proportionally to the regional population.

Table 1: EU Cohesion Policy expenditure 2014-2020, EU NUTS1 regions

Region	Yearly Cohesion Policy Expenditure per capita (Euro)	2014-2020 Cohesion Policy Expenditure milion (Euro)	2014-2020 Cohesion Policy Expenditure % GDP yearly average	Region	Yearly Cohesion Policy Expenditure per capita (Euro)	2014-2020 Cohesion Policy Expenditure milion (Euro)	2014-2020 Cohesion Policy Expenditure % GDP yearly average
AT1	10.65	388	0.03%	**FR5**	10.73	934	0.04%
AT2	9.21	163	0.03%	**FR6**	13.86	972	0.05%
AT3	8.82	268	0.02%	**FR7**	9.79	759	0.03%
BE1	9.18	107	0.02%	**FR8**	11.48	919	0.04%
BE2	5.77	369	0.02%	**HR0**	165.82	7068	1.66%
BE3	21.45	767	0.09%	**HU1**	69.55	2055	0.44%
BG3	83.06	3068	1.90%	**HU2**	216.36	6459	2.48%
BG4	81.64	2932	1.17%	**HU3**	214.05	8497	3.44%
CY0	67.69	586	0.34%	**IE0**	12.18	561	0.03%
CZ0	176.21	18531	1.21%	**ITC**	10.42	1652	0.03%
DE1	3.90	412	0.01%	**ITF**	85.83	11999	0.52%
DE2	5.28	661	0.01%	**ITG**	85.11	5652	0.51%
DE3	19.71	665	0.06%	**ITH**	9.83	1132	0.03%
DE4	37.79	926	0.14%	**ITI**	12.19	1424	0.04%
DE5	16.95	111	0.04%	**LT0**	189.61	5635	1.67%
DE6	4.14	72	0.01%	**LU0**	5.64	30	0.01%
DE7	4.52	272	0.01%	**LV0**	189.55	3836	1.69%
DE8	64.47	1032	0.30%	**MT0**	141.48	598	0.81%
DE9	9.98	776	0.03%	**NL1**	7.70	132	0.02%
DEA	7.89	1385	0.02%	**NL2**	4.80	171	0.02%
DEB	6.45	257	0.02%	**NL3**	3.56	282	0.01%
DEC	16.71	166	0.05%	**NL4**	5.87	211	0.02%
DED	54.56	2210	0.22%	**PL1**	55.91	4354	1.82%
DEE	64.75	1463	0.28%	**PL2**	243.94	19214	1.14%
DEF	11.51	323	0.04%	**PL3**	210.48	14012	2.93%
DEG	55.26	1199	0.24%	**PL4**	169.00	10382	1.70%
DK0	6.38	357	0.01%	**PL5**	172.29	6618	1.58%
EE0	225.32	2975	1.57%	**PL6**	184.60	10629	2.12%
EL3	126.80	4961	1.14%	**PT1**	125.86	12556	0.78%
EL4	236.91	2758	0.91%	**PT2**	388.62	962	2.60%
EL5	87.50	2754	0.31%	**PT3**	112.99	297	0.69%
EL6	44.73	1243	0.75%	**RO1**	92.15	4565	1.50%
ES1	39.70	1755	0.21%	**RO2**	97.46	5655	1.87%
ES2	21.06	942	0.08%	**RO3**	78.11	4210	0.77%
ES3	15.50	994	0.05%	**RO4**	95.01	3680	1.55%
ES4	59.19	3382	0.33%	**SE1**	6.06	225	0.01%
ES5	23.51	3192	0.10%	**SE2**	8.99	372	0.02%
ES6	71.45	7161	0.45%	**SE3**	36.73	626	0.10%
ES7	67.63	1424	0.37%	**SI0**	115.79	2384	0.67%
FI1	8.38	227	0.04%	**SK0**	217.70	11780	1.61%
FI2	24.77	672	0.05%	**UKC-K**	2.49	4245	0.03%
FR1	1.64	197	0.00%	**UKL**	47.72	1467	0.23%
FR2	13.00	1405	0.05%	**UKM**	10.63	564	0.04%
FR3	19.62	797	0.08%	**UKN**	26.90	490	0.12%
FR4	13.31	717	0.05%				

interventions in the model, the various spending categories are assigned to specific shocks triggering the relevant economic mechanisms behind the effects caused by the ERDF and CF interventions.

These can be broadly distinguished between temporary demand-side shocks and long-lasting supply-side effects with a more permanent impact on the economy.

1. **Transport Infrastructure (Trnsp_Inv)**: Investments in transport infrastructure generate temporary effects through increases in government consumption, accounting for the purchase of goods and services required to build infrastructure. On the supply side, these investments reduce transport costs, leading to an increase in trade flows. The estimated transport costs reductions are calculated using the transport model by Persyn et al. (2022b). Investments in transport infrastructure are assumed not to depreciate, thus leading to a different long run steady state. Overall, almost 22% of the ERDF and CF expenditures are modelled as Trnsp_Inv. Formally:

$$\Delta\overline{G}_r = CP_r^{TR}$$

where $\Delta\overline{G}_r$ is the change in public spending induced by the policy, and CP_r^{TR} is the total amount of funds spent on this category. The change in the transport costs caused by the policy injection is:

$$\Delta\tau_{r,i,r'}^{TR} = \tau_{r,i,r'}^{TR}\left(\xi_{r,i,r'}^{TR} - 1\right) \tag{49}$$

where ξ^{TR} is the transport costs shock, i.e. the estimated reduction in the cost of moving the item i from region r to region r' induced by cohesion policy investments. It is computed as total investment multiplied by a conversion parameter $TR_{r,i,r'}$, which take into account the actual cost of building new roads. $TR_{r,i,r'} < 0$ is calculated using a linear approximation of the transport model by Persyn et al. (2022b) and also explained in Persyn et al. (2022a):

$$\xi_{r,i,r'}^{TR} = CP_r^{TR} TR_{r,i,r'} \tag{50}$$

2. **Other Infrastructure (Publ_Inv)**: The spending categories referring to non-transport infrastructure investments such as for example, electricity networks improvements, water treatment, or waste management, are modelled as public investments. The latter increase demand and also produce a supply-side effect due to the increased stock of public capital which enters the production function as an unpaid factor. The public capital stock depreciates at a yearly rate of 5%. At the EU level, about 33% of the ERDF and CF spending is modelled as Publ_Inv. Formally:

$$\Delta\overline{I^g}_{r,t} = \theta CP_{r,t}^{PubInv} \tag{51}$$

and

$$\Delta\overline{G}_{r,t} = (1-\theta)\, CP_{r,t}^{PubInv} \tag{52}$$

where CP_r^{PubInv} is is the total amount of funds spent on public consumption and θ is the fraction of funds allocated to public capital.

3. **Aid to Private Sector (RPrm_Inv)**: The spending categories related to aid to the private sector increase private investments via a reduction in the risk premium, thereby increasing the stock of private capital, which depreciates every year at a 15% rate. These categories account for more than 20% of the funding considered here. Besides stimulating the production of goods and services, the change in capital stock also affects TFP in the model. The precise relationship in each region depends on the regional research and development intensity (measured as research and development expenditure over GDP, a data retrieved from Eurostat). The idea is that part of the investments, and therefore of the capital stock, are dedicated to research and development and is therefore capable of increasing total factor productivity. The reduction in risk premium is calibrated with the following formula:

$$\Delta\xi_{r,i,t} = -\frac{CP_{r,t}^{RP}}{K_{r,i,t=0}} \tag{53}$$

4. **Public Current Expenditure (Gov_Cons)**: Any other investment not associated to infrastructures or industrial processes is modelled as an increase in public current expenditure to account for purchases of goods and services associated with the transfer of resources, with no supply-side effects. About 25% of the ERDF and CF expenditures are modelled as a public current expenditure shock, with purely short-lived demand side effects.

$$\Delta G_t = CP_t^{Exp} \tag{54}$$

The mapping of the ERDF and CF spending categories into model shocks reported in Table 3 in the online Appendix 2 determines the policy mix applied to the NUTS 1 regions of the model.

6 Results

6.1 A first look at the results

This sub-section reports the results based on a scenario simulating the ERDF and CF investments both on the spending and on the financing side. The policy is financed through lump sum taxation distributed across all EU regions in proportion

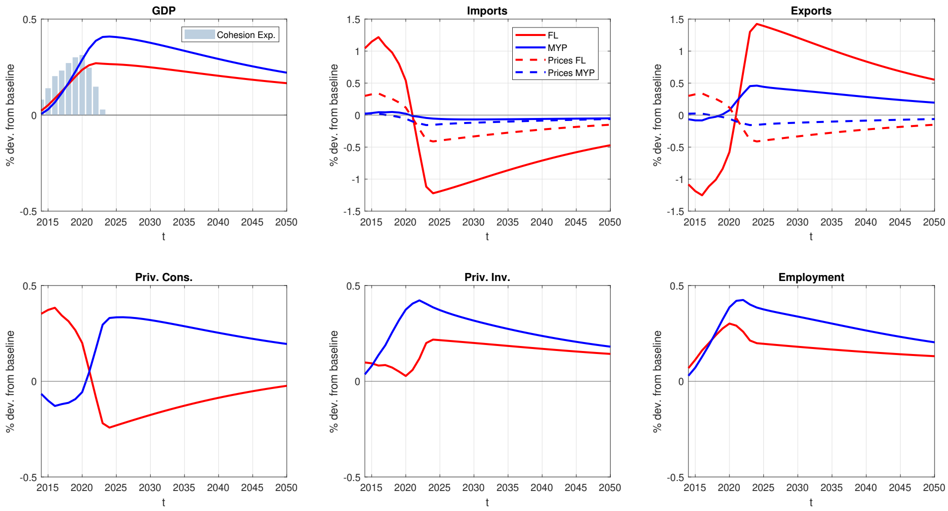


Figure 1: Selected macroeconomic variables over time, EU level, Forward-looking (red) and Myopic model (blue)

to their GDP[7]. Results are expressed as deviations from a baseline scenario in which no exogenous growth or exogenous drivers are assumed, thus allowing to interpret the results as solely resulting from the policy injection. The policy investments (and lump sum transfers used to finance them) last for the first ten years, from 2014 to 2023, while the structural effects remain after the end of the implementation period, albeit decaying in time due to depreciation, as explained in the previous section. The model is run forward for 60 periods so to ensure a smooth adjustment towards the new steady-state and to capture potential long-lasting effects.

Figure 1 shows the behaviour of some key macroeconomic variables at the EU level obtained with the forward-looking (red lines) and myopic (blue lines) version of the model. The bars in the GDP impact panel represent the policy injection with respect to EU GDP.[8]

Under the forward-looking assumption, the EU GDP increases steadily during the policy implementation period to reach a peak of +0.27% in 2022, that is at the end of the deployment of the cohesion investments, with a corresponding cumulated change over the first ten years of +1.68%. In 2033, ten years after the end of the

[7]This reflects the financial mechanisms adopted to contribute to the whole EU budget.

[8]Figure 2 in the online Appendix 2 reports the exogenous shocks that generate the dynamic of the endogenous variables described here in the main text. The different nature of the shocks emerges clearly from the figure . Government current expenditure, public investment and aid to the private sector are transitory shocks and at the end of the implementation period, the economy returns to the initial steady state. Investment in transport infrastructure lowers transport costs permanently and hence lead to another steady state.

interventions, the EU GDP is still +0.24% above its base year value, signalling significant legacy effects that persist well beyond the end of the programming period. This reflect the supply-side effects of the policy stemming from the increase in private and public capital stocks, as well as the endogenous increase in TFP and the permanent reductions in transport costs. Employment reacts in a similar way to GDP, although with a slightly different timing. The maximum deviation from baseline is recorded in 2020, at +0.30%. The policy interventions have a positive effect on prices which increase above their base year value for the first seven years of the simulation, driven by the demand stimulus. This is accompanied by a loss in competitiveness reflected in a rise in imports and a fall in exports of goods and services. However, the situation is reversed soon after the end of the implementation period, when prices go below their base year value by virtue of the policy-induced supply-side effects and structural changes. As a result, the EU economy gains competitiveness, with exports and imports adjustments leading to an improvement in the EU trade balance (with GDP free to increase without any inflationary pressure).

Regarding domestic demand, in the first ten periods, we observe a substantial increase in private investments due to the policy interventions. Afterwards, investments remain above the initial steady-state level, converging slowly to the new long-run equilibrium.

The myopic version of the model provides results which differ in several respects from the forward-looking ones. The impact on GDP is slightly lower during the very first years of the implementation period but soon becomes higher, reaching a higher peak of +0.41% above the baseline in 2024, for a larger cumulated impact over the first ten years of +2.04%. The peak impact on EU employment is also larger than that obtained under forward-looking case, being +0.42% in 2022.[9] As expected, the forward-looking agents anticipate the policy injection to come, and hence react sooner than myopic agents. On the other hand, myopic agents consider the policy as permanent and therefore respond more strongly to the policy shock than the forward-looking agents who rightly perceive it as temporary. The gap between the two responses increases as the policy injection builds up in time. Under the assumption of forward-looking agents, the economy departs less from its new steady-state than when assuming myopic agents. As a result, the transition to the new steady-state takes more time and the knock-on effects of prolonged adjustments of myopic agents generate larger cumulative GDP changes than the forward-looking counterpart.

This shows that anticipation can significantly affect the magnitude and the timing

[9]Interestingly, the GDP impact obtained with the forward-looking version of the model comes closer to the one obtained with the myopic one as the inter-temporal elasticity of substitution increases, as shown in the online Appendix 3 .

of the policy impact. Also, the assumptions selected to formulate expectations have strong implications regarding the assessment of the policy legacy effects. Obviously, the assumptions of myopic versus forward-looking agents with rational expectations are stylised representations of reality. Most probably, the results obtained under the two alternatives constitute the lower and upper bounds of the potential impact, as the real economic agents are neither entirely myopic nor perfectly rational regarding the nature of the policy and its implications of the economy.

Besides the difference in the investments behaviour (investments increase more in the myopic setting), the household consumption response differs substantially between the two settings. Forward-looking agents increase their consumption during the policy implementation period, decrease it afterwards, and then increase it again to reach the new steady-state value which is slightly above the initial one (due to the ever-lasting reduction in transport costs). On the other hand, myopic agents respond with a decrease in consumption during the implementation period driven by the financing of the policy which decreases their current disposable income, but then consumption increases free of the lump sum transfer pressure following the positive GDP impact of the policy interventions.

Another important difference between the two settings is the impact on the trade balance. With forward-looking agents, there is a large impact on exports and imports that results in a substantial deterioration of the EU trade balance in the first period of the policy. Then, a significant improvement of the EU trade balance is recorded, particularly at the end of the implementation period. In the myopic case, this is less clear because of a lower upward/downward pressure on prices in these two distinct periods, and therefore the impact on the trade balance is not as striking.

The results presented so far are those obtained with the full policy package, which is constituted by a mix of demand-side and supply-side interventions. However, the response of economic agents is likely to differ with the type of shock. It is thus worth exploring the results obtained with the various shocks separately. Typically, we would expect a larger and prolonged impact from policy interventions with a strong supply-side effect.

We report the results obtained by simulating separately the four shocks related to the ERDF and CF investments in Table 2 by showing the main distributional characteristics of the regional cumulative discounted GDP multipliers in 2023 and 2033 (10 and 20 years after the start of the implementation period, respectively).[10]

With forward-looking agents, we observe that the transport infrastructure and the public investment shocks generate the largest average and median multipliers.

[10] We define the multipliers as the ratio of the discounted cumulative GDP changes and the discounted cumulative monetary shock. The calculations reported in the table are based on the NUTS 1 regions for which policy investments are above 100 million euros over the entire implementation period (Gov_Cons: 73 regions; Trnsp_Inv: 36 regions; Publ_Inv.: 67 regions; Rprm_Inv: 76 regions).

Table 2: Distribution of cumulative discounted GDP multipliers in 2023 and 2033, shock by shock

	Gov_Cons		Trnsp_Inv		Publ_Inv.		RPrm_Inv	
Forward-Looking	2023	2033	2023	2033	2023	2033	2023	2033
Average	0.35	0.41	1.62	3.04	1.24	2.87	0.47	1.50
Std. dev.	0.76	1.44	4.67	9.37	1.05	1.67	1.06	1.56
25th perc.	-0.02	-0.21	0.42	0.67	0.41	2.07	-0.10	0.80
Median	0.19	0.18	0.59	1.13	1.05	2.31	0.35	0.93
75th perc.	0.32	0.34	0.87	1.52	1.51	3.39	0.47	1.38
Myopic								
Average	0.49	0.62	0.79	1.21	1.91	5.29	1.73	3.48
Std. dev.	1.16	1.48	1.10	5.76	0.81	2.09	1.68	2.67
25th perc.	-0.41	-0.53	0.45	0.79	1.20	3.60	0.85	1.48
Median	0.23	0.31	0.53	1.05	1.59	5.14	1.02	2.46
75th perc.	0.45	0.56	0.67	1.32	2.66	6.44	1.32	4.47

This happens despite the latter being affected by a congestion effect. The congestion parameter in the model is set to 0.5, enough to partially reduce the full potentiality of the public investments but not so high to completely offset the positive effect on the productivity of the factors of production. The multipliers associated with the aid to the private sector shock are particularly low in the forward-looking case due to the behaviour of the agents who perceive the temporary nature of the shock and react differently from the myopic ones. The forward-looking agents invest less, and in some cases reduce their investments, internalizing immediately the total cost of the policy, particularly in the net contributor regions that are called upon to a larger disbursement to finance the overall investments. The high average GDP multiplier of the transport infrastructure investments shock seems to be driven by some high values in the distribution, since the median is actually below the one observed for the public investment shock. The median 2033 multiplier is slightly above one, reflecting the fact that the transport infrastructure shock reduces the costs of bilateral shipping of goods and services, with a direct impact on trade in the first instance (which in our baseline covers around 25% of GDP), while the public investment shock acts directly on the public capital stock in the production function.

The little effects of a temporary increase in government consumption reflect the demand-side nature of the shock. Also, forward-looking agents transit faster to the steady-state which explains the lower values of the GDP multipliers with rational expectations.[11]

Interestingly, we notice a variegate regional distribution of the cumulative GDP across shocks. The standard deviation is large in the case of the transport infrastructure shock, with the median lower than the average suggesting a distribution skewed to the right. There is a lower dispersion or variability across regions following shocks to public investments and to the risk premium.

Things are different in the myopic case, according to which the largest average multipliers are associated with the public investment shock, followed by the aid to private sector shock. It appears that myopic agents react in a more decisive way to the public investment shock, possibly not realizing its temporary nature (the same goes for the current public expenditure shock). On the other hand, the GDP multipliers of the transport infrastructure shocks are lower than with forward-looking agents, as the latter immediately realize the permanent nature of the decrease in transportation costs, leading to a stronger reaction. The online Appendix 4 reports the full dynamics of the responses of some key macroeconomic variables at the EU level of the single shock simulations.

6.2 Additional regional insights

The results presented so far suggest significant heterogeneity across regions. Figure 2 shows the cumulative discounted multipliers calculated in each region in 2023 (panel a) and ten years after the end of the policy injection, in 2033 (panel b), in a forward-looking setting. These results highlight a specific pattern in the effects of the investments, suggesting that Southern and Eastern EU regions benefit substantially from the policy. Most of them are net beneficiary regions where the multipliers are larger than 1, or close to 1, already ten years after the beginning of the policy shock. The multipliers are particularly high, for instance, for all the regions of Spain except the capital region, and all the regions of Portugal. The rest of the regions mainly targeted by the policy present GDP discounted multiplier slightly below 1 in 2023, for example in Greece and in the South of Italy.

The net contributor regions for the most part benefit less than the net beneficiaries in terms of GDP impact and multipliers. This is partly due to the fact that in the short run, these regions bear a large share of the cost of the policy while receiving little funds. However, in the medium to long run, most of them end up benefiting from the policy. By 2033, most multipliers are positive and larger than 1 (or close to 1). This is partly explained by the strong positive spillover effects generated by the interventions in the main beneficiaries which account for most of the total GDP impact

[11] Note that regions do not have to repay via lump sum transfers the same quantity they get in terms of increased government consumption, so positive (negative) reactions should be expected in net receiver (contributor) regions.

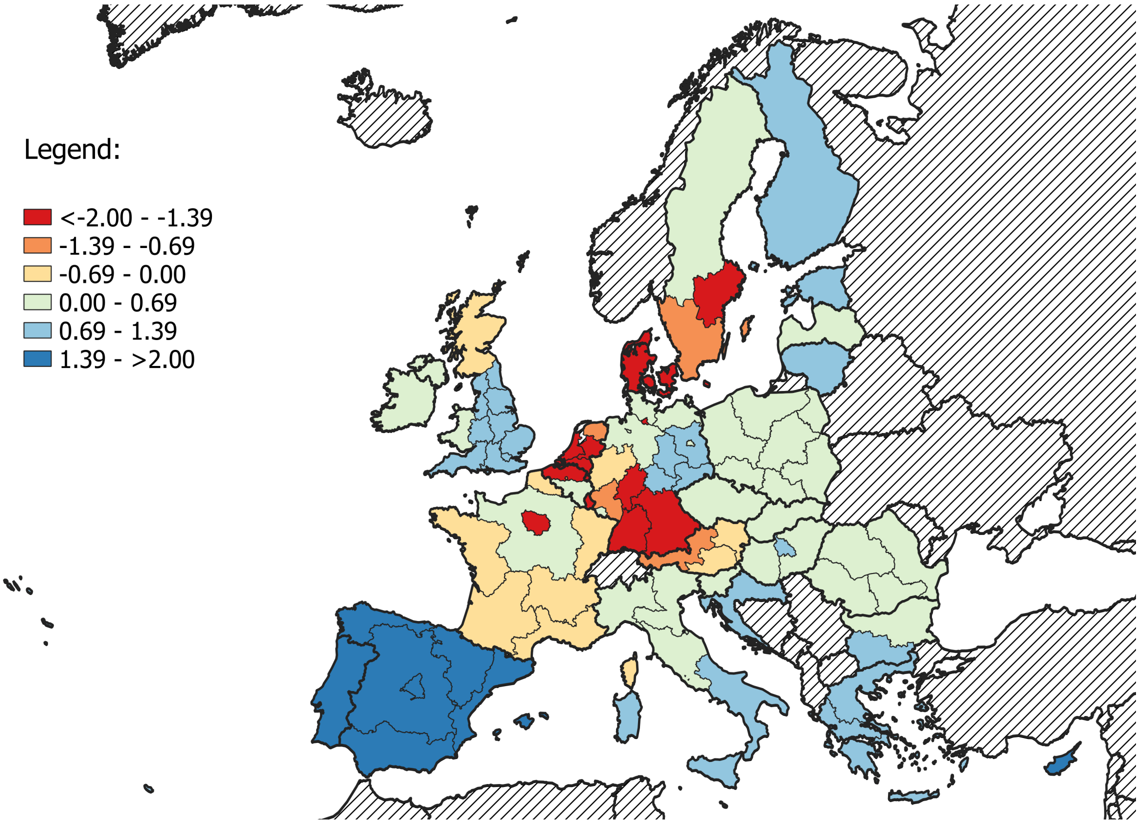
of the policy in some net contributor regions. In particular, the boost in economic activity triggered by the interventions in the main beneficiaries increase exports of the main contributors to these regions. Thus, it is not a surprise to see clusters of net contributor regions having strong trade links with some main beneficiaries ending up significantly benefiting from the policy. These are principally German regions that enjoy spillovers from the Eastern EU regions where a large share of investments of cohesion policy takes place. In contrast, central regions not in the proximity of main beneficiary regions report negative cumulative multipliers effects. These regions are contributing significantly to the financing of the policy, with a negative net injection (the difference between the allocated cohesion policy funds and the direct contribution to the budget) which is not counteracted by positive spillovers. Figure 2b suggests that 10 years after the end of the implementation period, almost all the EU regions report a positive GDP cumulative multiplier.[12]

We already mentioned that the impact of the policy is larger when simulated with myopic agents, as opposed to forward-looking ones. It is of interest to show in which regions the gap between the two setting is the largest. Figure 3 shows the distribution of the differences in the discounted cumulative GDP impact in 2033 obtained with the myopic version of the model versus the forward-looking one. According to the map, the highest differences are recorded in the net beneficiary regions where the policy injection is the most significant, that is in Eastern and Southern Europe. In these places, the difference in GDP impact between the two settings can be significant, reaching more than ten percentage points in Greece, Croatia, Estonia, and in some regions of Portugal and Poland. This means that the choice regarding the model agents' anticipation has a strong incidence on the assessment of the policy, particularly in regions where it matters the most.

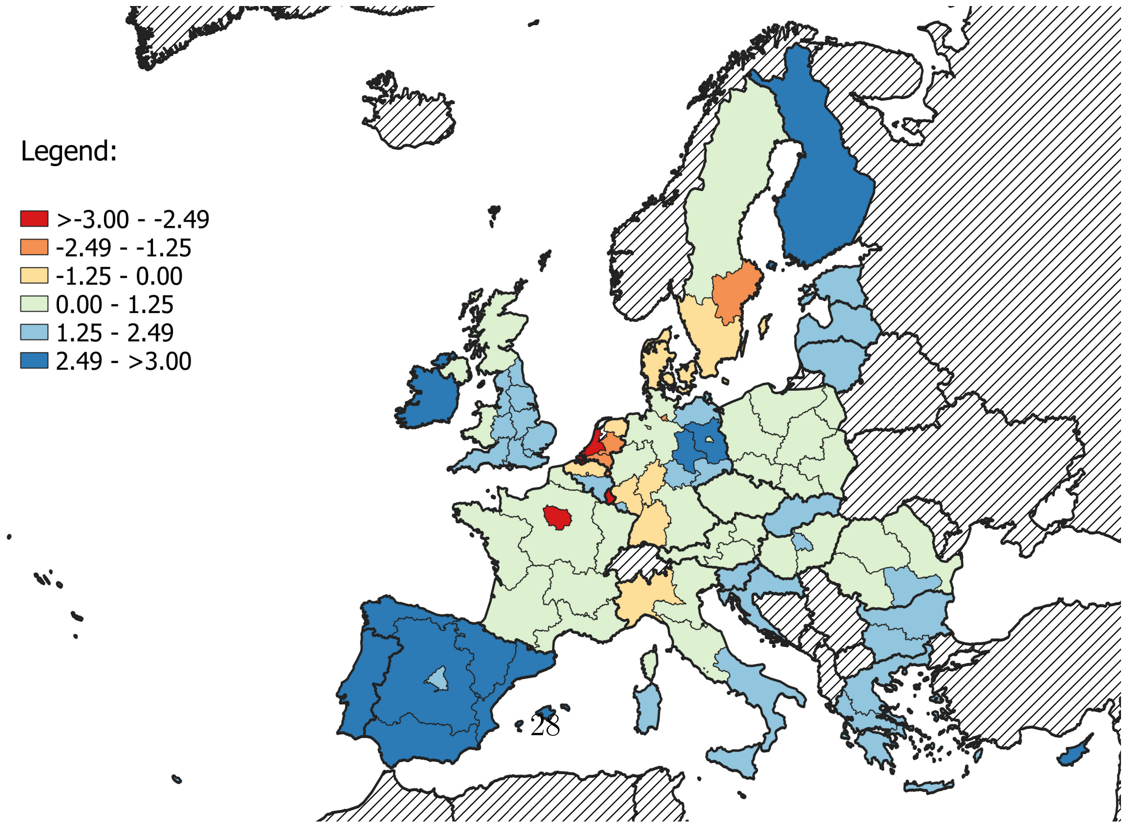
The response and the adjustment to the policy shocks vary from on region to another, especially between net contributor and net beneficiary regions. For both the myopic version and the forward-looking one, Table 3 reports the behaviour of some key variables at three critical points in time (beginning and end of the implementation period, that is 2014 and 2023, and ten years afterwards) for a Polish region targeted by cohesion policy such as Południowy (PL2), in the South of the country, and for a Belgian region which is a net contributor to the policy such as Flanders (BE2). Południowy receives a substantial amount of net investments in terms of its GDP, while Flanders receives little transfers from the EU, and contributes to the policy in a substantial way due to its high GDP.

The responses of GDP and employment differ between the two regions not only in

[12]There are few regions such as those located in the Netherlands, Denmark, the North-West of Italy and the capital region of France that still experience negative cumulative discounted multipliers. These regions need more time to fully compensate the initial disbursement. According to our model, all regions record positive cumulative multipliers 20 years after the termination of the policy.



(a) Cumulative discounted multipliers in 2023



(b) Cumulative discounted multipliers in 2033

Figure 2: Cumulative discounted multipliers - Forward-looking agents - Notice that the scale (and colour coding) of the positive values of panel (b) differs from that of panel (a).

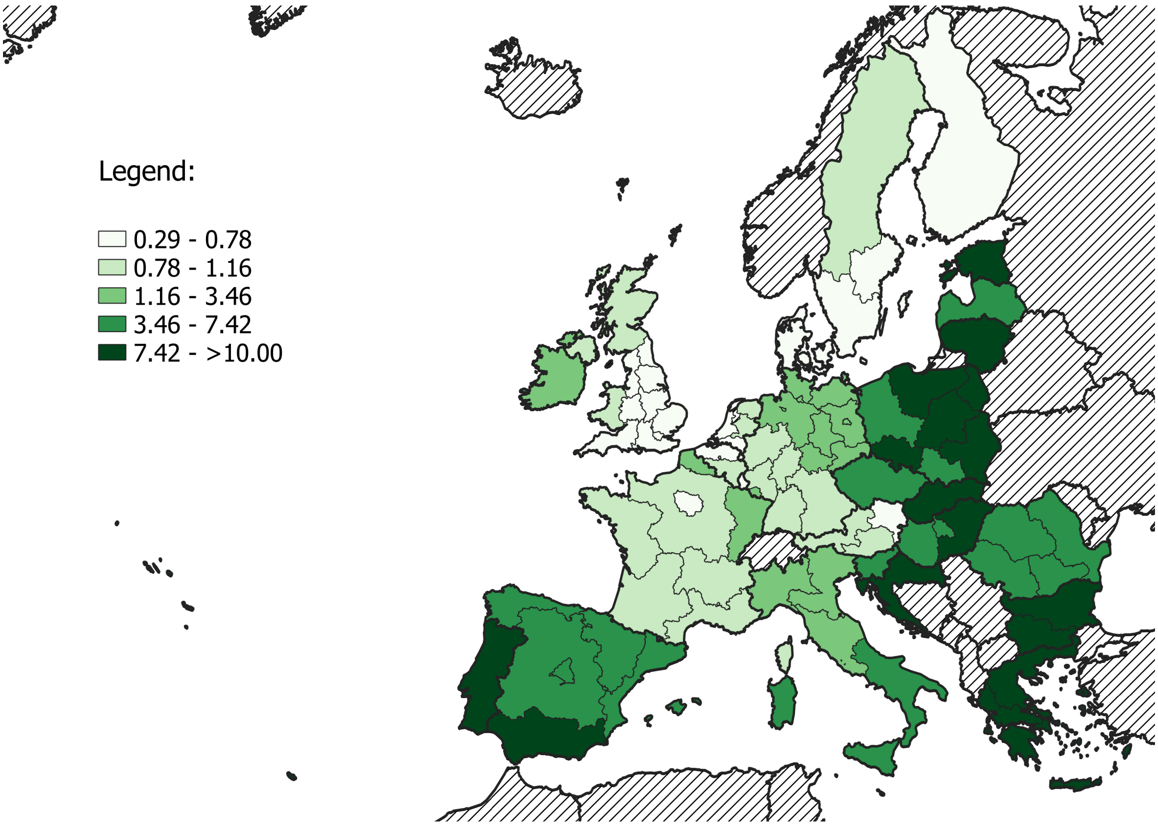


Figure 3: Myopic vs forward-looking differences in discounted cumulative GDP impact in 2033 (expressed in percentage points)

Table 3: Key macroeconomic variables deviations from baseline in PL2 and BE2

	PL2			BE2		
Forward-looking	2014	2023	2033	2014	2023	2033
GDP	0.09	1.33	0.97	0.00	-0.03	0.09
Employment	0.24	0.51	0.41	0.01	-0.02	0.03
Prices	0.89	-0.88	-0.52	0.18	-0.17	-0.19
Exports	-0.85	1.82	1.33	-0.12	0.08	0.24
Imports	1.48	0.27	0.38	0.10	0.03	0.00
Investment	1.21	0.53	0.59	-0.10	0.17	0.16
Hh. cons.	1.40	-0.09	0.21	0.19	-0.11	-0.13
Fin. W	0.92	0.35	0.46	1.67	-0.87	-1.37
Non-Fin. W.	0.69	0.31	0.44	-0.11	-0.09	-0.04
Myopic	2014	2023	2033	2014	2023	2033
GDP	0.06	1.95	1.34	0.00	0.01	0.10
Employment	0.14	0.91	0.69	0.00	0.01	0.05
Prices	0.41	-0.78	-0.25	-0.02	-0.03	-0.05
Exports	-0.43	2.15	1.41	0.04	0.05	0.15
Imports	0.56	1.36	1.25	-0.08	0.15	0.15
Investment	0.93	0.38	1.02	-0.10	0.34	0.14
Hh. cons.	0.23	1.37	1.25	-0.09	0.00	0.08

terms of magnitude, but also in terms of the dynamic response to the shock. Given the large policy intervention and the relatively low contribution of the region to the financing of the policy, the economic impact is particularly high in Południowy during the whole implementation period. At the end of the implementation period, GDP and employment under the forward-looking model increase by 1.33% and 0.51% respectively. On the contrary, the economic impact in Flanders is first negative, with GDP below its base year value by 0.03% (and employment by 0.02%) in 2033. This reflects the fact that the net-contributing regions bear a large share of the cost of the policy implemented in other EU regions which therefore outweigh its benefits. However, ten years after the end of the interventions the impact of the policy in Flanders becomes positive, which is due to the significant legacy effects stemming directly from the interventions implemented in the region and by the spillovers generated by those implemented in the main beneficiaries.

Prices increase in both regions at the beginning of the deployment of the cohesion investments, and they are below the base year values by the end of it, generating positive competitiveness effects and in turn improving the trade balance particularly in the region targeted by cohesion policy. Private investments decrease in the short run in the Flanders region, while they increase for the whole implementation period and beyond in Południowy thanks to the significant policy injection. Household consumption also increases more in the Południowy than Flanders region. In addition financial wealth consistently increases over the whole simulation period in the Polish region, while it initially increases in the Belgian region, only to decrease below its initial value at the end of the implementation period and for most of the remaining simulation periods. This reflects the behaviour of forward-looking agents who foresee the new steady state and adjust their consumption as soon as the policy is deployed making use of wealth. We observe then that the households in the region financing the policy use their wealth to smooth consumption, and eventually build up debt in order to keep a certain level of consumption. On the other hand, the households living in the beneficiary regions are capable of accumulating a stock of financial wealth during the economic expansion generated by the cohesion investments.

The results obtained assuming forward-looking agents differ more from those obtained under the assumption of myopic when the region is a net beneficiary of the policy, while they are closer for the net contributors. For example, in the Południowy region, the GDP at the end of the implementation period is 1.95% above its baseline value while it is 1.33% above it under the assumption of forward-looking agents, i.e. a difference of around 0.6 percentage points. In Flanders, the difference between the two settings is only 0.04 percentage points. On the other hand, in Flanders household consumption initially increases and then decreases in the forward-looking setting, while the opposite is true in the myopic case. The rest of the variables also react differently depending on this key assumption of the model. In particular, in the first ten years of the simulation, investments decrease more in the forward-looking version of the model (reaching a cumulative -1.42%) than in the myopic version (according to which the cumulative change is -0.57%).

7 Conclusion

In this paper, we use a spatial dynamic computable general equilibrium model defined over more than 80 NUTS 1 regions of the EU to analyse the macroeconomic impact of the regional investments deployed over the 2014-2020 period through the ERDF and the CF. We present the results obtained with the model that incorporates forward-looking agents capable of forming expectations over the future realisations of the economy as well as with a version in which agents are backward looking and form expectations solely based on current and past states of the economy. The model also features total factor productivity endogenously reacting to the changes in the capital stock, depending on the regional research and development intensity of the various regions. To the best of our knowledge, the analysis of this paper constitutes the first attempt at evaluating the European cohesion policy with two alternative dynamic structures with a spatial general equilibrium model.

The results of the modelling simulations suggest that the European GDP would be 0.3% higher at the end of the implementation period than it would have been in the absence of the policy. This effect is lower than what a model with myopic agents would suggest because myopic agents expect the policy to be permanent, rather than temporary. This implies a delayed response to the shock that see myopic agents increasing consumption and investments until the termination of the shock. The differences between the two settings are particularly large in the regions which are net beneficiaries from the policy, rather than in those which are net contributors. This suggests interesting implications in terms of policy credibility. If agents believe that the policy will persist in the longer term, that is, if they consider it sustainable, the adjustments on consumption and investment are delayed and larger than what would be implied by a shock perceived as temporary. In fact, if agents perceive the temporary nature of the policy shock (even though there may be permanent effects attached to it), they start anticipating the adjustments on consumption and investments well before the end of the policy, but the reaction would be smaller than in the first case.

Contrary to the standard approach adopted in the literature trying to assess the impact of cohesion policy, we have made an effort to identify distinctive channels to the several category of expenditures of the cohesion program, and to study the legacy effects of the policy in addition to its short term impact. The analysis suggests that supply-side shocks are characterised by larger multipliers than purely demand-side shocks like government current expenditure ones, with the former that also show a fast adjustment towards the post-policy equilibrium which limits the legacy effects of the interventions. On the contrary, programmes stimulating private and public investments generate larger impacts and long-lasting effects. There are few regions where the economic impact can mostly be explained by spillovers, that is GDP benefits which materialise due to investments taking place elsewhere. These spillovers are not uniform and typically benefit more the regions in the proximity of the objective regions.

There are substantial differences in the results when adopting a forward-looking setting versus a myopic one, demonstrating the usefulness of dedicating resources to the construction of spatial models featuring forward-looking agents. The findings presented here suggest that the differences in the results of policy impact assessments obtained in the two settings may be substantial, especially for the main target regions.

Cohesion policy is temporary by nature as the programmes have a clear end date. Formulating expectations as if agents were myopic may therefore be too strong of a simplifying hypothesis. Myopic agents base their decisions on past and present conditions only, abstracting from the future. They expect that the value of an economic variable next period to be equal to the current value of this variable, meaning that the shocks implemented at period t are expected to stay in place in period $t + 1$. Regarding cohesion policy, this amounts to assume that agents believe that the interventions programmed for a given period will never terminate until they actually do so. This is unrealistic for a policy whose duration is unambiguously locked for a clearly announced period within the context of the EU multi-annual financial framework.[13]

On the contrary, forward-looking agents are assumed to have rational expectations, which means that they correctly anticipate not only the duration and the content of the programmes, but also the manner they will affect the economy. Accordingly, their contemporaneous decisions are partly based on information concerning the interventions to come in the future, which is plausible for a policy whose time frame and programmes are known before their actual implementation. Even if rational expectations may be regarded as another extreme assumption, they may fit better the reality of cohesion policy than static expectations that are implicitly assumed when considering myopic agents. More generally, the results of this analysis highlight the important role played by the information and the predictability of a policy framework. In particular, the fact that when a policy is considered credible and/or time persistent by economic agents, its effects are larger (and materialise later) than when it is perceived as uncertain and/or temporary.

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

References

Albanese, G., de Blasio, G., and Locatelli, A. (2021). Does eu regional policy promote local tfp growth? evidence from the italian mezzogiorno. *Papers in Regional Science*, 100(2):327–348.

Allard, C., Choueiri, N., Schadler, S. M., and Van Elkan, R. (2008). Macroeconomic effects of eu transfers in new member states. *IMF Working Papers*, 2008(223).

Arcalean, C., Glomm, G., and Schiopu, I. (2012). Growth effects of spatial redistribution policies. *Journal of Economic Dynamics and Control*, 36(7):988–1008.

Armington, P. S. (1969). A theory of demand for products distinguished by place of production. *Staff Papers*, 16(1):159–178.

Bähr, C. (2008). How does sub-national autonomy affect the effectiveness of structural funds? *Kyklos*, 61(1):3–18.

Barbero, J. and Salotti, S. (2021). A general equilibrium analysis of the effects of the 2014-2020 european cohesion policy in the portuguese regions. Technical report, Joint Research Centre (Seville site), JRC Working Papers on Territorial Modelling and Analysis No. 02/2021, European Commission, Seville, JRC125285.

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

Bergstrom, T. C. and Goodman, R. P. (1973). Private demands for public goods. *The American Economic Review*, 63(3):280–296.

Berkowitz, P., Monfort, P., and Pieńkowski, J. (2020). Unpacking the growth impacts of european union cohesion policy: transmission channels from cohesion policy into economic growth. *Regional Studies*, 54(1):60–71.

Beugelsdijk, M. and Eijffinger, S. C. (2005). The effectiveness of structural policy in the european union: An empirical analysis for the eu-15 in 1995–2001. *JCMS: Journal of Common Market Studies*, 43(1):37–51.

Boldrin, M. and Canova, F. (2001). Inequality and convergence in europe's regions: reconsidering european regional policies. *Economic policy*, 16(32):206–253.

Bröcker, J. and Korzhenevych, A. (2013). Forward looking dynamics in spatial cge modelling. *Economic Modelling*, 31(C):389–400.

Cappelen, A., Castellacci, F., Fagerberg, J., and Verspagen, B. (2003). The impact of eu regional support on growth and convergence in the european union. *JCMS: Journal of Common Market Studies*, 41(4):621–644.

Ciani, E. and De Blasio, G. (2015). European structural funds during the crisis: evidence from southern italy. *IZA Journal of Labor Policy*, 4(1):1–31.

Crucitti, F., Lazarou, N., Monfort, P., Salotti, S., et al. (2021). A scenario analysis of the 2021-2027 european cohesion policy in bulgaria and its regions. Technical report, Joint Research Centre (Seville site), JRC Working Papers on Territorial Modelling and Analysis No. 06/2021, JRC126268.

Crucitti, F., Lazarou, N.-J., Monfort, P., and Salotti, S. (2022a). The rhomolo impact assessment of the 2014-2020 cohesion policy in the eu regions. Technical report, JRC Working Papers on Territorial Modelling and Analysis no. 01/2022, JRC128208.

Crucitti, F., Lazarou, N.-J., Monfort, P., Salotti, S., et al. (2022b). A cohesion policy analysis for romania towards the 2021-2027 programming period. Technical report, Joint Research Centre (Seville site), JRC Working Papers on Territorial Modelling and Analysis No. 06/2022, European Commission, Seville, JRC129049.

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

De la Fuente, A. (2002). Does cohesion policy work? some general considerations and evidence from spain. Technical report, Working Papers 563, Instituto de Analisis Economico.

Devarajan, S., G. D. (1994). The simplest dynamic general equilibrium model of an open economy. *Journal of Policy Modeling*, 20(C):677–714.

Dixit, A. K. and Stiglitz, J. E. (1977). Monopolistic competition and optimum product diversity. *The American economic review*, 67(3):297–308.

Ederveen, S., De Groot, H. L., and Nahuis, R. (2006). Fertile soil for structural funds? a panel data analysis of the conditional effectiveness of european cohesion policy. *Kyklos*, 59(1):17–42.

Edwards, J. H. (1990). Congestion function specification and the "publicness" of local public goods. *Journal of Urban Economics*, 27(1):80–96.

European-Commission (2018). Impact assessment of the european regional development fund and the cohesion fund. swd(2018) 282 final. strasbourg, 29.5.2018.

European-Commission (2021). Regulation (eu) 2021/1058 of the european parliament and of the council of 24 june 2021 on the european regional development fund and on the cohesion fund.

European-Union (2014). Commission implementing regulation (eu) no 215/2014 of 7 march 2014 laying down rules for implementing regulation (eu) no 1303/2013 of the european parliament and of the council laying down common provisions on the european regional development fund, the european social fund, the cohesion fund, (...) with regard to (...) the nomenclature of categories of intervention for the european structural and investment funds. l69/65, official journal of the european union.

Fisher, W. H. and Turnovsky, S. J. (1998). Public investment, congestion, and private capital accumulation. *The Economic Journal*, 108(447):399–413.

Fratesi, U. and Perucca, G. (2014). Territorial capital and the effectiveness of cohesion policies: An assessment for cee regions.

Fratesi, U. and Wishlade, F. G. (2017). The impact of european cohesion policy in different contexts.

Gianelle, C., Guzzo, F., Barbero, J., and Salotti, S. (2022). The economic implications of smart specialisation governance: a general equilibrium analysis for italy 2014-2020. Technical report, JRC Working Papers on Territorial Modelling and Analysis no. 05/2022, JRC128607.

Giua, M. (2017). Spatial discontinuity for the impact assessment of the eu regional policy: The case of italian objective 1 regions. *Journal of Regional Science*, 57(1):109–131.

Glomm, G. and Ravikumar, B. (1994). Public investment in infrastructure in a simple growth model. *Journal of Economic Dynamics and Control*, 18(6):1173–1187.

Glomm, G. and Ravikumar, B. (1997). Productive government expenditures and long-run growth. *Journal of Economic Dynamics and control*, 21(1):183–204.

Go, D. (1994). External shocks, adjustment policies and investment in a developing economy: illustration from a forward-looking cge model of the philippines. *Journal of Development Economics*, 44(C):229–261.

Hall, R. E. and Jorgenson, D. W. (1967). Tax policy and investment behavior. *The American Economic Review*, 57(3):391–414.

Lecca, P., McGregor, P. G., and Swales, J. K. (2013). Forward-looking and myopic regional computable general equilibrium models: How significant is the distinction? *Economic modelling*, 31:160–176.

Mohl, P. and Hagen, T. (2010). Do eu structural funds promote regional growth? new evidence from various panel data approaches. *Regional Science and Urban Economics*, 40(5):353–365.

Monfort, P., Piculescu, V., Rillaers, A., Stryczynski, K., and Varga, J. (2017). The impact of cohesion and rural development policies 2007-2013: Model simulations with quest iii. *European Commission. WP*, 5:2017.

Partridge, M. D. and Rickman, D. S. (2010). Computable general equilibrium (cge) modelling for regional economic development analysis. *Regional studies*, 44(10):1311–1328.

Pellegrini, G., Terribile, F., Tarola, O., Muccigrosso, T., and Busillo, F. (2013). Measuring the effects of european regional policy on economic growth: A regression discontinuity approach. *Papers in Regional Science*, 92(1):217–233.

Persyn, D., Barbero, J., Díaz-Lanchas, J., Lecca, P., Mandras, G., and Salotti, S. (2022a). The ripple effects of large-scale transport infrastructure investments. Technical report, Joint Research Centre (Seville site), JRC Working Papers on Territorial Modelling and Analysis No. 02/2022, European Commission, Seville, JRC128412.

Persyn, D., Díaz-Lanchas, J., and Barbero, J. (2022b). Estimating road transport costs between and within european union regions. *Transport Policy*, 124:33–42.

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

Sosvilla-Rivero, S., Bajo-Rubio, O., and Díaz-Roldán, C. (2006). Assessing the effectiveness of the eu's regional policies on real convergence: An analysis based on the hermin model. *European Planning Studies*, 14(3):383–396.

Stiglitz, J. E. and Rosengard, J. K. (2015). *Economics of the public sector: Fourth international student edition.* WW Norton & Company.

Varga, A., Járosi, P., and Sebestyén, T. (2011). Modeling the economic impacts of regional r&d subsidies: The gmr-europe model and its application for eu framework program policy impact simulations. In *6th International Seminar on Regional Innovation Policies, University of Lund, Lund, Sweden.*

Varga, J. and in't Veld, J. (2011). A model-based analysis of the impact of cohesion policy expenditure 2000–06: Simulations with the quest iii endogenous r&d model. *Economic modelling*, 28(1-2):647–663.

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