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## Working Paper

# The impact of Cohesion Policy 2007-2015 in EU regions: Simulations with the RHOMOLO Interregional Dynamic General Equilibrium Model

JRC Working Papers on Territorial Modelling and Analysis, No. 03/2018

## Provided in Cooperation with:

Joint Research Centre (JRC), European Commission

*Suggested Citation:* Di Comite, Francesco; Lecca, Patrizio; Monfort, Philippe; Persyn, Damiaan; Piculescu, Violeta (2018) : The impact of Cohesion Policy 2007-2015 in EU regions: Simulations with the RHOMOLO Interregional Dynamic General Equilibrium Model, JRC Working Papers on Territorial Modelling and Analysis, No. 03/2018, European Commission, Joint Research Centre (JRC), Seville

This Version is available at:

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## JRC TECHNICAL REPORTS

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*JRC Working Papers on  
Territorial Modelling and  
Analysis No 03/2018*

Di Comite, F., Lecca, P., Monfort, P.,  
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2018

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JRC114044

PDF      ISSN 1831-9408

Seville: European Commission, 2018

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How to cite this report: Di Comite, F., Lecca, P., Monfort, P., Persyn, D., and Piculescu V. (2018). The impact of Cohesion Policy 2007-2015 in EU regions: Simulations with the RHOMOLO Interregional Dynamic General Equilibrium Model. JRC Working Papers on Territorial Modelling and Analysis No. 03/2018, European Commission, Seville, 2018, JRC114044.

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## **Abstract**

In this paper we assess the system-wide economic impact of the key financial instruments adopted by the European Union for the implementation of the regional policy: The Structural funds and The Cohesion Funds. We take a bottom-up approach by aggregating the 86 categories of expenditures defined in the Structural and Cohesion Funds into six main policy variables. The outcomes of the simulations are the results of a combination of demand-and-supply-side shocks that are implemented into the RHOMOLO spatial and dynamic general equilibrium model calibrated on a set of inter-regional Social Accounting Matrices for the year 2010. In our analysis we document the direct, indirect, and general equilibrium effects of the EU regional policy at the regional, national, and EU level. In the short-run, our simulation exercise suggests a pronounced variegated pattern across EU regions. In the long-run, a more homogenous spatial distribution is detected. Moreover, we identify and quantify the interregional spillover effects arising from trade links and capital mobility.

# **The impact of Cohesion Policy 2007-2015 in EU regions: Simulations with the RHOMOLO Interregional Dynamic General Equilibrium Model**

*Francesco Di Comite, Patrizio Lecca, Philippe Monfort,  
Damiaan Persyn, and Violeta Piculescu  
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## **1 Introduction**

In this note we illustrate the likely economic impact of the EU Cohesion Policy (ECP) investment across the regions of the EU.<sup>1</sup> To this end, we use the RHOMOLO spatial Computable General Equilibrium (CGE) model developed by the European Commission for territorial impact assessment.

RHOMOLO provides sector-, region- and time-specific analysis to support EU policy making and investments. The version of RHOMOLO used for the analysis of this report covers all EU NUTS2 regions; each regional economy being disaggregated into six economic sectors. Spatial interactions between regional economies are captured through trade of goods and services, income flows, factor mobility and knowledge spillovers, making RHOMOLO particularly well suited for simulating human capital, transport infrastructure, and R&D and innovation policies. It captures the macroeconomic impacts of EU policies on regional economies, and notably on variables such as GDP, employment, income, consumption, investment and savings.

In order to assess the impact of the ECP on regional economies within RHOMOLO, the many ECP items have been thematically regrouped into the following six types: Transport infrastructure; Other types of infrastructures; Human Capital; R&D; Aid to Private sector; and Technical Assistance.

In order to simulate the effect of these policies, a combination of different types of policy shocks is required, as we describe in detail in the following sections. The ECP is assumed to be financed through non-distortionary taxation on household income. Therefore, some crowding-out effects could arise in some regions and/or economic sectors in the short-run during the financing period. However, it may also be that the reduction in disposable household income will only partially offset the overall positive impact of increased investments in regional economies and the structural effect of policies. The answers to these and other questions will be provided in the simulation exercise using the RHOMOLO model.

The remainder of the report is structured as follows. In Section 2 we outline the spatial and inter-temporal allocation of ECP funds. In Section 3 we provide a brief overview of the RHOMOLO version used for this analysis. Section 4 is dedicated to the explanation of how the ECP investment is translated into policy scenarios in the RHOMOLO modelling framework. In Section 5 we analyse the simulations results focussing primarily on key economic variables such as GDP and employment. In Section 6 an investigation of regional spillover effects is carried out measuring the cumulative multiplier effects resulting from the implementation of the Cohesion Policy. In Section 7, transport infrastructure improvements resulting from the implementation of the ECP are evaluated. Finally, policy conclusions are drawn in Section 8.

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<sup>1</sup> Some of the results of this analysis have been featured in the ex post evaluation of the ERDF and Cohesion Fund 2007-2013 (European Commission, 2016).

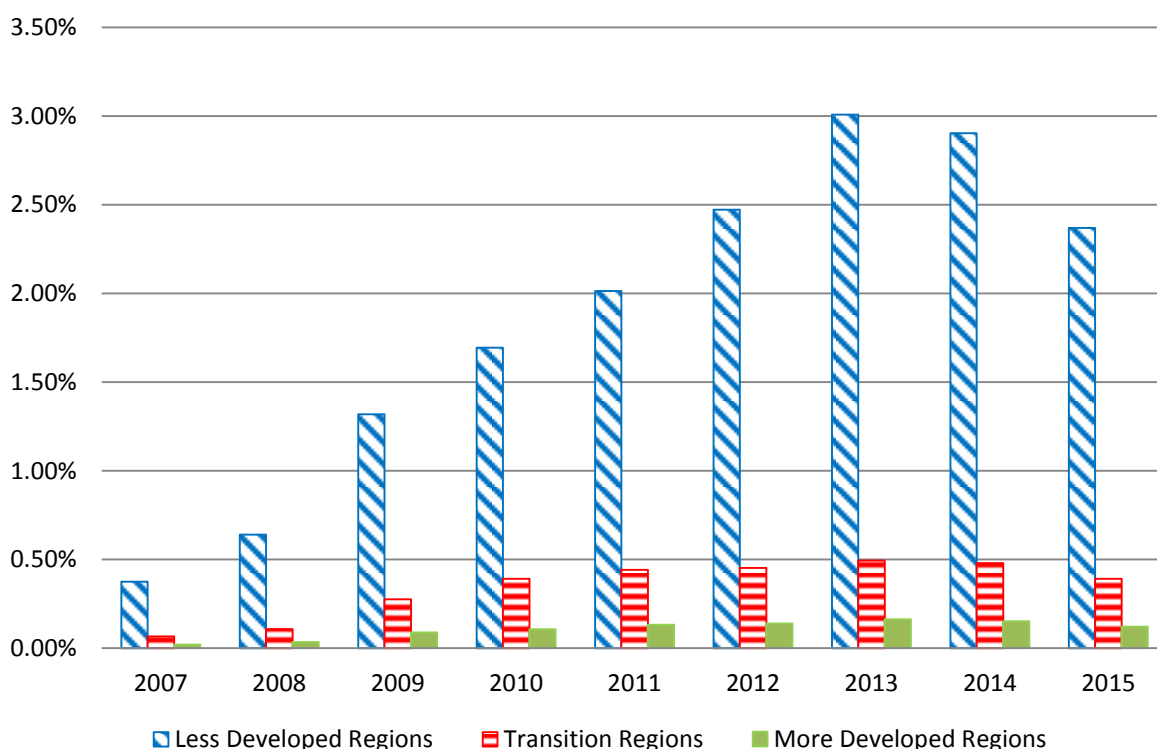
## 2 The allocation of the ECP funds

### 2.1 General Overview

This section briefly describes the allocation of the ECP funds which will be used for the simulations explained in the following sections. In Figure 1, we show the time profile of ECP funding as a share of GDP for three distinctive groups of regions according to their level of economic development: less developed regions (GDP per capita < 75% of EU average - 65 regions); transition regions (GDP per capita between 75% and 90% - 51 regions); and more developed regions (GDP per capita > 90% - 151 regions).<sup>2</sup>

ECP funds are mainly targeted to less developed regions. Over the period 2007-2015, these regions received around 60% of the total ECP investments, while transition and more developed regions receive respectively 16% and 24% of the total. ECP expenditures are unevenly distributed across the three groups of regions, but their time profile is rather similar. In all regions, the amount of allocated investments tends to peak in 2013 and slightly declines in the following periods.

Figure 1: Average ECP allocation per region group as a share of regional GDP



The regions receiving most of the ECP investment over the period 2007-2015 in absolute terms are PL12 (Mazowieckie), ES61 (Andalucia), and PT11 (Norte), corresponding respectively to the 3.35%, 2.72% and 2.52% of the whole ECP. With respect to their own GDP, the annual average values of such funds represent 1.65%, 0.68%, and 1.95% of their 2010 GDP, respectively. Thus, although these regions received more than others in absolute terms, these amounts in terms of GDP are less impressive, even though still large.

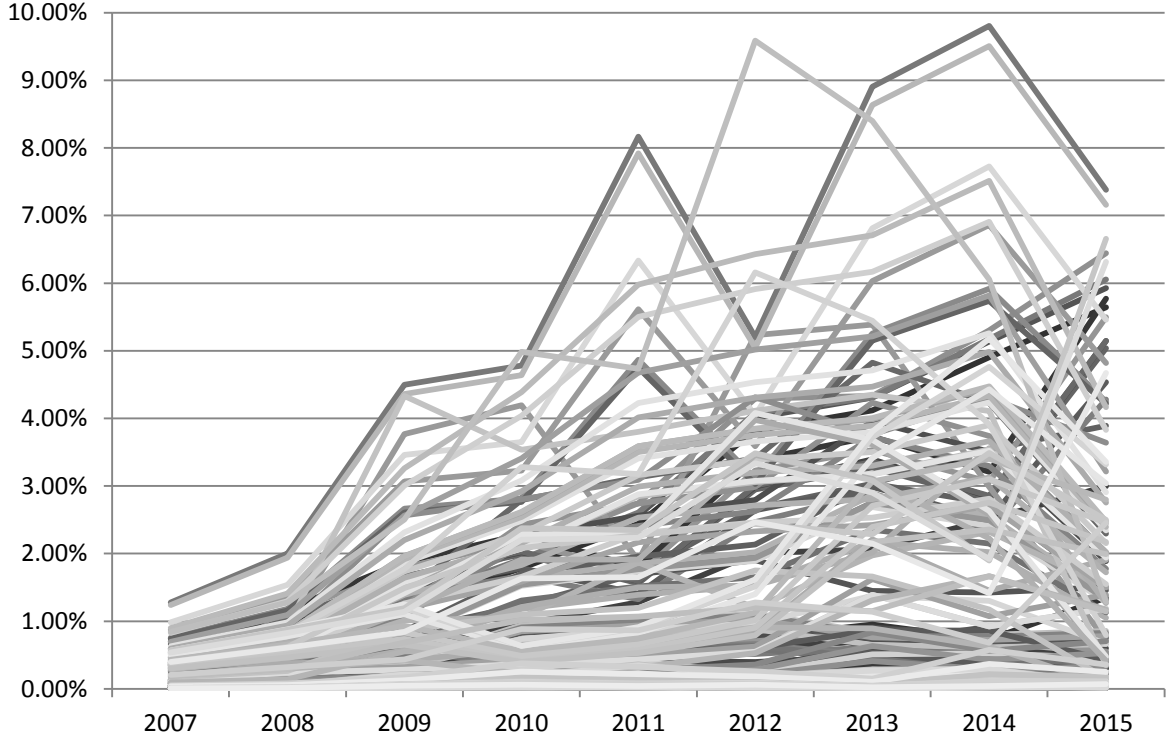
<sup>2</sup> NUTS2 regions are ranked and split into three groups according to the latest classification of regional development which is the one adopted for the allocation of the European Regional Development Fund (ERDF) and the European Social Fund (ESF) during the programming period 2014-20.

There are wide differences across EU regions in terms of size, population and GDP. For example, the NUTS2 regional population ranges from 28,501 people living in "Åland" (FI20) to 11,952,061 living in "Île de France" (FR10). Similarly, regional GDP ranges from €1,285 million in "Ciudad Autónoma de Melilla" (ES64) to €566,541 million in "Île de France" (FR10).

In Figure 2 we plot the ECP funds for all the NUTS2 recipient regions as a share of regional GDP. We observe a number of recipient regions whose ECP contribution represents a large share of GDP.

In terms of countries, Poland and Spain are the ones benefitting the most in absolute terms. However, Estonia, Hungary, Lithuania and Latvia are the countries receiving significant ECP funding relative to their GDP. Therefore, we would expect a bigger impact of this policy in these countries in terms of key economic variables, such as GDP, employment, investment, and consumption.

**Figure 2: Regional allocation of ECP expenditures over the period 2007-2015 as a share of regional GDP (all EU NUTS2 regions)**



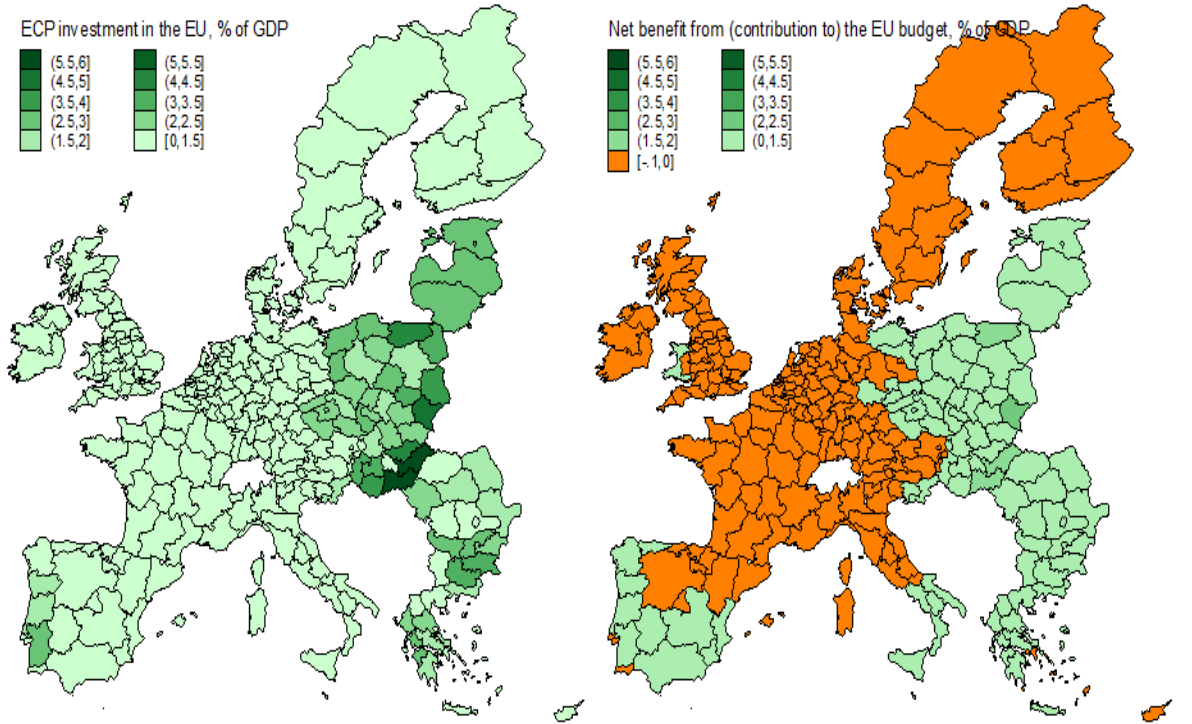
**2.2 The spatial distribution of the ECP investment**

In the left pane of Figure 3 we report the annual average regional (NUTS2) distribution of ECP funds over the period 2007-2015 as a share of regional GDP, while on the right pane we map the net receipts of EU regions computed as the difference between ECP investments and regional contribution to ECP budget, also normalised by regional GDP.<sup>3</sup>

<sup>3</sup> Each country contributes to the overall EU budget on the basis of a complex mechanism whose main component is the EU share of national GNI. In principle, it is not possible to distinguish the specific budget contribution related to the ECP. Therefore, in order to calculate the ECP related payment we use the country

By inspecting the two maps, it is clear that some regions located in Eastern Europe benefit significantly from ECP funding relative to their GDP. These regions are also net recipients, as we can observe from the right pane of Figure 3. In contrast, several regions in the centre of Europe, all regions in Scandinavia, France, Northern Italy, and Spain are essentially contributing more than what they are receiving in terms of ECP investments. However, relative to their regional GDP these net contributions are small.

**Figure 3: Spatial distribution of the direct ECP investment as a share of regional GDP (left pane) and net receipts (direct investment less contribution) as a share of regional GDP (right pane)**



*Note: Green darker colours denote a higher allocation of funding relative to GDP while orange colours identify net contributor regions to the ECP budget.*

**2.3 Transport infrastructure investment**

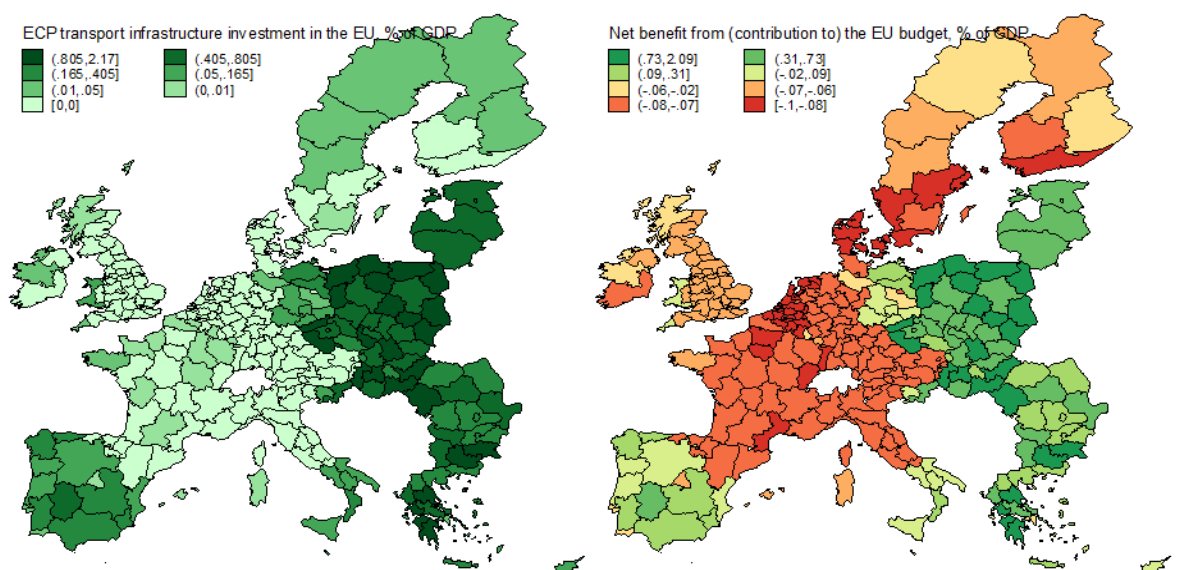
The relative allocation of funding across expenditure items is not identical in all regions, but is tailored to the specific needs of each territory. One example demonstrating this fact comes from the ECP investments allocation to transport infrastructure over the period 2007-2015, representing around 23% of the whole ECP. The allocation among EU regions of the transport infrastructure investment is shown on the left pane of Figure 4, where we show the annual average investment over the period 2007-2015 among the NUTS2 regions as a share of regional GDP. From this figure we can see that regions in Eastern Europe receive a particularly significant amount of funds for transport infrastructure investments. In addition, some regions in Spain and the South of Italy benefit significantly from EU transport infrastructure policies.

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shares of the total EU budget and then we split the country contribution at regional level on the basis of the regional GDP.



**Figure 4: ECP budget allocations for investments in transport infrastructure (left pane) and net ECP receipts (right pane).**



*Note: Green darker colours denote a higher direct benefit while orange colours mean a negative direct benefit.*

Furthermore, it is interesting to see the net contribution made by each region to finance transport infrastructure investments. To this end, on the right pane of Figure 4 we report the annual average difference over the period 2007-2015 between the money received and the contribution made by each region to support the transport infrastructure policy.<sup>4</sup> As it happened for the general ECP budget, for infrastructure investments too Central and Northern Europe are net contributors of the policy. This essentially means that these regions bear part of the cost associated to the construction of the transport infrastructure through cohesion funding in the rest of Europe.

### 3 Description of the RHOMOLO model

The domestic economy (which corresponds to the EU) consists of  $R-1$  regions  $r = 1, \dots, R-1$ , which are part of  $M$  countries  $m = 1, \dots, M$ . The rest of the world is introduced in the model as an exogenous external sector (indexed by  $R$ ).

The economy is composed of  $j$  different sectors (also called industries) in which firms operate under monopolistic competition à la Dixit and Stiglitz (1977). In each region-sector, identical firms produce a differentiated variety, which is considered an imperfect substitute for the varieties produced elsewhere. Final goods are consumed by Households, Governments and Investors (this is the form of capital goods), whilst firms consume intermediate inputs. The number of firms in sector  $j$  and region  $r$ , denoted by  $N$ , is endogenous and determined from the zero-profit equilibrium condition, according to which profits must be equal to fixed costs. In turn, this means that in equilibrium prices equal average costs.

Trade between and within regions is costly, implying that the shipping of goods entails transport costs assumed to be of the iceberg type, with  $\tau_{r,r',j} > 0$  representing the

<sup>4</sup> The regional contributions in this case are calculated applying the same shares of the whole ECP calculated contributions as mentioned above in Section 2.1.

quantity of sector  $j$  goods that needs to be sent from region  $r$  in order to have one unit arriving in region  $r'$  (see Krugman, 1991, for instance). Transport costs are identical across varieties but specific to sectors and trading partners (region pairs). They are based on the transport network model TRANSTOOLS, which considers different modes of transport, computes travelling times and then convert them into iceberg costs.<sup>5</sup> These costs are positive within regions and asymmetric between regions (i.e.  $\tau_{r,r',j}$  is allowed to differ from  $\tau_{r',r,j}$ ).

Regional goods are produced by combining the value added (labour and capital) with domestic and imported intermediates, creating vertical linkages between firms. This means that the spatial configuration of the system of regions has a direct impact on the competitiveness of regions, because firms located in more accessible regions can source their intermediate inputs at lower price and thus gain larger market shares in local markets.

Regional investments are determined by a simple adjustment rule, according to which the additional level of investments is generated in each region by the gap between the desired level of capital and the actual level of capital. This is a typical accelerator model developed originally by Jorgenson and Stephenson (1969) and consistent with the capital adjustment rules of Uzawa (1969). Everything else equal, higher user costs of capital are associated with lower desired capital stock and disinvestments due to lower profits. Given the spatial unit of analysis in the model (the regional level), the demand for investment can be satisfied by the domestic and external markets, without constraints. The capital stock in each region is updated period by period through the realised investment adjusted for depreciation.

For the purpose of this exercise RHOMOLO is disaggregated into 267 EU regions and 6 NACE 1.1 economic sectors: Agriculture (AB), Manufacturing and construction (CDEF), Trade services (GHI), Business Services (JK), R&D (R&D) and other services (LMNOP). All shift and share parameters are calibrated to reproduce the base year dataset, represented by the inter-regional Social Accounting Matrix for the year 2010.

RHOMOLO distinguishes three different labour categories: low-, medium-, and high-skill. For each labour type, the wage setting relationship is represented by a wage curve (Blanchower and Oswald, 1995), whose implication is that lower levels of unemployment increase workers' bargaining power, thereby increasing real wages. Labour supply is fixed at the EU level, but workers, differentiated by skills, can migrate among EU regions according to real wage and unemployment differences.

The structural parameters of RHOMOLO are either borrowed from the literature (Okagawa and Ban, 2008) or estimated econometrically. The parameters related to the elasticities of substitution both on the consumer and on the producer side are based on similar models or derived from the econometric literature. Typically, we assume a rather low elasticity of substitution in production (0.3), a relatively higher elasticity of substitutions in consumption (1.2) and a fairly high for trade between regions (6.0). The elasticity of substitution between different types of labour skills equate to 1.5. The interest rate (faced by producers, consumers and investors) is set to 0.04, the rate of depreciation applied to the private capital equates to 0.15 while public capital depreciate at the rate of 0.04 (Gupta et al., 2014).

The model calibration process assumes the economies to be initially in steady-state equilibrium. This means that the capital stock is calibrated to allow depreciation to be fully covered by investments. The steady-state equilibrium calibration implies that the data observed should provide unbiased information about preferences and technologies

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<sup>5</sup> For more details see <http://energy.jrc.ec.europa.eu/transtools/>

in each region and therefore relative magnitudes should not vary in the baseline scenario.

We assume that there is no natural population change and we do not make any assumptions about the economic growth of regions due to external factors. The main reason behind these baseline scenario assumptions is that, the simulation results are not intended to provide any direct evidence for the EU policy design. Moreover, by avoiding asymmetric changes in the baseline scenario, such as regionally differentiated population or GDP growth, greatly facilitates the interpretation of simulation results. Furthermore, we should stress that this is not a forecasting exercise. The results derived from the model should help us to track the effects of an exogenous stimulus using impact analysis within a general equilibrium framework and a numerical support represented by the SAM.

A full description of the RHOMOLO model can be found in Mercenier et al. (2016) and a newer version of the model is illustrated in Lecca et al. (2018).

## **4 Implementation of EU Cohesion Policy shocks in RHOMOLO**

### **4.1 Translating ECP expenditures into shocks in the model**

In this section we detail the implementation of the ECP in RHOMOLO. In the 2007-2015 programming period, ECP expenditures have been officially split into 86 categories but, for the purposes of the present simulation, we regroup them into six main groups of policies: transport infrastructure investments (TRANSP); other infrastructure investments (INFR); investments in human capital (HC); investments in research and innovation (RTD); aid to the private sector (AIS); and technical assistance (TA). These six categories of investment are implemented in RHOMOLO through eleven different variables (policy shocks) as described in Table 1.

The ECP financial resources amount to roughly €300 billion. These are allocated from the EU budget to the to the EU regions with the aim to generate self-sustaining growth and reduce inequalities between EU territories. Each policy category is assumed to generate both demand and structural effects on regional economies. The demand effects reflect directly the transfer of resources resulting from the implementation of the Cohesion Policy package, while the structural effects are introduced with the idea to capture long-lasting changes.

The following four types of EU-related expenditures are covered: government purchases of goods and services from the market, as in shocks number 1, 3, 4, 5, 6, 10 and 11 in Table 1; public investments, as in shock number 2; production subsidies, as in shock number 8; and investment subsidies aimed at reducing the risk premium, as in shocks number 7 and 9.

There are five main types of structural shocks: reductions in transport costs (shock number 1); increase in TFP (shock number 6); increase in labour productivity in combination with a temporary reduction in labour market participation (shocks number 4 and 5).

The resources needed to finance the ECP are collected from the EU Member States and regions according to yearly contributions to the EU budget observed from 2007 to 2015. Throughout this analysis, we assume that each Member State contributes to the ECP proportionally to its contribution to the overall EU budget. The regional shares of national contributions are then allocated according to the regional shares of GDP within each country.

**Table 1: Introduction of Cohesion Policy shocks in RHOMOLO**

Type of Shock	TYPE	Model variable	Shock no.	Temporary effect /EU budget money flow	Permanent policy effect
Infrastructure - Transport	TRNSP	TCOST	1	Increase in government consumption	Decrease in transportation costs
Infrastructure - Other	INFR	IG	2	Increase in public investment	
		G	3	Increase in government consumption	
Human Capital	HC	TRAIN	4	Decrease in labour supply (all workers) + Increase in government consumption	Increase in labour productivity (all types of labour)
		TRAINH	5	Decrease in labour supply (highly skilled workers) + Increase in government consumption	Increase in high-skill labour productivity (highly skilled workers)
R&D	RTD	FCA	6	Increase in government consumption	Increase in TFP
		RPREMA	7	Investment subsidy to reduce risk premium	
Aid to Private Sector	AIS	FCY	8	Production subsidy	
		RPREMK	9	Investment subsidy to reduce risk premium	
		G	10	Increase in government consumption	
Technical Assistance	TA	G	11	Increase in government consumption of "other services" in recipient regions (financed by the others)	-

TCOST – inter-regional transportation costs; IG – government investment; G – government consumption; FCA – entry costs to intermediates; FCY – fixed costs final demand firms; TRAIN(L,M,H) – worker training; RPREMK – shock to tangible capital cost; RPREMA – shock to intangible capital cost.

#### 4.2 Policy shock no. 1: Infrastructure – Transport

The corresponding resources allocated to transport infrastructure are assumed to generate temporary effects through increases in government consumption in order to account for the purchase of goods and services required to build a given infrastructure (e.g. of construction services and materials).

The associated permanent effect is simulated through a reduction in bilateral transport cost. Ideally, a transportation model should be used to 'translate' ECP investments in the transport infrastructure into inter-regional transportation cost reductions. To do so, we use a simple though empirically robust approach to 'translate' ECP investments in transport infrastructures into reduction in inter-regional transportation cost.

First, in order to construct an infrastructure investment scenario we construct an aggregate measure of the total ECP expenditure on the transport infrastructure for each region. For this purpose, all policy instruments directly affecting transport infrastructure are aggregated in one category, *TRNSP*, using the aggregation scheme reported in Table 2 below.

In a second step, we impute the spatial dimension of the transport infrastructure funds based on region-specific expenditures by estimating how a region-specific investment in transport infrastructure translates into region-pair-specific expenditure. The spatial

dimension is crucial, as a transport infrastructure investment affects not only the region where the ECP money is invested, but through trade linkages, factor movements and income flows also all the other regions. We use the following formula to impute a spatial matrix of bilateral transport investments,  $T_{r',r}$ :

$$T_{r',r} = \phi_{r',r} \left( \frac{TE_{r'} + TE_r}{2R} \right) \quad (1)$$

Where  $TE_{r'}$  and  $TE_r$  are the ECP transport infrastructure investments in regions  $r'$  and  $r$ , respectively, while  $\phi_{r',r} \equiv \tau_{r',r}^{1-\sigma}$  is a measure of the trade freeness, which ranges from zero, when trade is perfectly un-free (bilateral trade costs are prohibitive between  $r'$  and  $r$ ), to unity, when trade is perfectly free and bilateral trade costs are zero (Baldwin et al., 2005). Parameter  $\tau_{r',r}$  denotes bilateral trade costs between (and within) regions.  $R$  is the total number of regions in RHOMOLO.

The bilateral measure of transport infrastructure investments accounts for both the amount of the ECP expenditure and for proximity between the region pairs. The second term on the right-hand side in equation (1) calculates the average (virtual) transport investment for every pair of regions. The first term on the right-hand side introduces the spatial structure (economic geography) in the bilateral measure of transport infrastructure investment by weighting the proximity (integration) of regions. The further away the trading regions are (trade is more costly), the less weight is being attributed to transport infrastructure improvements between the trading regions. The assumed weighting implies that the further away are the two regions, the lower impact has a fixed amount of expenditure (1 km of road can be improved much better than 10 km of road with the same amount of funds).

In a third step, we transform the bilateral measure of expenditures,  $T_{r',r}$ , into changes in bilateral trade costs between regions, which are measured as a share of the traded goods value. This is done by pre-multiplying the bilateral measure of transport infrastructure investments,  $T_{r',r}$ , by a transportation cost elasticity measuring the effectiveness of transport infrastructure investments. This elasticity of trade costs with respect to the infrastructure quality is retrieved from previous studies of the European Commission, as no comparable elasticities are available for the 2007-2015 ECP investments in the transport infrastructure.

**Table 2: Aggregation of ECP expenditures**

Category Cd	Category	TYPE	MODEL VAR
01	01_R&TD activities in research centres	RTD	RPREMA
02	02_R&TD infrastructure and centres of competence in a specific t	RTD	FCA
03	03_Technology transfer and improvement of cooperation networks _	RTD	FCA
04	04_Assistance to R&TD, particularly in SMEs (including access to	RTD	FCA
05	05_Advanced support services for firms and groups of firms	AIS	FCY
06	06_Assistance to SMEs for the promotion of environmentally-frien	AIS	FCY
07	07_Investment in firms directly linked to research and innovation	RTD	RPREMA
08	08_Other investment in firms	AIS	RPREMK
09	09_Other measures to stimulate research and innovation and entre	RTD	RPREMA
10	10_Telephone infrastructures (including broadband networks)	INFR	IG
11	11_Information and communication technologies (___)	INFR	IG
12	12_Information and communication technologies (TEN-ICT)	INFR	IG

13	13_Services and applications for citizens (e-health, e-government	INFR	IG
14	14_Services and applications for SMEs (e-commerce, education and	INFR	IG
15	15_Other measures for improving access to and efficient use of I	INFR	IG
16	16_Railways	TRNSP	TCOST
17	17_Railways (TEN-T)	TRNSP	TCOST
18	18_Mobile rail assets	TRNSP	TCOST
19	19_Mobile rail assets (TEN-T)	TRNSP	TCOST
20	20_Motorways	TRNSP	TCOST
21	21_Motorways (TEN-T)	TRNSP	TCOST
22	22_National roads	TRNSP	TCOST
23	23_Regional/local roads	TRNSP	TCOST
24	24_Cycle tracks	TRNSP	TCOST
25	25_Urban transport	TRNSP	TCOST
26	26_Multimodal transport	TRNSP	TCOST
27	27_Multimodal transport (TEN-T)	TRNSP	TCOST
28	28_Intelligent transport systems	TRNSP	TCOST
29	29_Airports	TRNSP	TCOST
30	30_Ports	TRNSP	TCOST
31	31_Inland waterways (regional and local)	TRNSP	TCOST
32	32_Inland waterways (TEN-T)	TRNSP	TCOST
33	33_Electricity	INFR	IG
34	34_Electricity (TEN-E)	INFR	IG
35	35_Natural gas	INFR	IG
36	36_Natural gas (TEN-E)	INFR	IG
37	37_Petroleum products	INFR	IG
38	38_Petroleum products (TEN-E)	INFR	IG
39	39_Renewable energy: wind	INFR	IG
40	40_Renewable energy: solar	INFR	IG
41	41_Renewable energy: biomass	INFR	IG
42	42_Renewable energy: hydroelectric, geothermal and other	INFR	IG
43	43_Energy efficiency, co-generation, energy management	INFR	IG
44	44_Management of household and industrial waste	INFR	IG
45	45_Management and distribution of water (drink water)	INFR	IG
46	46_Water treatment (waste water)	INFR	IG
47	47_Air quality	INFR	IG
48	48_Integrated prevention and pollution control	INFR	IG
49	49_Mitigation and adaption to climate change	INFR	IG
50	50_Rehabilitation of industrial sites and contaminated land	INFR	IG
51	51_Promotion of biodiversity and nature protection (including Na	INFR	G
52	52_Promotion of clean urban transport	INFR	G
53	53_Risk prevention (___)	INFR	G
54	54_Other measures to preserve the environment and prevent risks	INFR	G
55	55_Promotion of natural assets	AIS	G

56	56_Protection and development of natural heritage	AIS	G
57	57_Other assistance to improve tourist services	AIS	G
58	58_Protection and preservation of the cultural heritage	AIS	G
59	59_Development of cultural infrastructure	AIS	G
60	60_Other assistance to improve cultural services	AIS	G
61	61_Integrated projects for urban and rural regeneration	AIS	G
62	62_Development of life-long learning systems and strategies in f	HC	TRAIN
63	63_Design and dissemination of innovative and more productive wa	HC	TRAIN
64	64_Development of special services for employment, training and	HC	TRAIN
65	65_Modernisation and strengthening labour market institutions	HC	TRAIN
66	66_Implementing active and preventive measures on the labour mar	HC	TRAIN
67	67_Measures encouraging active ageing and prolonging working liv	HC	TRAIN
68	68_Support for self-employment and business start-up	HC	TRAIN
69	69_Measures to improve access to employment and increase sustain	HC	TRAIN
70	70_Specific action to increase migrants' participation in employ	HC	TRAIN
71	71_Pathways to integration and re-entry into employment for disa	HC	TRAIN
72	72_Design, introduction and implementing of reforms in education	HC	TRAIN
73	73_Measures to increase participation in education and training	HC	TRAIN
74	74_Developing human potential in the field of research and innov	HC	TRAINH
75	75_Education infrastructure	INFR	IG
76	76_Health infrastructure	INFR	IG
77	77_Childcare infrastructure	INFR	IG
78	78_Housing infrastructure	INFR	IG
79	79_Other social infrastructure	INFR	G
80	80_Promoting the partnerships, pacts and initiatives through the	TA	G
81	81_Mechanisms for improving good policy and programme design, mo	TA	G
82	82_Compensation of any additional costs due to accessibility def	TA	G
83	83_Specific action addressed to compensate additional costs due	TA	G
84	84_Support to compensate additional costs due to climate conditi	TA	G
85	85_Preparation, implementation, monitoring and inspection	TA	G
86	86_Evaluation and studies; information and communication	TA	G

### 4.3 Policy shocks no. 2 & 3: Infrastructure - Other

Regional investments in non-transport infrastructures are typically related to electricity networks improvements, water treatment, and waste management. These are modelled and implemented in RHOMOLO as a public capital-enhancing investments when associated with industrial processes (e.g., "energy efficiency investments"), and as a government consumption when aimed at enhancing the quality of life (e.g., "promotion of clean urban transport"). The reclassification of the total infrastructure expenditure into investments (IG) and government consumption (G) of the 86 ECP financial items is shown in Table 2.

Public capital-enhancing investments are implemented as an exogenous increase in the public investment augmenting the amount of the public capital stock in regions, which is then becoming more abundant and more efficient (see shock number 2 in Table 1). The

remaining investments are instead implemented as a government consumption, to account for the purchase of construction services and materials, etc. (see shock number 3 in Table 1).

Both types of expenditures in the non-transport infrastructure (IG and G) are assumed not to have corresponding permanent structural change effects on regional economies.

#### 4.4 Policy shocks no. 4 & 5: Investment in human capital

The implementation of human capital policies in RHOMOLO consists of a number of steps. First, we calculate the additional school year-equivalents of training that can be purchased with the ECP investment in human capital, per region and skill-group. This estimate permits us to compute how much the average amount of school years embedded in the labour force would change due to the cohesion policy. Then, following QUEST and the empirical literature on Mincer-type regressions (see e.g. Card 2001), one additional school year is assumed to increase labour efficiency by 7%. This parameter is assumed to be identical between all countries and regions. As an attempt to correct for differences in educational quality between countries, we lower the return to education by the education efficiency index (using the EU-wide average of 76% in the case of missing data).<sup>6</sup>

A key piece of the required information is the cost per pupil of different levels of schooling, which is obtained from Eurostat. These data are used as an estimate of how much one year of additional training would cost to train one worker in each of the three skill groups. We take one year of the tertiary-level education as the cost of training for all skill levels, because the majority of the ECP investment in the human capital aims at training of workers.<sup>7</sup>

The last piece of information we use is employment per NUTS2 region by skill level, obtained from Eurostat.

Bringing everything together, we calculate the additional years of schooling which can be purchased with ECP expenditures on human capital per each region and skill group. For the investments under the program "TRAIN" (Policy shock number 4), the ECP investment is split proportionally among skills, relative to their employment shares. For the policy shock number 5, all expenditures are allocated to the high-skill labour. Each year, the number of training-years purchased with the cohesion policy is subtracted from the labour force, such that there is a temporal decrease in the labour supply, as part of the labour force is supposedly unavailable while retraining. Each year, the newly trained from the last year are added back to the labour force and the average productivity is increased. In some regions, and given that the cohesion policy expenditure is increasing steadily over time, this short-run labour supply effect may dominate the increase in the labour productivity in the last years. This masks the unambiguous positive effect in the years after 2015, where there is no more short-run labour supply effect and only a level effect on productivity is present.

Omitting indices for regions, writing  $ld_{e,t}$  for employment of skill group  $e$  in time  $t$ ,  $ld_{e,t}^*$  for the new employment level under the scenario  $TRAIN_{s,t}$  is the total funding under  $TRAINH_{s,t}$  (note that  $TRAINH_{s,t} = 0$  for  $s = \{L, M\}$ ). Write  $empshare_{e,t}$  for the share of employment of skill group  $e$  in the total regional employment, suppose that  $c$  is the cost of education of one pupil for one year in the tertiary education, write  $TLP_{s,t}$  for the labour productivity,

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<sup>6</sup> See Dolton et al. (2014).

<sup>7</sup> The education data are missing for Denmark (we use Sweden as a proxy), Greece (we use Cyprus as a proxy). For a number of countries some data are missing.



and finally assume that  $\theta = 0.07$  for the Mincer-elasticity corrected for the efficiency of the educational system, we then have:

$$ld_{e,t}^* = ld_{e,t} - \frac{empshare_e TRAIN_{e,t}}{c} - \frac{TRAINH_{e,t}}{c} \quad (2)$$

$$TLP_{e,t} = TLP_{e,t-1} + \theta \frac{empshare_s TRAIN_{e,t-1}}{c ld_{e,t}^*} + \theta \frac{empshare_e TRAINH_{e,t-1}}{c ld_{e,t}^*}. \quad (3)$$

Some shortcomings in this approach, which could be improved on in future analyses, are the assumption of an equal Mincer-parameter governing the returns to education in all countries, the fact that educational quality is not properly controlled for, and the fact that the Mincer-parameter excludes the *social* return to education, which stems from externalities.

#### 4.5 Policy shock no. 6: R&D expenditure

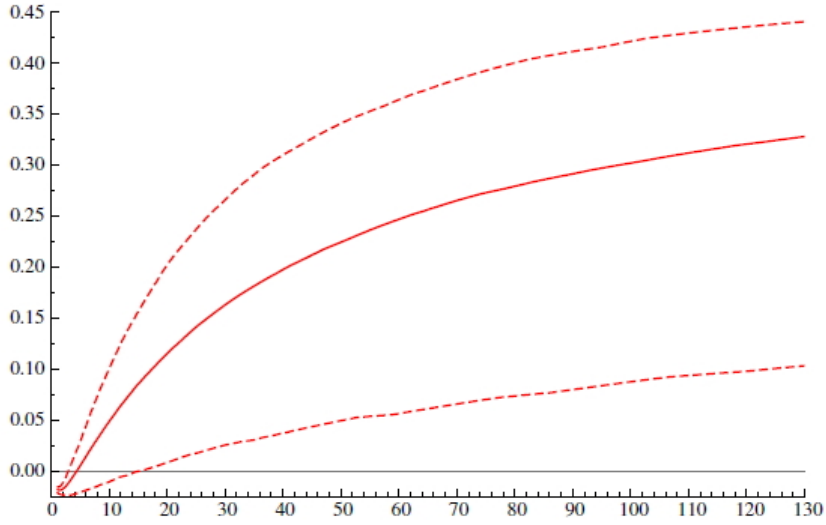
This expenditure is implemented in RHOMOLO through a temporary increase in government expenditure to reflect the additional purchase of good and services related to the firm's investment in RTD.

The permanent effects associated to this policy are simulated through a Total Factor Productivity (TFP) improvement. In order to translate the money injection into TFP shocks in RHOMOLO, we use a simple accounting approach according to which the amount of investments in RTD is directly augmenting the total output in the economy. The TFP improvement is then calculated as follow:

$$\dot{A} = \frac{\delta}{Y} Z \quad (4)$$

where  $\dot{A}$  represents the change in TFP, that is the scale parameter of the production function,  $Z$  is the R&D expenditure,  $Y$  is the output while  $\delta$  is the R&D output elasticity. The parameter  $\delta$  reflects the intensity of the R&D input in the total economy and it is derived from the R&D-productivity relationship estimated by Kancs and Siliverstovs (2016) plotted below in the Figure 5. In order to use this elasticity in our simulations, we need to compute R&D intensities in each region. The regional R&D intensities are calculated by taking the ratio of R&D firms' value added to the total value added (of all sectors) in the region of policy intervention, and adjusting for differences in units. Having regional R&D intensities in the same units as on the horizontal axis in Kancs and Siliverstovs (2016), we can use the corresponding elasticity values on the vertical axis.

**Figure 5: The estimated elasticity of the R&D intensity to TFP**



**Fig. 3.** All companies: Elasticity of the average expected response of TFP (2007) [Y-axis] to R&D intensity in 2006 [X-axis], GPS-adjusted. Dashed lines: bootstrapped 90% confidence interval based on 1000 replications.

Source: Kanacs, D. and B. Siliverstovs (2016).

#### 4.6 Policy shocks no. 7 & 9: Investment subsidies to reduce the risk premium

Regional governments also use the ECP to support investors who want to engage in risky activities that can have a high growth potential for regions, creating jobs and wealth. These funds can be associated with research and innovation activities (as in shock number 7) or any other production activities (as in shock number 9). The two types of shocks are modelled in the same way in simulations because the national R&D sector in RHOMOLO employs only high-skill labour and it is not associated with investments in a specific capital stock. It should also be noted that innovation services in RHOMOLO are only consumed by other firms as intermediates, and therefore innovation is implicitly embedded in other products and services supplied in the regional economy.

The way the risk premium policy is modelled is by affecting the user cost of capital, which in the RHOMOLO model is given by:

$$uck_r = (r + \delta_r)p_{EU}^I + \dot{p}_r^I + rp_r \quad (5)$$

where  $r$  is the interest rate,  $\delta$  is the depreciation rate,  $p_{EU}^I$  is the investment price index in the EU,  $\dot{p}_r^I$  is the change between two subsequent time periods of the investment price index in the regional economies and  $rp$  is the risk premium. Therefore, a change in the risk premium is reflected in  $uck$  as well. In the baseline the capital accumulation rate, that is the ratio between private investments  $I^P$  and the private capital stock  $K^P$  are determined as follows:

$$\frac{I^P}{K^P} = \delta \cdot \left( \frac{rk}{uck} \right)^\rho \quad (6)$$

where  $\rho$  is an elasticity parameter that governs the magnitude of the gap between the rate of the return to capital,  $rk$  and the user cost of capital,  $uck$ .

After the policy shock  $x$  we have

$$\frac{I^P + x}{k^P} = \delta \cdot \left( \frac{rk}{uck'} \right)^\rho \quad (7)$$

where  $uck'$  is what we should obtain after the shock.

$$(uck')^\rho = (rk)^\rho \cdot \frac{\delta K^P}{I^P + x} \quad (8)$$

where the value of  $\rho$  is currently assumed equal to 2. The difference between  $uck'$  and  $uck$  yields the change in the risk premium,  $rp$ .<sup>8</sup>

#### **4.7 Policy shocks N°8, 10 & 11: Production subsidies, Aid to private firms and technical assistance**

The temporary impacts of these shocks on the economy are modelled as increases in the public consumption to account for purchases of goods and services associated with the transfer of resources (shocks number 10 and 11) and as an increase in subsidy to production (shock number 8) There are no direct permanent effects associated to these policy interventions.

## **5 Economic impact analysis**

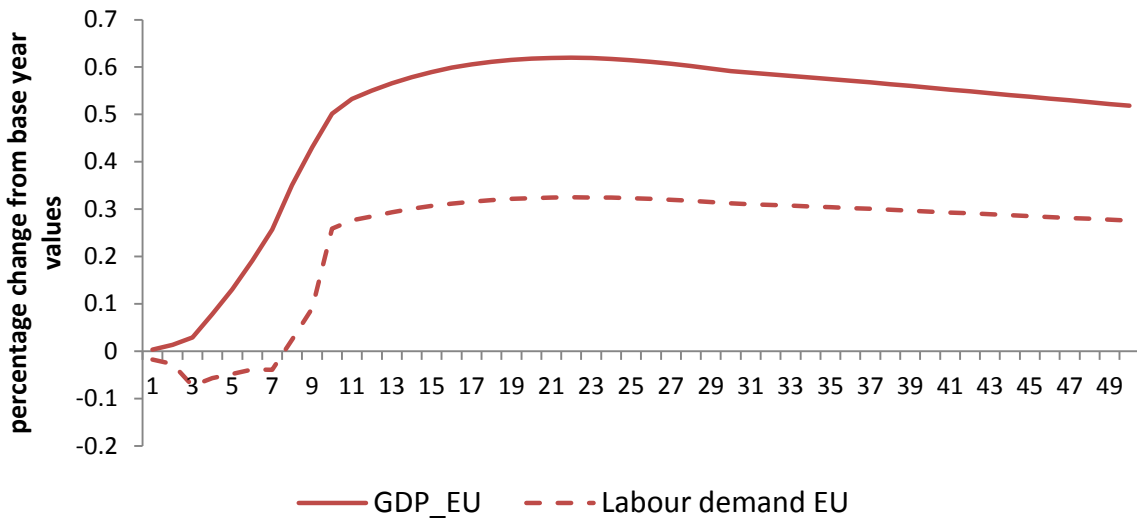
### **5.1 Overall economic impact in the EU**

RHOMOLO simulation results suggest a permanent increase in the aggregate EU GDP for the entire period of the ECP and beyond, with long-lasting effects generated by the structural policies simulated (see Figure 6). In the long-run, GDP increases by 0.5% from its base year value. As for employment, the results suggest a 0.3% long-run increase from the initial steady-state. We observe that over time the simulated change in GDP increases faster than employment. Furthermore, for the first seven periods we observe a fall in employment compared to base year values. This means that capital stocks are rising more than the GDP because of the stimulus to investments provided by the injection of ECP funds in the EU economy mainly targeted to support capital. Moreover, the initial fall in employment is also generated by the labour productivity shocks associated with the ECP, where the demand for labour in efficiency units is constrained by the rise in productivity. However, overall employment does rise in the long-run, implying that the general equilibrium demand curve for labour is wage-elastic over time. Naturally, due to a reallocation of workers from work to training, it would not be a surprise to observe a temporary significant reduction in employment in some EU regions.

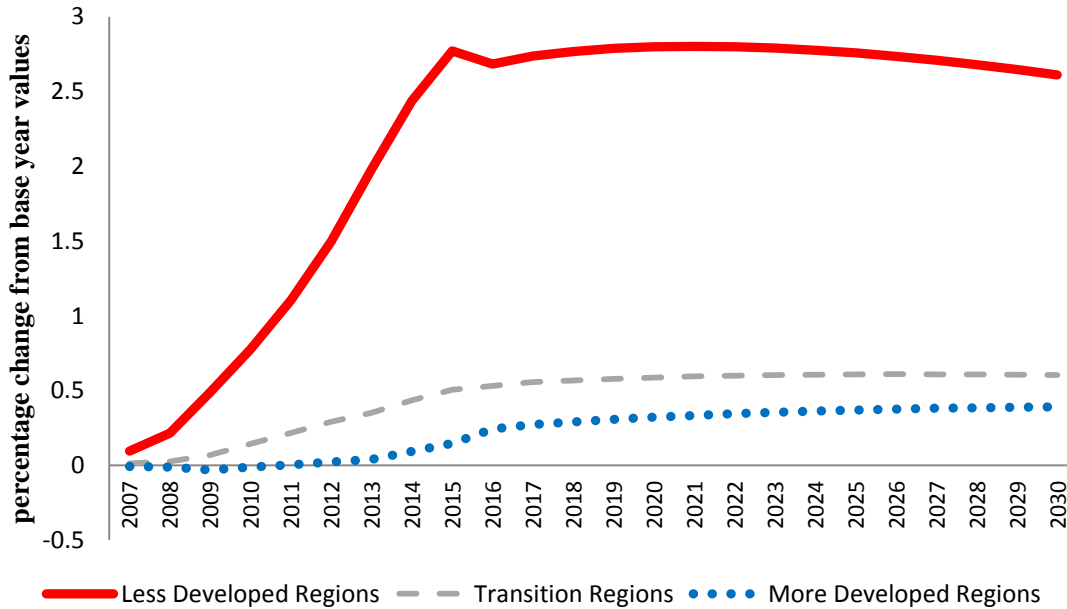
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<sup>8</sup> A similar strategy has been adopted in the ECFIN's QUEST model to assess impacts of the EFSI. It seems a rather conservative estimate considering that implicitly we assume a multiplier of 1. Future simulations will include a sensitivity analysis with multipliers  $>1$ .

**Figure 6: ECP impact on EU GDP and employment as percentage changes from base year values**



**Figure 7: The average impact on GDP per region groups as percentage changes from base line values**



As shown in Figure 1, less developed regions receive a large share of ECP funds with respect to their GDP; therefore we would expect a higher economic impact in this group of regions. In order to facilitate the tractability of simulation results, Figure 7 plots the average impact on GDP in terms of percentage deviations from the baseline GDP by regrouping all regions according to their level of the economic development: less developed regions, transition regions, and more developed regions.

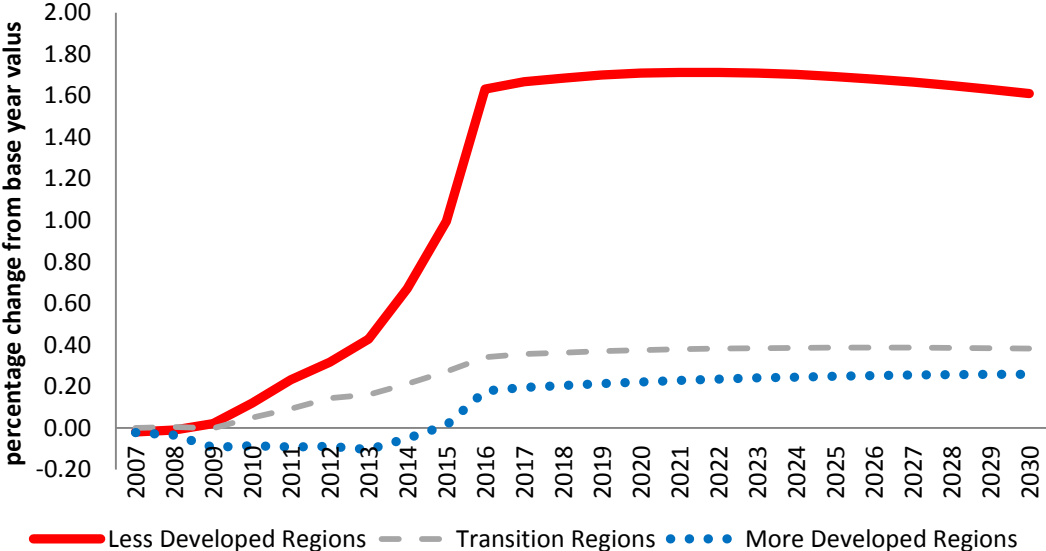
Unsurprisingly, the results depicted in Figure 7, are consistent with the allocation of the ECP funding. According to our simulations results, less developed regions would enjoy the highest increase in GDP in the long-run: by 2030, around 2.18% above the base year values. The long-run impact is significantly lower for the other two groups of regions: around 0.6% and 0.4% for regions in transition and more developed regions, respectively.

In the short-run, our simulation results suggest a much less pronounced difference relative to the impact of ECP funds among the three groups of regions. In all three cases, economic activities increase. Yet, the larger economic impact is estimated to occur for less developed regions. As for the other two groups of regions, it is worth noticing that the group of more developed region records negative changes in GDP until 2011. This effect has to be attributed to the effort made by the richer countries to transfers resources to the poorer regions. Furthermore, given the large presence of high skill workers in these regions the productivity potential tends to materialize with some delays. It is likely therefore to expect a drop in employment in these regions in the first periods of the shock.

As for the change in employment, the transition path follows that of GDP, as we can appreciate from Figure 8. The long-run employment impact suggests that total employment in the year 2030 increases by more than 1.6% in less developed regions, while the employment change in transition regions and more developed regions is about 0.4% and 0.25% above base year values, respectively. In the short-run, more developed regions and less developed regions register a fall in employment, while regions in transition records positive change in employment since the beginning of the shock. The lower demand for labour in more developed regions is related to the fact that these regions are net contributors of the policy. As seen above in Figure 7, in the firsts four periods of the simulation these regions experience a fall in economic activity that is naturally reflected in lower labour demand.

As for the less developed regions, the drop in employment is undoubtedly related to the fact that in more developed regions economic activities is less labour intensive. Given that the shock implies a massive increase in investments, greater substitution effects in favour of capital and away from labour occur in these regions.

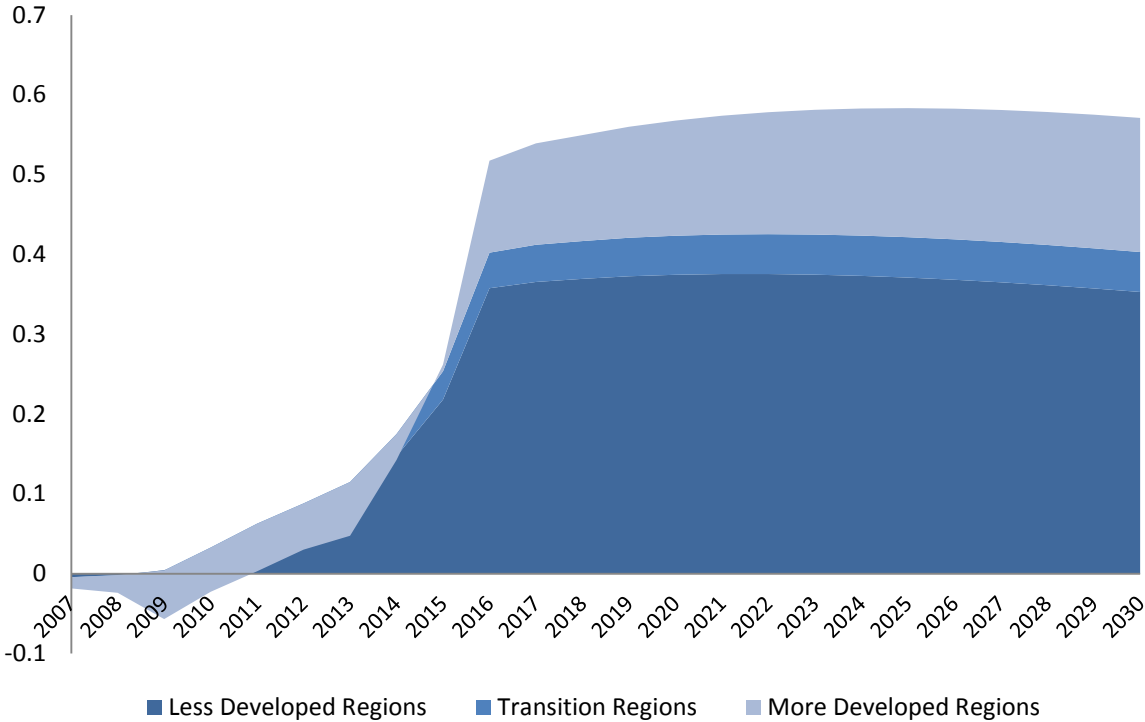
**Figure 8: Average impacts on employment in terms of percentage deviations from the base year employment (three region groups)**



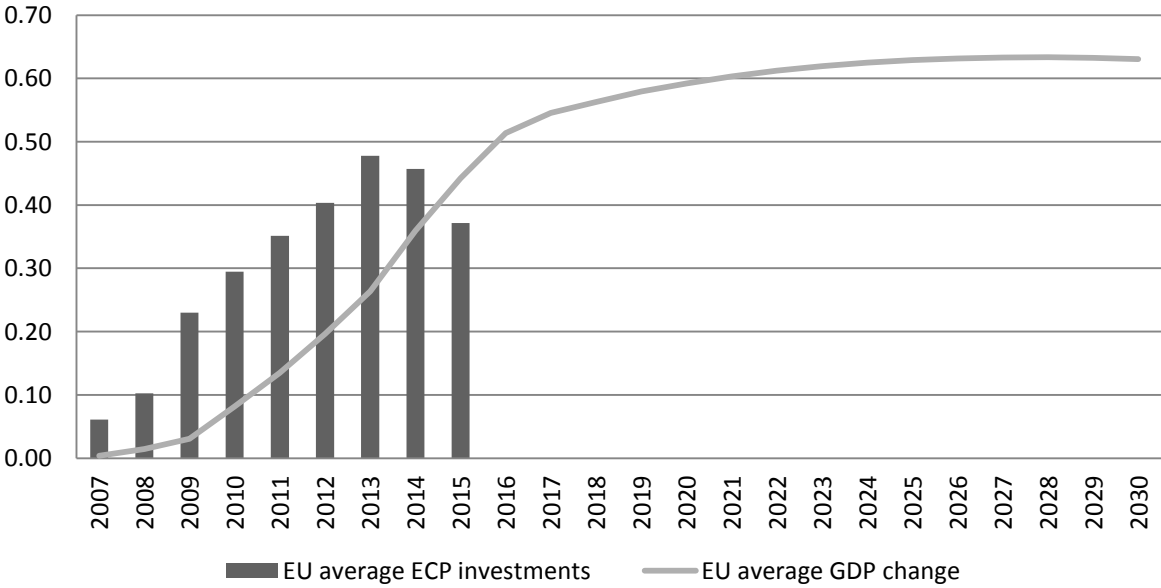
It is interesting to analyse the relative contribution of each group of regions to the change in the aggregate EU GDP due to the policy shock. For this purpose, in Figure 9, we report the relative contributions to the overall impact on the EU GDP generated by the three groups of regions in percentage of the total EU GDP. This chart suggests that not only less developed regions were largely enjoying higher GDP effects, but these

regions are also contributing significantly to the overall EU growth. They are generating more than half of the overall GDP growth in the EU, despite their lower GDP per-capita.

**Figure 9: Contributions to the overall impact of the EU GDP in % of total EU GDP (three groups of regions)**



**Figure 10: ECP investments as a share of GDP (bars) and ECP impact as percentage changes from the base year GDP (grey line)**



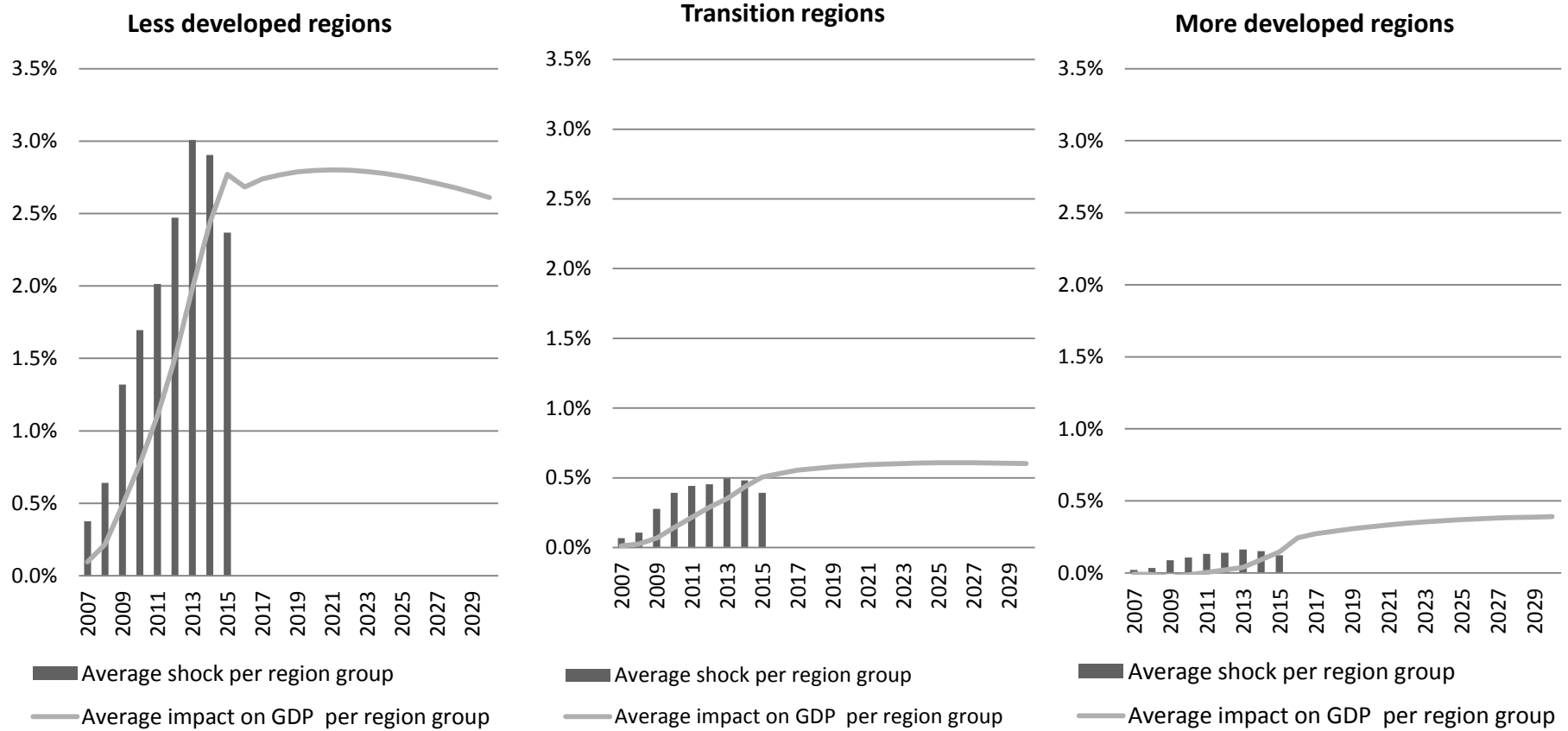
Next, we attempt to investigate whether and to what extent the costs associated with the funding of ECP policies are fully offset by the benefits generated from the increase in economic activity in the entire EU economy. For this purpose, Figure 10 shows the level of the investment shock (bars) as a share of GDP and the average impact on GDP (grey line) for the whole EU. Figure 10 above suggests that in the short-run and for the period ranging from 2007 to 2014, investment costs are higher than investment benefits. Nevertheless, after this period, positive permanent effects dominate over financial costs of the simulated policy. We should remind the reader that multiplier effects are positive for the whole transition path, but in the initial periods the multipliers are lower than one.

It takes time before the full supply-side effects of the ECP intervention materialize in a multiplier effect greater than 1. This simulation results advise that at the beginning of the injection period crowding out effects and displacement effects may emerge in some regions (particularly those which are net contributors). However, the structural change effects associated to the intervention might be very substantial and able to generate multipliers greater than 1 in the medium to long run.

By regrouping all EU regions according to their levels of economic development, we notice some differences between the three groups of regions as reported in Figure 11 where, for the sake of comparability, the vertical axis coincides for all three groups of regions.

We observe that the simulated difference between costs and benefits in all three groups of regions reflects by and large those reported for the overall EU economy. Despite the fact that less developed regions enjoyed a higher investment support relative to their own GDP than transition and more developed regions throughout 2007-2015, for all three macro-regions the benefits of the policy become higher than the investment cost only five periods after the beginning of the EU programme. It is also interesting to see that for more developed regions the curve of the average GDP change is below the corresponding average investment curve for the firsts three periods, resulting therefore in very small multiplier effects.

**Figure 11: ECP investments as a share of GDP (histogram) and percentage deviations in GDP due to the ECP (grey lines) for less developed regions (left), transition regions (centre) and more developed regions (right)**





The dynamics of the short-run multiplier is very similar for all three groups of regions: multiplier effects are small and not enough to offset the financial costs related to the policy. This could be explained with the argument that a relatively long time is needed before the economies are able to fully capture the benefit of the policy. For example, financing R&D and innovation projects may generate little benefit in the short-run, since it takes time to train high-skill researchers or to attract them from other regions. As a result, the full impact of public investment may be delayed. Furthermore, it takes time before the accumulated stock of R&D generated through more employment in R&D sectors is able to produce the expected system-wide productivity effects.

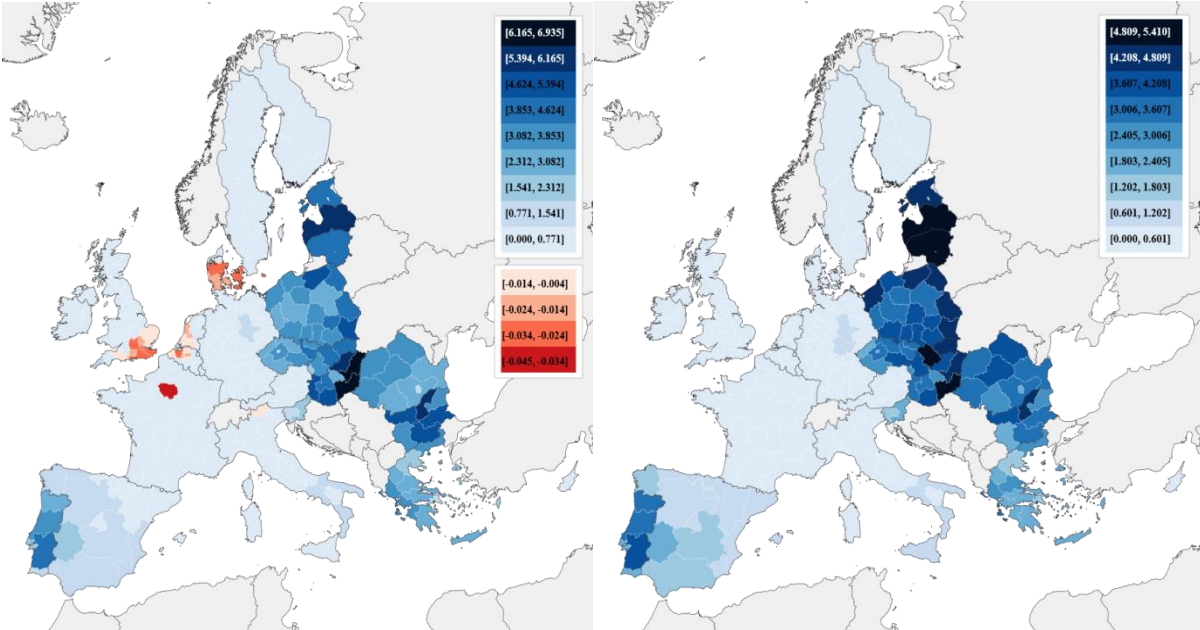
In this Section we have only focused on the multiplier effects obtained for the EU as a whole and for three macro regions. We offer a more detailed regional analysis in the remainder of the paper, particularly in Section 5.2.

**5.2 Regional Economic Impact**

We have seen that the simulated ECP shock is expected to generate a significant positive impact for the overall EU. However, the uneven allocation of ECP funds associated to endogenous trade and spillover effects among regions, could determine a different geographical pattern. Some regions (even within the same group identified above) could in principle gain less than others.

In Figure 12 we report the spatial distribution of the ECP impact for 2015 (left pane) and 2023 (right pane). Note that darker colours denote higher regional changes in GDP with respect to the base year values, while red colours identify negative changes in GDP.

**Figure 12: GDP impact of the ECP investment in EU regions in 2015 (left pane) and in 2023 (right pane) - percentage changes from the base year**



According to Figure 12, several regions located in the Eastern Europe, Spain, and Portugal would benefit significantly from the ECP investment in terms of the GDP growth. Notice that the spatial pattern of investment-induced GDP growth is distributed more evenly across EU regions than the direct investment pattern reported in Figure 3. This result is due to spatial linkages across regional economies, such as trade of goods and

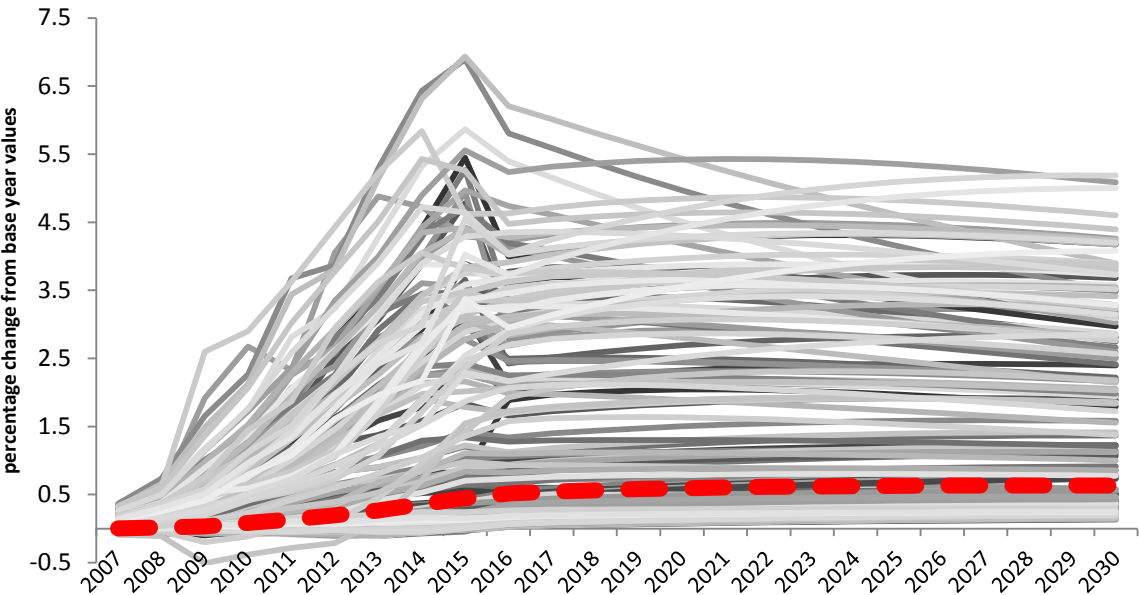
services, income flows, factor mobility and knowledge spillovers, which lead to dissemination of the policy support in a region across space to other regions.

We can observe that in year 2015 some of the regions are still not able to fully capture and thus absorb the benefit of the ECP investments. Some regions in Belgium, Netherland, Denmark, and the South of the UK, report negative changes in GDP from the base year values. This is also the case of Île-de-France, the only French regions with a negative impact in the 2015. As explained above, the short-run impact obtained in these regions is strictly affected by the additional effort made by these more developed regions to finance the overall ECP at the benefit of less developed regions. However, as the economy expands further, none of the EU regions record negative GDP impact in 2023.

Given the size of the monetary injection received, some regions in the Eastern part of the EU alongside the South of Italy and the South of Spain are able to gain relatively more than others from the ECP monetary injection.

We now present the dynamics of the ECP investment-induced impact on regional GDP. Figure 13 plots the impact on the regional GDP for all the EU regions and for the EU total (the latter being the bold dashed red line).

**Figure 13: The regional impact of ECP investments in terms of percentage deviations from the baseline GDP (grey lines) and EU total (bold dashed line)**



The investment-induced medium- to long-run impact on the GDP growth in the EU stabilises at about 0.7% above the baseline scenario (i.e., in the absence of ECP investments).

However, there are important differences across EU regions and over time. While in the long-run all EU regions benefit from ECP investments, there are a number of regions where changes in GDP are below the EU average. In the first period after the shock, the EU average GDP is around 0.01% from the baseline steady state, with regional impacts ranging between -0.1% and 0.35%. In 2030, the difference of the impact between regions becomes even wider, in the order of 0.24% to 5%. This is due to the fact that in the short-run it takes time for regions to adjust their specialisation and production patterns according to the changed macroeconomic conditions. However, over time capital constraints are relaxed and regional economies move towards a full adjustment; and

building on their competitive advantage and productivity levels, regions could in principle amplify their market shares in the rest of EU markets at the detriment of less specialised regions and in the rest of the World. Naturally, one could expect that less supported regions could partially loosen up their market potentials as it would be the case, if two similarly specialised regions are located close to each other and only one of them receive the ECP investment support. In this case, the increased competitive advantage of the supported region (e.g. due to higher productivity) may subtract market shares from the non-supported region. However, these effects turn out to be limited, as there is not a single region which would have a negative net impact of ECP investments in the long-run.

### **5.3 The economic impact in three representative regions**

We have observed that more developed regions experience in the short-run negative economic impact, while in transition regions and less developed regions the economic activity increases since the outset. Given the different combination of shocks resulting from the implementation of the ECP and the heterogeneous structure of the economy associated to these three macro regions, it is likely to expect a distinctive economic adjustments occurring in each of these regions. To better understand the nature of these adjustments, we select one representative region belonging to each macro region and report the evolution of a set of selected variables. In Figure 14 we report the percentage changes from base year values for the Île-de-France region of France (FR10) where GDP, employment, export, household consumption, investments and the consumer price index (CPI) are plotted. The same economic variables are reported in Figure 15 and Figure 16 for Andalusia (ES61 - transition region) and Warmińsko-Mazurskie (PL62 - less developed region), respectively.

In the case of the capital region in France, we observe negative changes in GDP, employment, investments and household consumption for the firsts nine periods, namely for the whole ECP disbursements period. Household consumption drops with a negative peak recorded in 2013. This occurs as a result of the transfer of resources from richer to poorer regions implying a significant reduction in household income able to fully offset the positive benefits associated to the increase in investments. Indeed, it results in an average annual contribution of this region, over the 2007-2014 periods, of around 0.32% of its GDP, while the average annual payments received in the same period is in the order of 0.025% of the GDP.

The gap between payments and receipts is determining the sign of the economic impact in the first periods of the shock. In this time frame, the fall in demand of goods and services is also able to reduce the demand for capital goods that in turn generate a fall in capital stock. Firms must therefore reduce employment. It is interesting to see that competitiveness in the regions increase, although not enough to generate net economic benefit in the short run.

However, this is a region with a large share of high skill workers, especially employed in the R&D sector. Consequently, soon after 2015 the stock of knowledge accumulated yields a system-wide productivity improvement which allows the economy to increase competitiveness even further and finally generate an increase in output and employment.

Figure 14: Regional impact of ECP investments in FR10 (percentage changes from base year values)

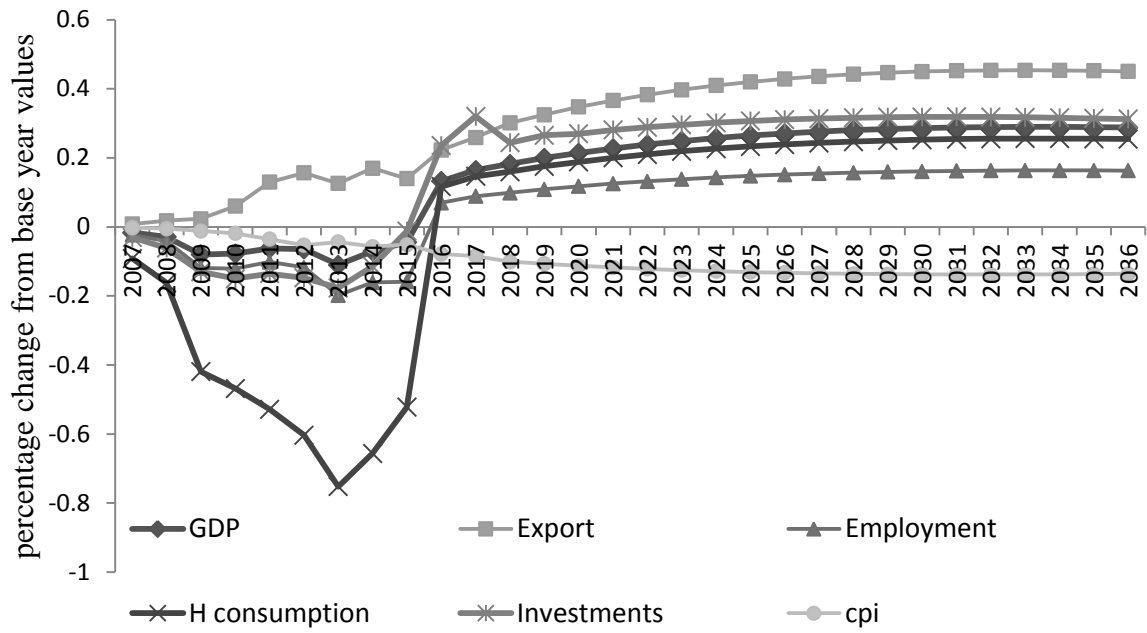


Figure 15: Regional impact of ECP investments in ES61 (percentage changes from base year values)

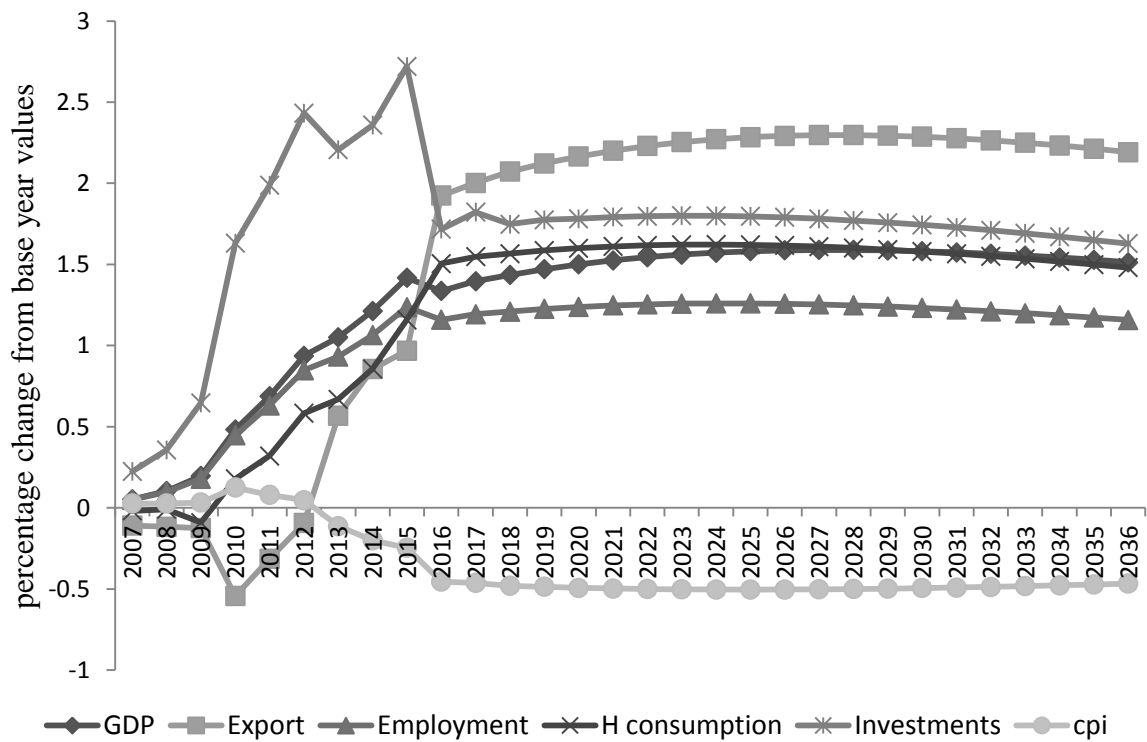
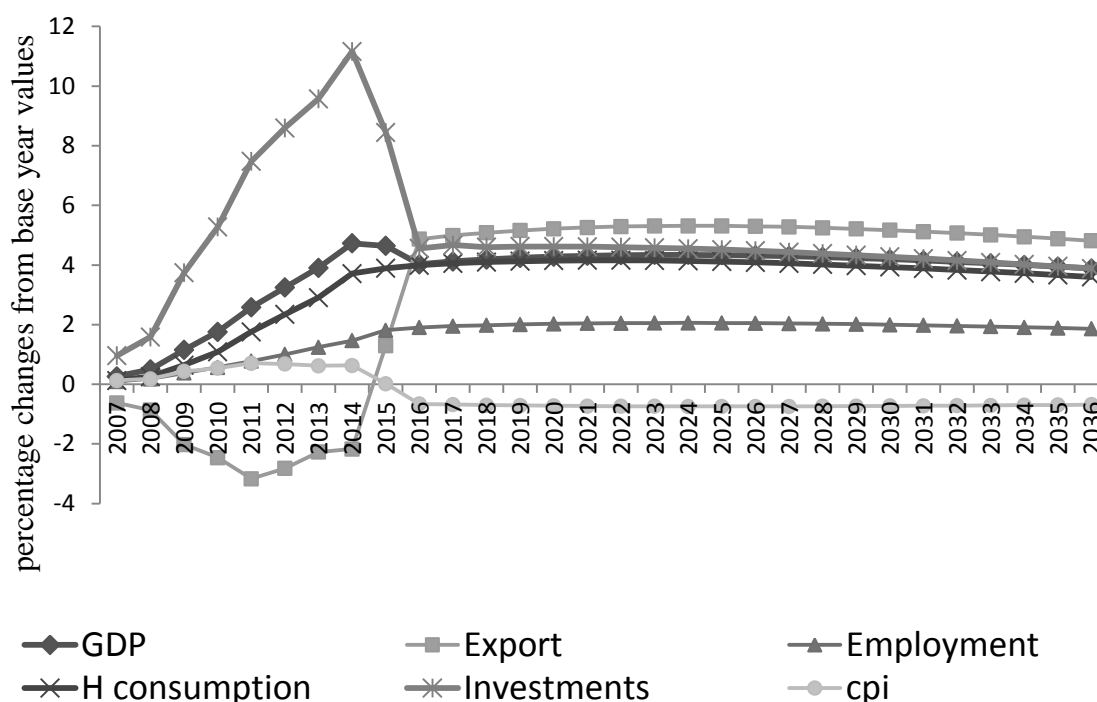


Figure 16: Regional impact of ECP investments in PL62 (percentage changes from base year values)



A different economic adjustment path occurs in the case of the transition region, here represented by the region of Andalusia (Figure 15). Here household consumption is slightly falling for the first three periods of the shock, meaning that the burden attached to this region is substantially lower than that of Île-de-France and indeed too small to counteract the positive effects associated to the increase in investments. This is indeed a region with substantial positive net receipts (direct investment less contribution). Hence, it is not surprising to observe a dramatic increase in investments reaching its peak in 2015, as well as an immediate rise in GDP and employment since the beginning of the shock. However, in the very short-run Andalusia experiences a fall in competitiveness due to an increase in prices (see the CPI line) that generates a reduction in export below its base year value lasting until 2012. Nevertheless, this temporary negative effect is too small to produce offsetting effects on the economic activity.

A similar adjustment path is observed for the case of Warmińsko-Mazurskie as depicted in Figure 16. In this region, the change in household consumption is positive since the outset. The contribution made by this region in terms of ECP funds it is a tiny share of its own GDP and very little compared to the case of the Île-de-France region and Andalusia. The average annual contribution made to the ECP for the 2007-2014 period is about 0.33% of its own GDP, while the direct monetary injection received through ECP funds equates to an annual average of 4.2% of GDP. This can be appreciated from the huge increase in investment (private and capital), as shown in Figure 16, rising constantly until 2014.

The magnitude of the impacts and the different adjustments path between the three regions is generally determined but the contribution made by a given region relative to the monetary injection received in term of ECP funds. We have seen that, if a region is a net recipient, even in the short-run multiplier effects are positive and crowding-in effects are registered not only for GDP and employment, but also for household consumption.

However, if a region is a strong net contributor, crowding-out effects on GDP, employment and consumption are likely to occur in the short-run. Nonetheless, in the long-run, due to the high share of skill labour generally present in these regions, productivity effects arise making these economies growing faster and eventually enjoying the full benefits of the ECP.

## 6 Cumulative multiplier effects

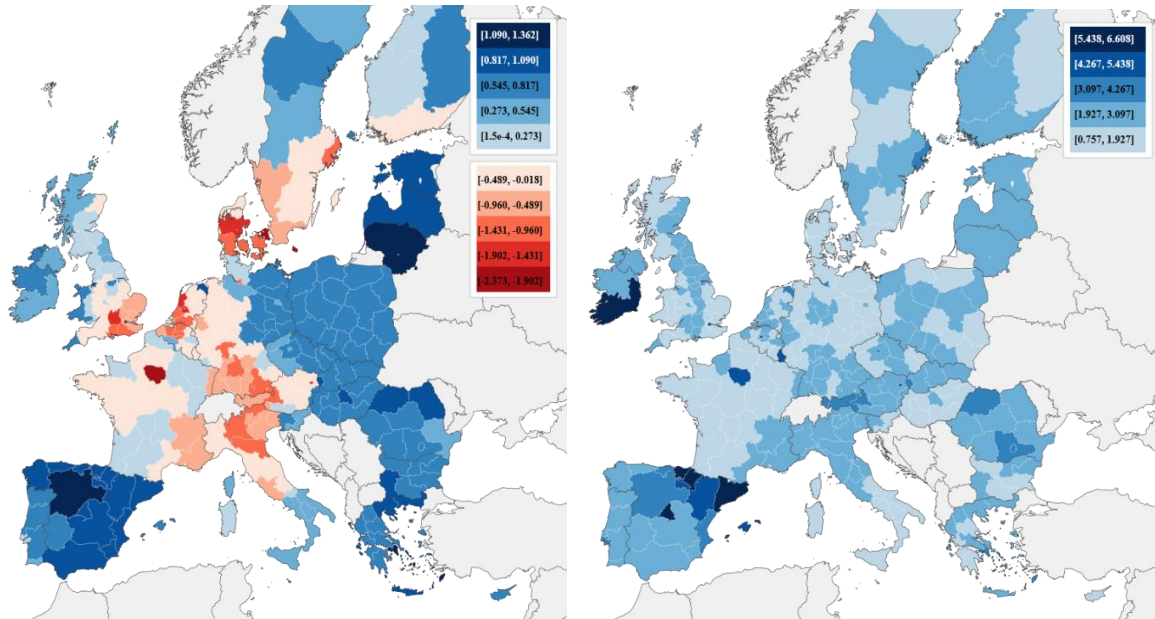
In the preceding sections we discussed the results by reporting and analysing the period by period percentage deviation from base year values of main economic variables. In this section, however we are investigating the extent to which an injection of one euro into the economy is able to generate an overall increase in output. To do so, we calculate for each region the multiplier effects associated to the ECP expenditures. The calculated multiplier is given by the ratio of absolute changes in outputs  $\Delta Y$  to the additional expenditure introduced exogenously into the economy  $\Delta G$ . For instance, if the multiplier is equal to 1.2, it means that 1 additional euro introduced into the economy generate a rise in output of 1.2 euro.

The multiplier is very useful especially when policymakers are interested to quantify the capacity of the economy to generate indirect economic effects derived from the policy intervention. Our main focus is however on the cumulative multiplier effects, given the dynamic nature of the ECP intervention. The measure of cumulative multiplier is obtained by dividing the cumulative absolute changes in output resulting from model's simulation to the cumulative changes in expenditures (the policy intervention) for a given time interval. In particular, we focus on the cumulative multiplier in 2015 and in 2023 obtained by summing up changes in output and expenditure from the year 2007 to the year 2015 and from the year 2007 to the year 2023, respectively.

In Figure 17 we plot the cumulative multiplier impact in 2015 (left pane) and 2023 (right pane). Focussing for the moment on 2015, we observe that only 157 regions register positive multiplier effects, while for the rest of 267 regions of the EU, the sign of the multiplier is negative. Furthermore, it is worth noticing that among those regions with positive multiplier effects, only 8 regions are able to generate additional effects that are greater than the direct injections, that is to say with a multiplier which is greater than 1. These are three regions in Spain (ES41, ES21 and ES22), four regions in Greece (GR11, GR22, GR30 and GR42) and Lithuania (LT00).

We observe that all the central regions in Europe, and specifically all the net-contributor regions, are generally reporting negative multiplier effects. These are signalled in red in the map of Figure 17. These regions, through the reduction in household income, are financing a substantial share of the entire ECP, therefore we would expect positive effects to occur with some delay. On the other hand, the Eastern European regions, along with the South of Italy and France, and all the regions of Spain are not only those receiving bigger injections, but are typically net-receiver regions, therefore recording positive multiplier effects.

**Figure 17: Cumulative multiplier impacts in 2015 (left pane) and 2023 (right pane)**



More homogenous effects are registered in 2023 (Figure 17, right pane). The cumulative impact up to this period is such that all regions in the EU except DK02 are able to generate cumulative multiplier greater than 1. A great number of regions record a cumulative multiplier effects around 2, meaning that 17 periods after the first ECP injections, a significant number of regions are able to at least double the direct effects of the policy. Essentially, we can say that at least half of the regions populating the EU (specifically, 136 regions) have a multiplier larger than 2. The maximum multiplier of around 6.5 is recorded in ES22, ES30, and IE02.

The size and the sign of the multipliers are affected by a number of factors. One of the factors determining the magnitude of the multiplier is whether the region is a net receiver or a net contributor of the ECP. The structure of the economy (labour intensity, export orientation...) is also crucial to understand whether a region is capable to generate additional impacts. For example, small import shares amplify the multiplier effects because the economy is able to satisfy the internal increase in demand generated by the ECP through domestic production of goods and services.

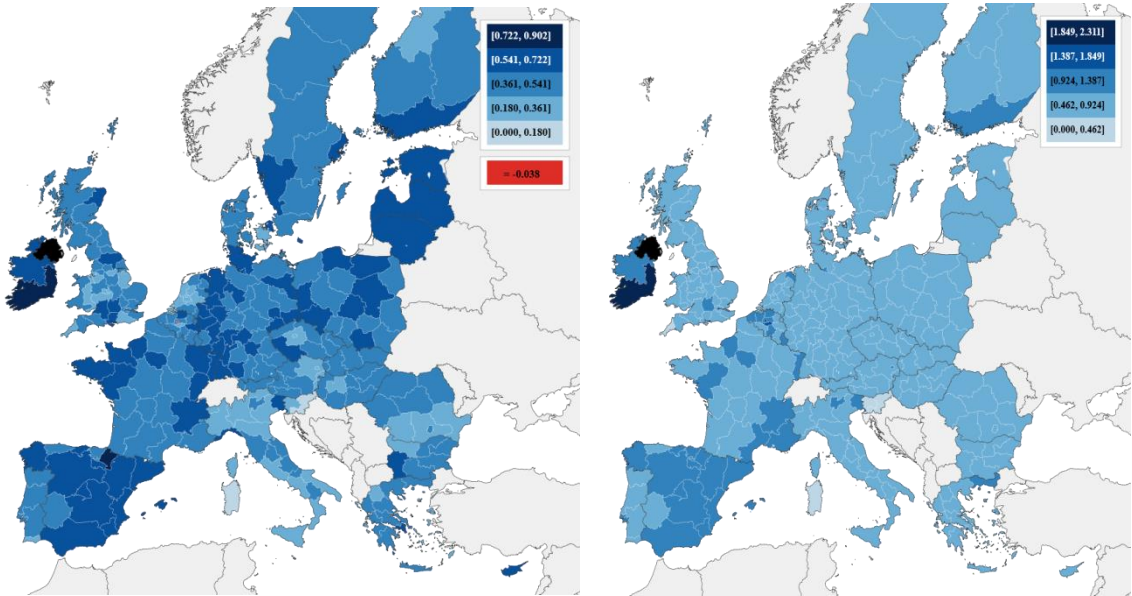
However, since the ECP is simulated through a combination of shocks and due to the spillover effects modelled in RHOMOLO, it is hard to disentangle the importance of a single shock in one region and of the specific characteristic of its economic structure. For instance, a labour productivity shock is able to generate higher impacts if the share of labour in the region is relatively higher. The multiplier effects in this case will expand further if the region is also particularly export-oriented with low import shares.

At least for the whole injection period (2007-2015), we would expect relatively high correlation between the capital shares in GDP and the multiplier effects registered in 2015, since a significant amount of the ECP goes directly to stimulate capital through an increase in investment (implemented in the model reducing the risk premium). As expected, the calculated correlation coefficient equates to 0.4 in 2015 and 0.2 in 2023. Moreover, the fact that we are simulating the policy in all regions simultaneously adds further complexity while trying to separate the factors determining the multiplier effects. For this reason, we separately simulate the shocks in the 267 regions imputing the corresponding combination of shocks in one region at a time. The results of this



experiment are plotted in Figure 18 below where we report the cumulative multiplier impact for 2015 (left pane) and 2023 (right pane). We can immediately appreciate the differences with Figure 17. In 2015, all regions except BE10 have positive multipliers. In addition, in both time frames the homogeneity of results is surely more marked than in the case analysed above. In 2023, the multiplier impact lies between 0.33 and 2.3 (and the BE10 region is now recording the highest multiplier).

**Figure 18: Cumulative multiplier impacts in 2015 (left pane) and 2023 (right pane) - shocks to individual regions**



For each region, the multiplier calculated with single-region shocks are lower than those obtained by shocking all regions simultaneously. This is not a surprising outcome. When all regions are receiving an injection, the increase in output in one region spills over to other regions through increased trade and amplifies the magnitude of the multiplier.

It is interesting to determine the relationship between the multipliers calculated in the two different ways. To this purpose, in Figure 19 we show the scatter plot of the 2015 multiplier obtained by shocking all regions simultaneously (vertical axis) and the multiplier obtained with each region shocked separately (horizontal axis). In Figure 20 we do the same exercise for the year 2023.

These charts suggest that there is almost no correlation between the two types of simulations in 2015. However, the correlation coefficient is relatively high when the year 2023 is considered. The main reason for this is that in the latter period all regions are gaining from the ECP and a significant number of regions are able to get higher multiplier effects regardless of how the shocked is performed.

This suggests some caution when analysing the simulated ECP impact. In the short-run, coordinated policy interventions among the EU regions could result in negative spillover impacts that in some cases yield crowding out effects. However, in the long-run all EU regions enjoy the spillover effects of the coordinated policy and these effects are certainly higher than those of unsynchronized policies.



Figure 19: Correlations between 2015 multipliers (all regions vs single regions shocks)

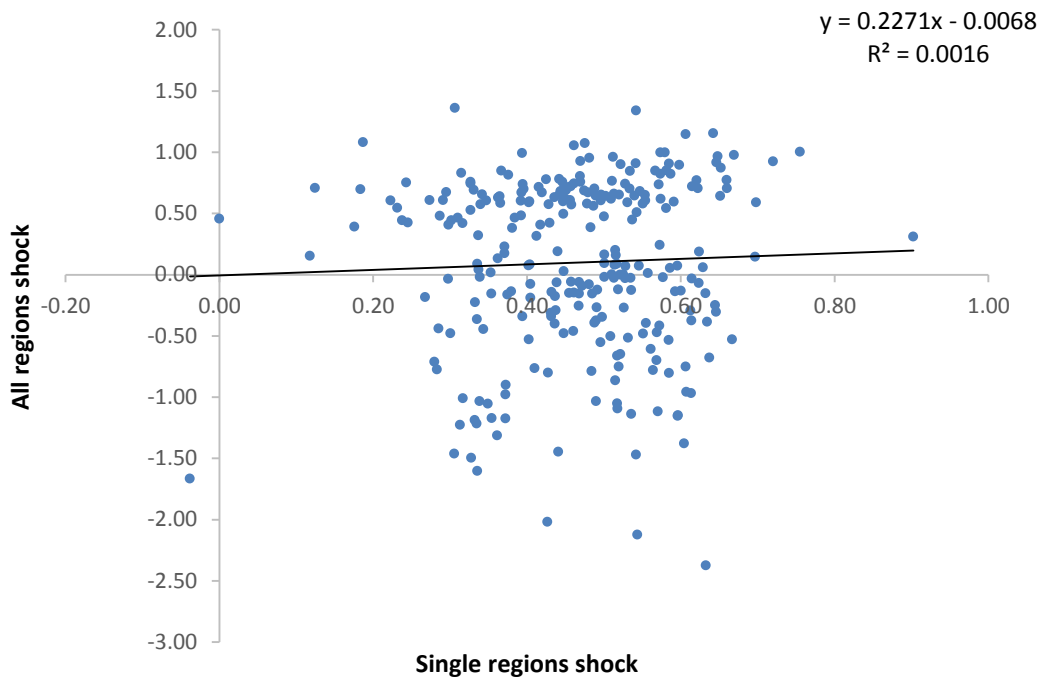
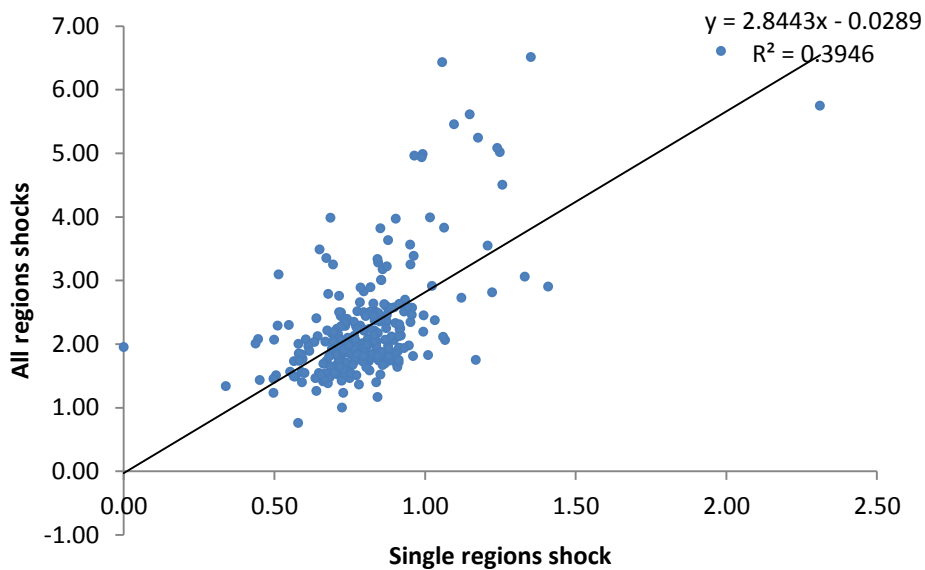
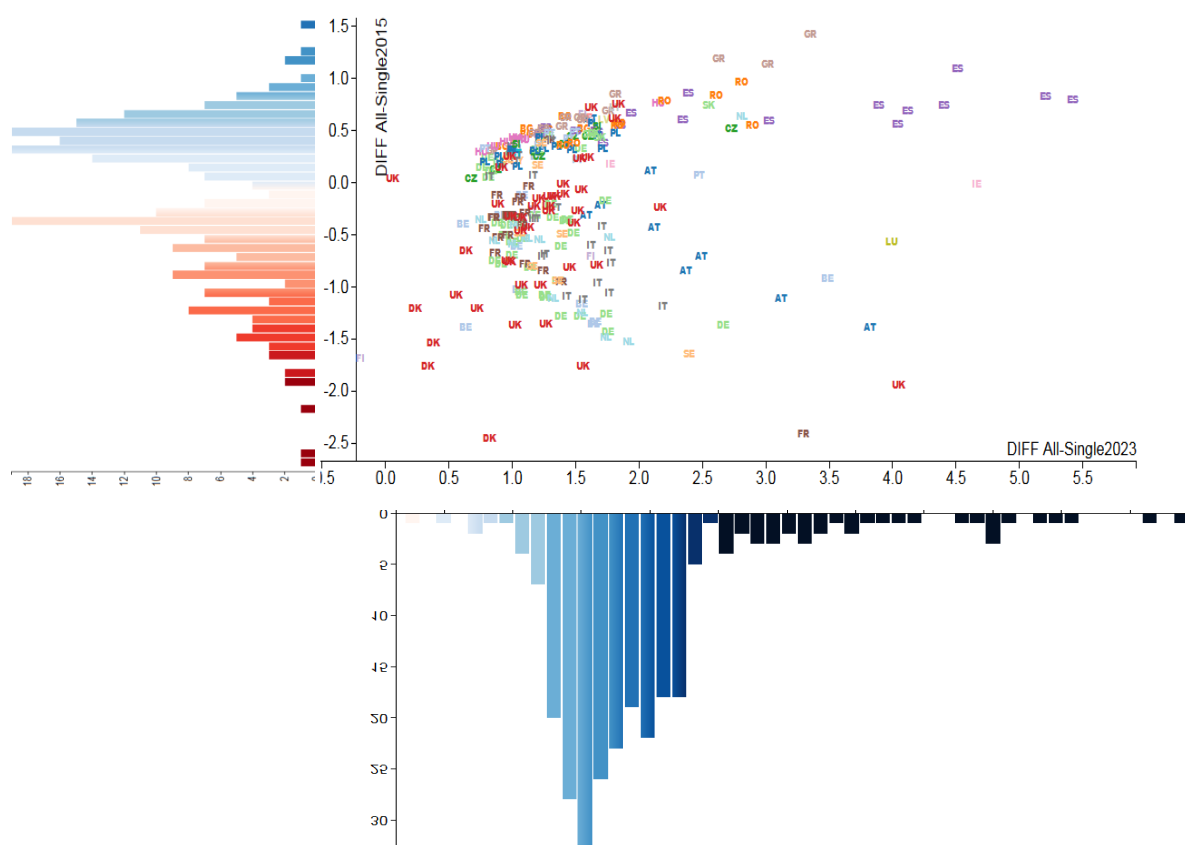


Figure 20: Correlations between 2023 multipliers (all regions vs single regions shocks)



To reinforce this message, in Figure 21 we show the scatter plot and the associated histograms between the differences between the multipliers arising from the two types of simulations for the period 2015 (vertical axis) and the period 2023 (horizontal axis). There is no correlation between the two differences. Essentially, while the cumulative multiplier differences between the two types of shocks in 2023 lie between 1 and 2, the same multiplier differences in 2015 record a wider gap, between -1.5 and 1.

**Figure 21: Scatter plot and histograms of the multiplier differences obtained by shocking regions either simultaneously or individually for 2015 (vertical axis) and 2023 (horizontal axis)**



## 7 The macroeconomic impact of improving accessibility within EU

In the previous sections we presented the regional macroeconomic impact for the whole ECP resulting from the combination of a number of policy shocks: transport infrastructure investments, other infrastructure investments, investments in human capital, investments in research and innovation, aid to the private sector, and technical assistance.

In this Section, however, we analyse solely the impact of the transport infrastructure investment, particularly focussing on the permanent economic impact of this policy. This is particularly relevant because an important share of the 2007-2015 ECP is allocated to the construction of the transport infrastructure. Furthermore, transport infrastructure-related policies represent a suitable example for analysing potential dispersion and agglomeration effects. Indeed, spatial interactions between regional economies are captured through trade of goods and services which are subject to trade costs, and the RHOMOLO model is particularly well suited for the analysis of such policies.

The ECP long-run effects related to transport infrastructure investments have been translated into a reduction of bilateral transportation costs between and within NUTS2 regions within RHOMOLO. This affects the domestic and export price of goods and services making regional economies more competitive, and generates a further increase in economic activities driven by a fall in prices, triggering further general equilibrium effects. In principle, a negative impact is possible for some regions, as for some regions the policy could imply a loss in relative competitiveness.

**Figure 22: Accessibility improvement expressed in percentage changes due to the ECP in transport infrastructure during the 2007-2015 period**

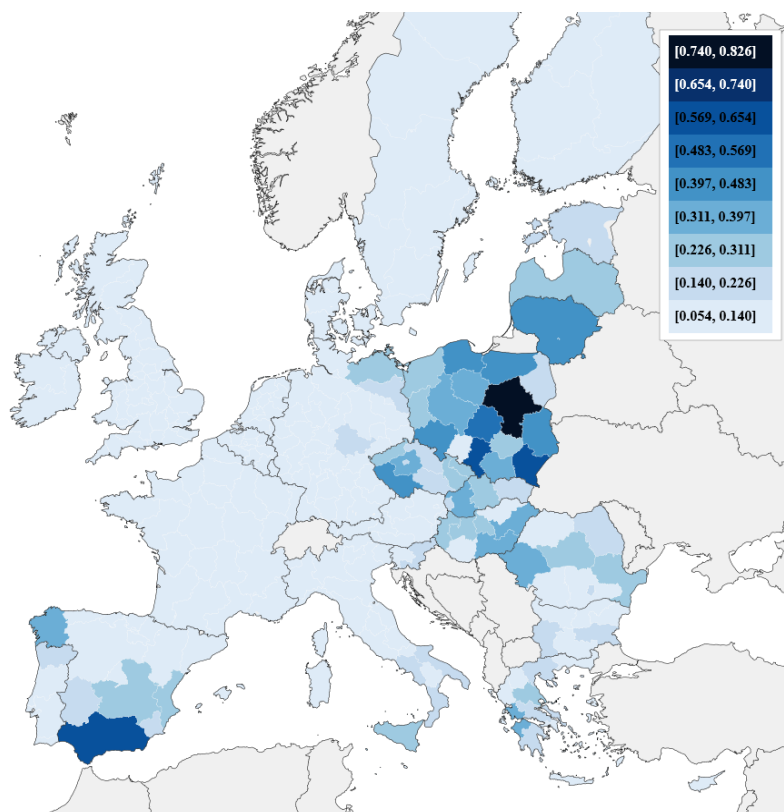


Figure 22 shows how ECP-financed investments in transport infrastructure change the accessibility of EU regions. Lighter colours denote lower improvements in accessibility, while darker blue shades identify better accessibility through lower transportation costs. This accessibility information is the result of the combination of information from RHOMOLO data and the TRANSTOOLS model and of our own estimations.

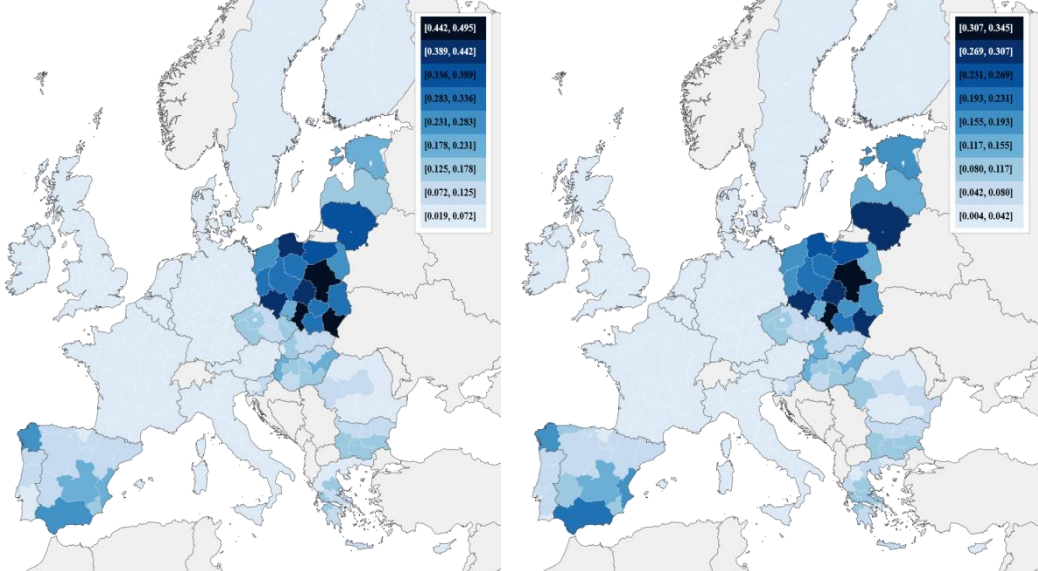
A number of regions in Southern and Eastern Europe would significantly benefit from ECP-financed transport infrastructure investments in terms of improved accessibility. In the rest of the EU regions accessibility would also increase, though less significantly.

Our focus is to quantify the contribution of the improvement in transport infrastructure on the overall ECP intervention. The simulation implies an exogenous temporary increase in final demand of goods and services to emulate an increase in consumption resulting from the construction of new infrastructures, and an associated permanent effect simulated through a reduction in bilateral transport costs. This means that it is believed that policies aiming to enhance transport infrastructures should generate permanent effects although subject to some depreciation (a 3% annual rate is applied). This specific policy intervention is assumed to be financed by a reduction in household income in all regions according to the individual contribution to the EU budget as identified in Figure 4.

In the long-run, EU GDP is above its base year values although some countries such as Luxemburg, Denmark, Ireland and Sweden experience negative economic changes in the short-run. Long-run results for all the EU regions are mapped in Figure 23 where the changes in GDP and employment are shown for the full policy intervention. Results suggest that the indirect effect associated with the transport infrastructure investment

and the induced impact generated by the positive spillover effect of the transport shock fully offset any potential negative direct impact in regions which are net contributors to the policy. There is an estimated positive impact on GDP and employment in the long run for all regions

**Figure 23: Impact of the ECP investments in transport infrastructure on GDP growth (left pane) and employment (right pane) - percentage changes from the base year**

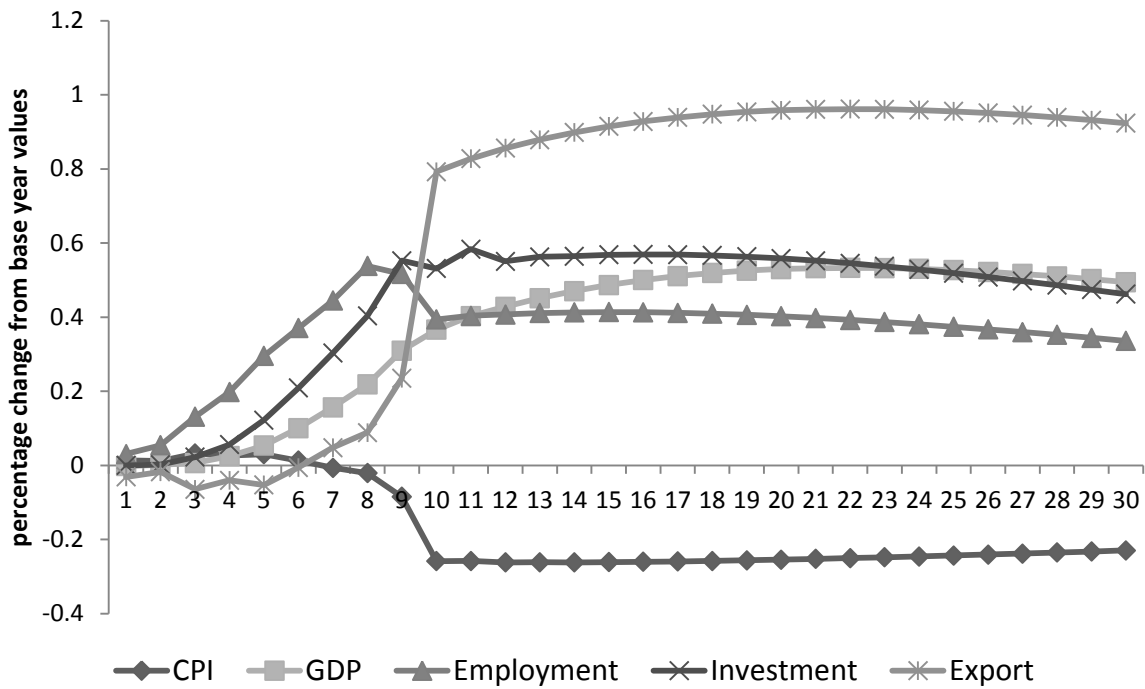


There are a number of regions in Poland, Lithuania, and Spain with particularly high economic benefits. Not only these regions are net recipients, but they also receive a large amount of investments compared to the size of their economy and population. However, transport infrastructure policies would generate significant benefits not only for those regions that directly benefit from the construction of roads and other transport infrastructure, but for all the regions in the EU.

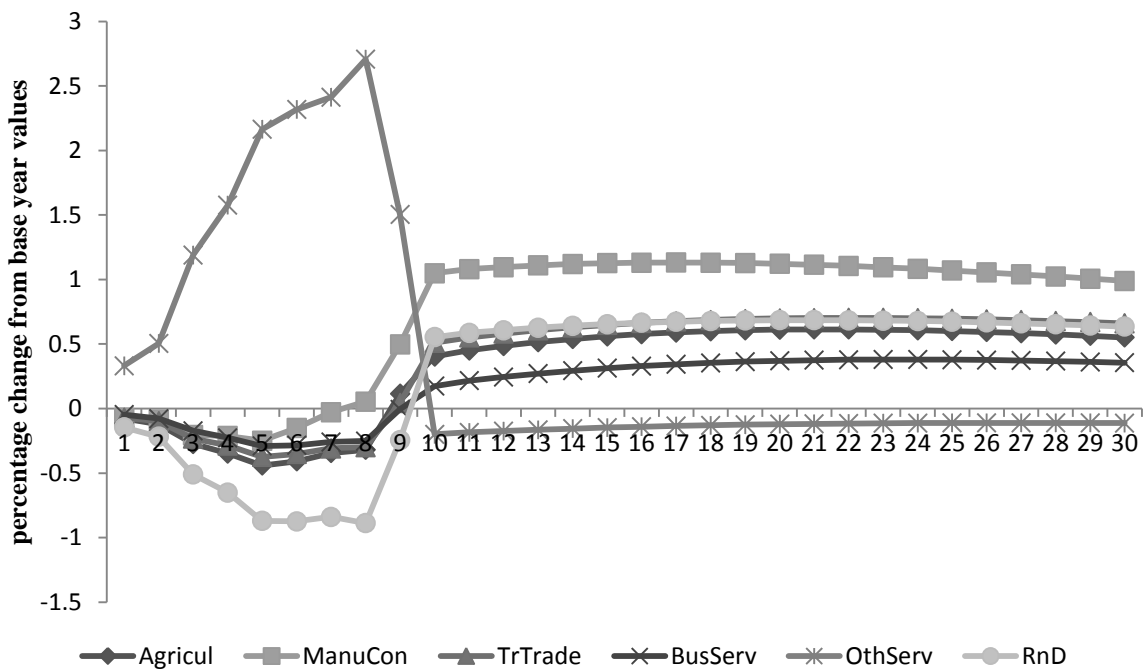
To provide more information of the model's economic adjustment resulting from an improvement in transport infrastructure, in Figure 24 we show the evolution of some economic variables for the Mazowieckie region in Poland. The model suggests that the GDP, employment and investments are above base year values since the outset. For the whole period of money injection, the employment changes are bigger than those of GDP, meaning that capital is growing at a lower rate. At the end of the demand shock, GDP starts growing more than employment, which suggests that the capital stock is growing faster than employment. Changes of preferences in the demand of goods and services alongside the sectoral composition explain the non-linear relationship between GDP and employment.

In the initial periods the policy consists of a monetary injection simulated through an increase in government expenditure that is composed largely by consumption of services which are labour intensive sectors. At the end of the demand shock, the supply side effects of a reduction in transport costs become dominant, increasing in turn the demand for manufacturing goods and R&D services (see the sectoral disaggregation in Figure 25) that on the contrary are more capital intensive sectors. Shortly after the demand-side shock terminates, the supply-side effects of a reduction in transport costs prevail, putting downward pressure on prices (CPI) and increasing competitiveness in the region through increases in export.

**Figure 24: Economic impact on key economic variables in the Mazowieckie region - Percentage changes from base year**



**Figure 25: Economic impact on output disaggregated by economic sectors in the Mazowieckie region - Percentage changes from base year**



## 8 Conclusions

In this report we have quantified the short-and long-run impact of the ECP. We have started our analysis by providing a detailed description of the impact that the ECP generates on GDP and employment for the EU as a whole. We have also investigated the economic impacts at the regional level and highlighted the potential benefits of coordinated policy intervention by investigating the cumulative multiplier effects under two alternative simulation scenarios.

Generally, we can conclude that for the entire ECP package, not only the long-run effects are positive but even in the very short-run the overall EU GDP growth will accelerate as a result of ECP investments. Only in very few regions some crowding-out effects may occur as a result of negative spillovers in the short-run, though such adverse effects disappear soon afterwards when firms react by making investments to satisfy the additional demand and output generated by other regions.

Naturally, the results presented here depend on a number of crucial assumptions. Different elasticity parameters, especially in the equations governing trade, could significantly affect the estimated impacts. For example, if we assume inter-regional trade to be more elastic, the effects will be larger. Conversely, if we were to introduce rigidities or reduce trade elasticities, the impacts would be smaller. Further, we have also made a number of assumptions related to the contributions made by each Member State to finance the ECP investment. It is not possible to identify the contribution made by each Member State solely in relation to the ECP. Therefore, we have decided to apply country-specific shares proportionally to the EU budget contribution made by each Member State to the EU budget. This was treated in the model as an exogenous negative transfer on household income.

Because of these and other assumptions made in the analysis, in order to ensure robustness of the results presented in this note, a more accurate and systematic sensitivity analysis with respect to behavioural and structural parameters is required and planned for future impact assessment exercises.

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