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The RHOMOLO economic impact assessment of the R&I and Low-Carbon ERDF Investment programme in Apulia, Italy

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Abstract

In this note we present the economic impact assessment of the European Regional Development Fund (ERDF) for thematic objectives TO1 "Research and innovation" and TO4 "Low-carbon economy" in the region of Apulia, Italy. The results are based on the RHOMOLO-IO demand multiplier analysis and on computer simulations with the multi-regional dynamic computable general equilibrium (CGE) model RHOMOLO. The former approach is used to calculate the sector-specific output multipliers following a demand-side shock, while the CGE simulations provide evidence of significant spillover effects spreading beyond the Apulian borders and stimulating economic growth in other regions with significant trade links with Apulia. Our results suggest that a €536 million increase in demand for the Manufacturing & Construction sector would entail an increase in total value added of €329 million, which is roughly 0.46% of the regional GDP. The RHOMOLO simulations show that the effects of policy interventions reach their peak in the last years of ERDF programming period (2020-2022), when the absorption of investment funding is at its full potential. In 2022, T01 and T04 investments of the ERDF increase Apulian by 0.2% above the baseline GDP projections. Given the high import intensity of the region, only one fourth of the overall effect is driven by the direct investments and three fourths depend on the productivity improvements achieved as a result of the specific policy design. This demonstrates that the implementation of policies that are effective in raising productivity ensures long term economic benefits even in the absence of continuous funding.

The RHOMOLO economic impact assessment of the R&I and Low-Carbon ERDF investment programme in Apulia, Italy

Francesco Di Comite, Olga Diukanova, Giovanni Mandras, and Javier Gómez Prieto

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1 Introduction

The ex-ante evaluation of the macroeconomic effects of public investment is an important contribution to the policy making process. In recent years, computable general equilibrium (CGE) models have become one of the key tools for policy analysis (see, among others, Sakkas, 2018).[1] The results of computer simulations help decision-makers to form better expectations on how the effects of planned policy interventions could materialise within and beyond national regional borders. Analyses based on a sound, well-defined, and transparent analytical framework can support policy making at different governance levels and help shaping alternative courses of action to increase the benefits (or mitigate the losses) related to the policy interventions.

We employ the multi-regional CGE model RHOMOLO based on Mercenier et al. (2016) to quantify the macroeconomic impact of the European Regional Development Fund (ERDF) that is allocated to the Apulia region of Italy over the period 2014-2020 under the Thematic Objectives (TOs) TO1 "Strengthening research, technological development and innovation" and TO4 "Supporting the shift towards a low-carbon economy".

The version of the RHOMOLO model used to simulate the impact of ERDF thematic investments in Apulia covers all EU NUTS2 regions with each regional economy being disaggregated into six NACE Rev. 1.1 sectors. Goods are consumed by households, governments, and firms. Interregional spatial interactions are captured through trade in goods and services, factor mobility, and knowledge spillovers. These features make the model well suited for the evaluation of regional investments in the EU over a wide range of policies.

The ERDF aims at reducing economic inequalities among EU regions by providing financial support to the least developed ones in line with the Europe 2020 targets for smart, sustainable, and inclusive growth (European Parliament and Council, 2013). In terms of budget allocations for the 2014-2020 programming period, the ERDF amounts to €196.3 billion which represents 43.2% of the European Structural and Investment Funds (ESIF). These investments support, among other things, actions oriented to strengthen Research and Innovation (R&I) activities in public and private centres, and the shift towards a low-carbon economy by promoting energy efficiency and renewable energy, smart grids, renewable energy use, sustainable transportation, education and training, and institutional capacity of public administration.

In the 2014-2020 programing period, a total ERDF contribution of €2,788 million has been earmarked for Apulia to be invested in 11 TOs, which amounts to roughly 4% of regional GDP.[2] Funding priorities in this region include public and private R&I projects, and networking and cluster support for universities and business networks primarily benefiting small and medium enterprises (SMEs).[3] Low-carbon activities are also part of the regional ERDF investment package in Apulia and include projects related to the promotion of clean energy, efficient ways of energy consumption, and strategies for sustainable multimodal urban mobility.

[1] The ex-post analysis is equally important (see, for instance, Di Comite et al., 2018).
[2] TOs are described in article 9 of the Common Provisions Regulation 1303/2013 for the ESIF.
[3] See "Deliberazione della Giunta Regionale n. 1732 del 1 agosto 2014" and "Le Aree Prioritarie di Innovazione" available at http://www.sistema.puglia.it/SistemaPuglia/smart_puglia2020

The Regional Innovation Strategy of Smart Specialisation (RIS3) provides the framework to combine ERDF with other public and private investments.[4] The Apulian RIS3 strategy includes specialisation priorities related to R&I in the field of renewable energy and energy efficiency as a way of facing the environmental challenges and reducing CO2 emissions. Apulian priorities are also aligned with the goal of achieving a 14.2% share of renewable energy sources in final energy consumption by the year 2020.

The remainder of the report is organised as follows. In Section 2 we give a brief overview of the socio-economic context of the Apulian region. In Section 3, we describe the process of economic impact assessment and evaluation of ERDF investments. In particular, we present the RHOMOLO-IO (IO stands for Input-Output) multiplier analysis, the structure of the CGE model RHOMOLO, and the design of the simulation scenarios. Section 4 is dedicated to the discussion of results. Section 5 presents the discussion of policy implications and Section 6 concludes.

2 The economic context of Apulia Region

Apulia is a densely populated region (above the national average) characterised by a complex mix of urban and rural landscapes. Located in the South-East of Italy, this region has 4.09 million inhabitants living in a territory of approximately 19 000 km^2.

2.1 Socio-economic profile

Despite its low industrialization rate and modest contribution to the national GDP (see Table 1), Apulia is very active in terms of policy experimentation and participation to EU-sponsored interventions (IPRES, 2015).

Table 1: Main economic indicators in Apulia Region

	Apulia	Italy	EU28
GDP per capita (euro)	€17400	€26500	€27500
GDP (and shares of Italian and EU28 GDP)	€70,973M	4.4% of Italian GDP	0.5% of EU28 GDP
Economically Active Population rate (%)	53.8	63.9	72.3
Unemployment rate (%)	21.5	12.7	10.2
Employment rate (%)	42.1	55.7	64.8
Long-term unemployment (% on EAP ([1]))	13.7	7.7	5.0
Youth unemployment (% on 15-24 EAP*)	58.1	42.7	22.2
Primary education attainment (%)	41.5	33.6	20.5
Secondary education attainment (%)	41.3	47.1	48.0
Tertiary education attainment (%)	17.2	19.3	31.1

(1) EAP-Economic Active Population. *Source:* Eurostat, 2016.

The region is strongly specialised in industries that make intensive use of the land, including the landscape. The agricultural sector is one of the national champions in the production of vegetables, wine and olive oil. The service sector accounts for more than 30% of employment and more than 50% of regional firms. The region is home to a large number of manufacturing Small and Medium Enterprises (SMEs) specialised in medium- and low-tech products and organised into very dense and localised networks. Apulia-based industrial districts compete globally in food processing, footwear, textiles and clothing, and wood and furniture. Many of these clusters of firms are located in easily accessible rural areas close to large urban centres (OECD, 2012).

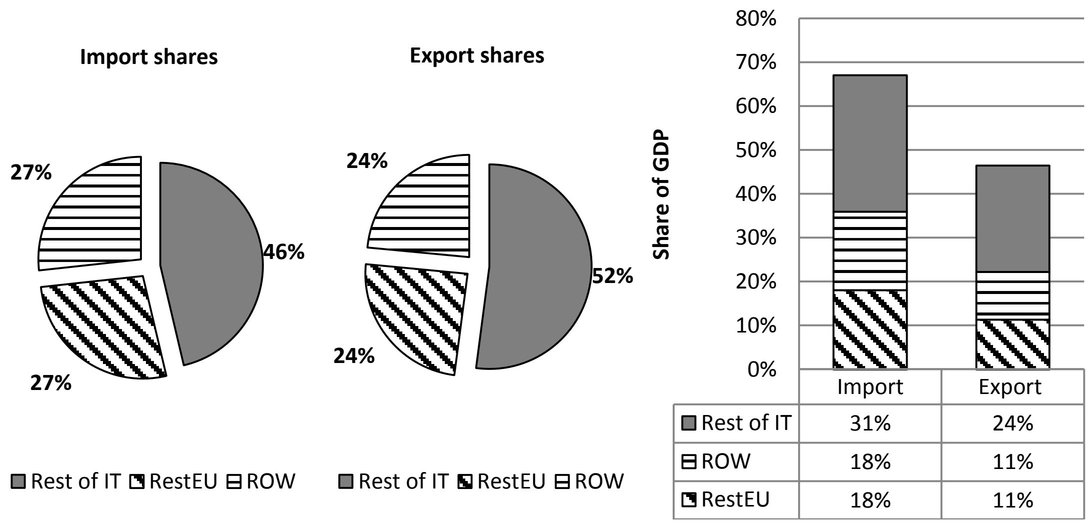
[4] See http://s3platform.jrc.ec.europa.eu/regions/ITF4/tags/ITF4?s3pv=1 and http://s3platform.jrc.ec.europa.eu/-/smart-specialisation-in-energy-how-europe-s-regions-are-implementing-their-priorities?inheritRedirect=true&redirect=http%3A%2F%2Fs3platform.jrc.ec.europa.eu%2Fhome

Labour productivity varies much among sectors, being lowest in agriculture and highest in the service sector. Apulia has specialised in producing electricity both from both traditional and renewable sources, becoming a net exporter of electricity to the rest of the country. More than 90% of the electricity is generated in conventional power stations: Apulia does not have any hydroelectric installations due to its lack of rivers or lakes, but it hosts Italy's largest coal plants.

Apulia is the leading region in Italy in renewable energy production. In 2011, its total installed capacity was 1.3 GW for wind, almost 1 GW for photovoltaic energy (PV), and 0.14 GW for biomass and waste energy. These were respectively 21%, 17%, and 9% of the national totals. Apulia has also good potential for producing renewable energy from agricultural residues. Finally, the region has specific demonstration processes launched by the national government in the field of concentrated solar power (OECD, 2012).

In terms of trade performance, and according to the RHOMOLO NUTS2 regional dataset based on regionalized national Social Accounting Matrices (SAMs), regional exports amount to 46% of the regional GDP and imports to 67% (see Figure 1), resulting in a significantly negative regional trade balance (Álvarez-Martínez and López-Cobo, 2016; López-Cobo, 2016).

Figure 1. Left pane: Import and export shares in Apulia by destination (rest of Italy, rest of the EU, and rest of the world). Right pane: imports and exports as a share of regional GDP



Source: authors' estimations based on the data of López-Cobo, 2016 and Álvarez-Martínez and López-Cobo, 2016.

Exports to the rest of Italy, to the rest of the EU, and to the rest of the world account, correspondingly, to 24%, 11%, and 11% of the GDP in Apulia. The share of imports from Italian regions, from the rest of Europe, and from the rest of the world, amount, correspondingly, to 31%, 18%, and 18%, showing a high level of trade openness, especially on the import side (see the right pane of Figure 1).

Such trade openness provides a first intuition of the potential impact of external shocks hitting the regional economy. While relatively closed economies are expected to be more responsive to demand shocks (stimulating internal production), more open economies are expected to benefit more from supply-side shocks and to generate higher spillover effects to the other regions. With Apulia being such an open region in terms of trade linkages, we can expect large inter-regional spillover effects from investments in this region.

2.2 Cohesion Policy interventions and Smart Specialisation in Apulia

Following the EU Cohesion Policy reform for the period 2014-2020, EU member states and regions are expected to actively support innovation within the context of Smart Specialisation. The ex-ante conditionality for ESIF linked to TO1 requires that the national or regional R&I strategy for smart specialisation contains a monitoring mechanism in place and adopts a framework outlining the available budgetary resources (European Parliament and Council, 2013). Despite the clear link between TO1 and R&I, innovation can also contribute to other ERDF investment priorities like those covered by TO2 (ICT: e-commerce, e-government, etc.), TO3 (competitiveness of SMEs), and TO4 (shift toward low-carbon economy), among others.

The RIS3 of Apulia establishes the framework for facing the actual and forthcoming innovation challenges. Based on the objectives of supporting the competitiveness, facilitating joint and efficient investments and optimizing the innovative system, Apulia identifies three key strategic areas of innovation: (i) Sustainable manufacturing; (ii) Human health and environment; and (iii) Digital, creative and inclusive communities.

For instance, renewable energy and energy efficiency are part of the (ii) S3 domain "Human Health and Environment". Specific goals in these domains are to achieve a ratio between renewable energy sources production and gross final energy consumptions of 14.2% by year 2020 (estimated to be equal to 11.9% in 2016) and creating new business opportunities for the regional companies through R&I. The Apulian government is in charge of coordinating projects that are co-funded by the European Commission, whereas the national Italian government supports the creation of a renewable energy supply chain, including the manufacturing and service sectors in Italy's Southern regions (Apulia, Campania, Calabria, and Sicily). Municipalities can also influence renewable energy deployment, as they control land use and zoning.

The smart specialisation strategy of Apulia also addresses interregional cooperation with other EU regions with similar S3 priorities. The interest for establishing cooperation synergies outside administrative borders has motivated for instance the organization of the interregional workshop in the field of energy and smart-grids on June 2016 (see box 1). Supported by the Smart Specialisation Platform on Energy[5], this cooperation exercise has permitted the identification of trends, challenges, and complementarities related to smart-grids deployment in several EU regions.

Box 1. Smart Specialisation and Interregional Cooperation. Smart Mediterraneo workshop

On June 23th and 24th, 2016, the Apulian public authorities hosted the workshop "Smart Mediterraneo. Best practices, innovation and pilot projects in smart grid development in the Mediterranean region". This workshop was organised in the framework of the Smart Specialisation Platform for Energy (S3PEnergy) and aimed at building synergies among the regions of the Mediterranean Sea to exchange experiences and best practice in the field of smart grids.

Regional authorities, companies, universities and research centres met and exchanged knowledge on smart specialisation, energy and cohesion policy, opportunities and challenges coming from the new regulation of the retail market. This workshop served as the occasion for interactions between local and international stakeholders with the aim to reinforce links between their projects, needs and expertise along with the perspectives of smart specialisation including activities in smart grids technologies.

[5] The S3PEnergy is managed by the Joint Research Centre of the European Commission along with the DGs REGIO and ENER. The S3PEnergy facilitates interaction among regions manifesting similar interests by, for instance, organising kick-off meetings where regions initiate the reflections on operational work, leadership and co-leadership, governance systems, roadmaps and rules, among others. So far, S3PEnergy interregional partnerships aim at strengthening implementation of smart specialisation in the areas of: Bioenergy, Sustainable Construction, Energy Off-shore and Smart-Grids. Support on additional inter-regional cooperation groups related to other energy-priorities of interest (e.g. heating and cooling, fuel cells, solar), would be provided by the S3PEnergy platform upon joint request of EU regions. More information of the S3PEnergy at http://s3platform.jrc.ec.europa.eu/s3p-energy

As a main conclusion, the smart-grids sector faces several challenges and obstacles such as need of more targeted interregional cooperation and higher engagement of private sector.

Future scenarios, initiatives, and interventions in this field should capitalise on existent evidence and results facilitated for instance in the frameworks of the 459 projects carried out across Europe (see for instance the Smart Grids Outlook Report published by JRC). Addressing smart grids according to regional specific contexts could provide more efficient results.

In terms of EU Cohesion Policy classification, Apulia is regarded as an "Objective 1" or "convergence" region, meaning that its GDP per head is less than 75% of the EU average. With 62.946 projects, the largest share of Mezzogiorno Cohesion Policy interventions (IPRES, 2015) is concentrated in Apulia.[6] The ERDF focuses its investments on few key priority areas to maximise the impact by exploiting a 'thematic concentration'. The areas of intervention include R&I, the digital agenda, support for SMEs, and the low-carbon economy. For the programing period 2014-2020, the ERDF allocates €536 million to TOs 1 and 4 related to R&I and low-carbon activities, respectively. Table 2 shows the disaggregation of ERDF funding according to the TOs.

The objectives of ERDF investments have to be achieved by the end of the programming period 2014-2020. In Apulia, targets related to R&I include, among others: (a) support of 85 enterprises; (b) fostering cooperation of 50 firms with research institutions; (c) support of 23 enterprises aimed at the (d) creation of 100 full time equivalent jobs in R&I. Some of the targets associated to low-carbon activities are the following: (e) achieving 210 MW of additional capacity from renewable energy production; (f) reduction of annual primary energy consumption in public buildings by 12.000.000 kwh/year; (g) connecting 10.000 additional users to smart grids and (h) annual decrease of greenhouse gas emissions by 125 Tons of CO_2eq.[7]

Table 2. ERDF allocation for TO1 and TO4 in Apulia for the period 2014-2020

Thematic objective	Amount, (M€)
01 - Strengthening research, technological development and innovation	
002 - Research and innovation processes in large enterprises	100
003 - Productive investment in large enterprises linked to the low-carbon economy	20
056 - Investment in infrastructure, capacities and equipment in SMEs directly linked to research and innovation activities	50
057 - Investment in infrastructure, capacities and equipment in large companies directly linked to research and innovation activities	70
058 - Research and innovation infrastructure (public)	5
059 - Research and innovation infrastructure (private, including science parks)	8
062 - Technology transfer and university-enterprise cooperation primarily benefiting SMEs	25
063 - Cluster support and business networks primarily benefiting SMEs	19

[6] Mezzogiorno includes the Italian regions of Abruzzo, Apulia, Basilicata, Campania, Calabria, Molise, Sicilia, Sardinia, and part of Lazio.
[7] See the Open Data Portal for the European Structural Investment Funds maintained by the European Commission, DG REGIO.

064 - Research and innovation processes in SMEs (including voucher schemes, process, design, service and social innovation)	28
066 - Advanced support services for SMEs and groups of SMEs (including management, marketing and design services)	10
067 - SME business development, support to entrepreneurship and incubation (including support to spin offs and spin outs)	3
04 - Supporting the shift towards a low-carbon economy in all sectors	
013 - Energy efficiency renovation of public infrastructure, demonstration projects and supporting measures	102
015 - Intelligent Energy Distribution Systems at medium and low voltage levels (including smart grids and ICT systems)	15
043 - Clean urban transport infrastructure and promotion (including equipment and rolling stock)	58
044 - Intelligent transport systems (including the introduction of demand management, tolling systems, IT monitoring, control and information systems)	3
068 - Energy efficiency and demonstration projects in SMEs and supporting measures	20
Total (TO1 +TO4)	**536**

Source: European Commission, ESIF-viewer, visualising planned investments using European Structural and Investment Funds, Regional Operational Programs*:* http://s3platform.jrc.ec.europa.eu/esif-viewer

3 The economic impact assessment of ERDF investments

Public investments affect the economic performance of regions by influencing demand, capital accumulation, productive capacity, and by generating spillover effects. For the policy impact assessment in Apulia, we combine the IO and CGE modelling techniques.

By incorporating information about inter-industry relationships, the regional RHOMOLO-IO multiplier analysis allows us to highlight the impact of demand changes on a particular industry within a region to provide an initial idea of the potential economic impact of a regional investments strategy. RHOMOLO-IO is the IO version of the RHOMOLO model which is equivalent to a standard IO model and does not feature the more complex characteristics of the "full" CGE version of RHOMOLO.

CGE models account for complex behavioural relationships between the economic agents and permit to trace changes in both prices and quantities in response to policy interventions, thus estimating the magnitude and direction of spillover effects resulting from the investment project implementation.

3.1 RHOMOLO-IO multiplier analysis

In order to get an overall idea of the Apulian economic structure, we refer to its 2010 regional SAMs and, in particular, to the inter-industry flows matrix (IO table), which is the basis for the derivation of the analytical tables on the structure of the regional economy. The SAMs and the IO tables represent a snapshot of the economic transactions between sectors and agents (households, firms, and government) of an economy in a particular year when all markets are equilibrium. The basic principle of an IO table is to identify and disaggregate all the flows of expenditures between industries in the economy.

A key output of the IO analysis is the calculation of the industry linkages (i.e., its multipliers[8]) used to study the knock-on effects throughout the economy of a change in final demand. IO multipliers allow to measure how an increase in final demand for the output of one sector entails expansionary effects on the output of intermediate sectors which, due to such demand change, increase their own demand for their intermediates inputs and so on. The activity generated by the sum of these demands for intermediate inputs is known as the indirect effect.

Two types of multipliers can be computed. The simpler multiplier (Type-I) treats household consumption as an exogenously determined final demand category. A more complete multiplier (Type-II) can be obtained by estimating the total effect of a demand side disturbance linking consumption to employment income. Based on the assumption of a constant savings rate for different levels of income, the latter multiplier allows capturing in the model the additional effects of household income generation through payments for labour and the associated consumer expenditures on goods and services produced by the various sectors: this additional expansionary effect is known as the induced effect. It should be kept in mind that IO multipliers do not take account of economies of scale, unused capacity, or technological change. Thus, IO multipliers could be used to quantify the economic impact derived from a demand shock assuming that the average relationships in the IO table apply at the margin.

Table 3 reports the Type-I and Type-II multipliers, together with the transmission mechanism of indirect effects obtained with RHOMOLO-IO. The highest Type-I multiplier is associated with the agricultural sector (2.258), meaning that investments in this sector may be expected to have the greatest impact on the rest of the regional economy.

However, when household final demand is considered endogenous so that induced effects are included in the analysis (Type-II multipliers), we see that it is actually the Other Services (essentially public services) sector that has the highest multiplier (4.151) and, consequently, where the additional effects of household income generation have the greatest impact on the economy.

Table 3. Type I and Type II IO multipliers - Apulia region

	Final demand change	Sector indirect effect	Industrial support effect	Type-I output multipliers	Type II output multipliers	Type I value added multipliers	Type II value added multipliers
Agriculture	1	0.107	1.150	2.257	3.919	0.706	1.223
Manufacturing & Construction	1	0.433	0.427	1.860	2.618	0.379	0.614
Transport & Trade	1	0.213	0.638	1.851	3.961	0.614	0.959
Business Services	1	0.223	0.218	1.442	2.211	0.670	0.909
Public Services	1	0.073	0.446	1.519	4.151	0.827	1.646

To provide some guidance on the interpretation of the multipliers, consider an increase of €1 in final demand of the Agriculture sector. The Type-I multiplier for this sector shows that a change in final demand of €1 induces an increase in total output of €2.257. In other words, in order to produce an additional unit of output in the target sector, the national economy's output must increase by an additional €0.107 in order to provide inputs to the agriculture sector itself, and in turn an increase of €1.15 in all stages of the production chain to provide inputs to the suppliers of the sector under concern is needed.

The effects captured by the Type-I multiplier are the direct effect (1.00), the indirect effect on the sector where a change of final demand is assumed (0.107), and the industrial support effects (1.15). The sum of all these effects gives us the Type-I output

[8] IO tables and multipliers focus on the supply and use of products, which distinguishes them from other multipliers like fiscal (or Keynesian) multipliers focusing on macroeconomic relationships.

multiplier, highlighting the importance of considering the inter-industry linkages in an economic impact analysis. The same logic applies for all the other sectors of the economy, as well as for Type-II multipliers. Considering the same example of €1 in additional demand, when households' consumption is considered endogenous the final effect of the initial change would be of €3.919.

It is generally more interesting to analyse the economic impacts of changes in final demand in terms of increased household earnings and value added rather than simply in gross output by sector. Hence, value added multipliers are also included in Table 3. Looking at the Type-II multipliers, the effect of €1 invested in Agriculture generates an increase in total value added of €1.223 (including direct, indirect, and induced effects).

The RHOMOLO-IO analysis allows us to have an initial idea of the potential demand impact of a regional investments strategy. For example, assuming that the ERDF €536 million are all channelled to increase demand for the Manufacturing & Construction sector (for example, by purchasing machines for the local companies), then the local increase in total value added associated with this policy would total €329 million over the years, which is roughly 0.46% of the regional GDP. However, for a more detailed characterisation of the impacts taking also into account inter-regional interactions and behavioural responses from agents resulting from differences in prices and wages, we now turn to the simulation analysis based on the fully-fledged RHOMOLO CGE model.

3.2 The RHOMOLO analysis

Multi-regional CGEs have been acknowledged as key instruments to examine geographic features of economic phenomena (e.g. factor mobility, transport and transaction costs, and regional price differentials) which influence the speed and extent of economic development. These models allow for the spatial disaggregation of country-wide policy impacts and also for the evaluation of policies implemented at regional level. Model results help identifying the territories where the benefits or losses will be concentrated, and clarify which impacts can be attributed to policy intervention and which are due to spillover effects. This helps to identify priority areas for investment and policy interventions, and also provide a basis for comparing net welfare benefits with prospective investment costs.

CGE models represent a decentralised market economy where agents make optimal choices given a system of resource constraints, behavioural preferences, and technology. Producers maximize their profits while consumers maximize the utility derived from their bundle of consumption, with market prices adjusting endogenously so as to keep supply and demand balanced in all markets. Functional forms describe the agents' technology in terms of converting inputs into output, featuring behavioural preferences in substitution among the inputs in response to price changes.

A SAM forms the main database of a single-region CGE model. In multi-regional CGE models, SAMs are complemented with matrices of bilateral trade and factor flows. A CGE model is calibrated to replicate the base year data when no shocks are introduced into the model. The simulation of a policy shock leads to a new, counterfactual equilibrium, which can also be visualized in the form of a new SAM. The simulation associated with a policy shock can be defined as the "counterfactual scenario", whereas the reproduction of the initial equilibrium in the economy can be referred to as the "benchmark scenario". Therefore, simulating a policy change with a CGE model is a “what if” comparison of two equilibrium states of the economy.

The structure of the multi-regional CGE model RHOMOLO employed in this study closely follows Mercenier et al. (2016). The statistical unit of RHOMOLO is the European NUTS2 region, since such regions are the basic administrative entities identified for the application of regional policies in the EU. The SAMs of the NUTS2 regions used in RHOMOLO are based on López-Cobo (2016) and Álvarez-Martínez and López-Cobo (2016) and are complemented with the matrices of trade and transport flows between regions in order to characterize the full RHOMOLO modelling all the EU regions. Transport costs for trade between regions are of iceberg type and are sector- and region-pair specific. An asymmetric trade cost matrix was derived from the European Commission's transport model TRANSTOOLS[9] (Brandsma and Kancs, 2015; Brandsma et al., 2015).

The following six NACE Rev. 1.1 sectors are featured in the model: Agriculture, Manufacturing & Construction, Business services, Transport & Trade, Public services, and R&D. Goods in RHOMOLO are consumed by households, governments, and firms. Industries can function in either perfectly or monopolistically competitive markets (Dixit and Stiglitz, 1977). Labour is disaggregated into high-, medium- and low-skill groups. R&D output is produced at a national level, with high-skilled labour being the only production input to the national R&D. National R&D is consumed by the regional non-R&D sectors within a country and is not traded internationally. Unemployment is modelled through a wage curve (Blanchflower and Oswald, 1995) which negatively relates real wages to the unemployment rate.

Due to the high dimensionality implied by its extensive regional disaggregation, the dynamics of the model is kept relatively simple: expectations of economic agents are assumed to be myopic, as they optimize within a one-year period, and the model is solved recursively year by year. Due to myopic expectations, the recursive framework acts as a "surprise-announcement of policy changes" which can result in steep economic adjustment paths. RHOMOLO is used here for the ex-ante economic impact assessment of ERDF investments in Apulia because of the importance of modelling explicitly spatial linkages and interactions and spillovers between regional economies.

3.3 Design of model scenarios

The objective of the policy simulations is to understand how an economy would react to a given policy shock. Because of the sectoral aggregation of RHOMOLO, the simulated policy exercise reported in this section does not consider the 62.946 individual projects financed in Apulia at the micro-level, but rather provides an overall evaluation of ERDF policies at the macro-level. Table 4 shows how the aggregated amounts of funding of TO1 and TO4 policy objectives were translated into policy shocks within RHOMOLO.

The thematic objective "Research and innovation activities in public and private research centres, including networking" was modelled as funding allocated to R&D activities in large and small enterprises belonging to all the economic sectors of RHOMOLO. Considering that in the version of RHOMOLO used for this analysis the R&D sector is modelled at a national level, and all regional non-R&D sectors conduct R&I activities, for this policy exercise the TO1 investments were translated into total factor productivity (TFP) improvements in all productive sectors. The calculation of TFP growth is based on the econometric estimates of R&D-productivity relationships in Kancs and Siliverstovs (2016). Therefore, the cumulative amount of policy funding that corresponds to the categories 002, 003, 056, 057, 058, 059, 062, 063, 064, 066, and 067 enters the model as TFP improvements in Agriculture, Manufacturing and construction, Transport and trade, Business services, and Public services.

On the other hand, investments for "Institutional capacity of public administration" under the categories 013 and 068 are allocated as lump-sum transfers to the public sector (see the second row of Table 4). Finally, since energy supply and demand flows are not explicitly represented in RHOMOLO, policies related to low-carbon development, energy efficiency, and renewable energy can be captured only indirectly. In order to account for them, the cumulative amounts of funding that correspond to the categories 015, 043, and 044 enter the model as a "Subsidy to the production of Manufacturing & Construction sector" (see the last row of Table 4). This approach permits to capture the resource-saving and cost-reducing nature of these policy objectives.

[9] TRANS-TOOLS ("TOOLS for TRansport Forecasting ANd Scenario testing"), http://energy.jrc.ec.europa.eu/transtools/

Table 4. Translation of funding of TO1 and T04 objectives into the model shocks

TOs' categories	Amount of policy funding (M€), 2014−2020	Model shock
01 - Strengthening research, technological development and innovation		
Research and innovation activities in public and private research centres, including networking (categories of funding 002,003, 056, 057, 058, 059, 062, 063, 064, 066, 067)	338	Total Factor Productivity (TFP) shock in all non-R&D sectors in Apulia
04 - Supporting the shift towards a low-carbon economy in all sectors		
Institutional capacity of public administration (categories of funding 013, 068)	122	Increase in provision of public services in Apulia
Shift towards a low-carbon economy promoting energy efficiency and renewable energy, smart grids, renewable energy use, sustainable transportation, education and training and Institutional capacity of public administration (categories of funding 015, 043, 044)	76	Subsidy to the production of "Manufacturing & Construction" sector in Apulia

Source: policy funding based on the data of the LUISA Territorial Modelling Platform, https://ec.europa.eu/jrc/en/luisa, and authors' assumptions.

In line with the EU regional policies setup, we consider that TO1 and TO4 policies in Apulia are financed through a lump-sum tax paid by EU households proportionally to the imputed contribution made by each region to the EU budget. Thus, in our simulation experiment Apulia bears only a small part of overall project cost, whereas the biggest part is financed by the rest of the EU. The total amounts of TO1 and TO4 funding that amounts to €536 million is split into uneven annual instalments along the funding period 2014−2022, in line with the N+2 rule for EU budgetary commitments (stating that the entire funding must be spent within the two years following the end of the Framework Programme). Therefore, we employed a working assumption that over the 2014−2022 period the whole amount of policy funding is used according to the same proportions of the previous Cohesion Policy budget commitment period (2007-2015). This results in a low absorption rate in the first years which gradually increases to peak in the last year of the programming period (i.e. 2020) and stays high during the following two years. This also means that the allocated investment funding is fully utilised by 2022, with most of the funds being absorbed between 2019 and 2022.

Considering the highly innovative and research-intensive content of ERDF projects, it would be unlikely to assume that their effects vanish as soon as the policy funding is terminated. Therefore, we consider the policy-induced TFP improvements to be maintained, although at a decreasing rate, even in the absence of continuous investment injections. Specifically, we employed an assumption that after peaking in 2022, TFP declines at a constant annual rate of 15%. We define this post-2022 period as the investment-induced structural phase.

4 Simulation results

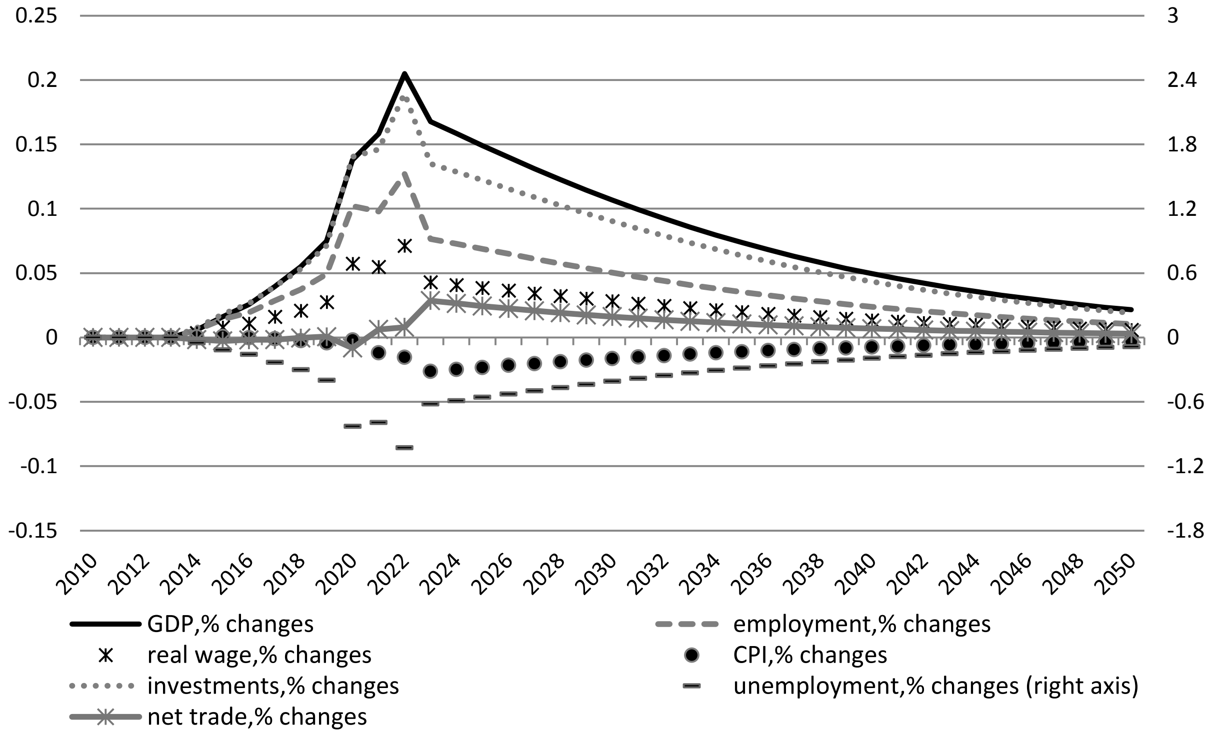
In this Section we present the results of the RHOMOLO simulations focusing on key macroeconomics variables such as regional GDP, production, trade, consumption, the consumer price index (CPI), and employment. Our analysis is not limited to Apulia, but also considers the spillover effects in other regions.

The simulations show that the short-run economic impacts of policy interventions are mainly driven by the demand effects generated by T01 and T04 investments during the

ERDF programming period of 2014-2022. When the programming period is over, inter-regional investment transfers to Apulia cease, the demand effects dissipate, and the structural effects of investments on productivity improvements gain momentum and become the main drivers of the results during the investment-induced structural phase.

Unless otherwise specified, all the following results are presented as model outcomes expressed in terms of percentage changes from the baseline values (which can be interpreted as the evolution of the economy in the absence of policy interventions). Figure 2 shows the percentage changes in GDP, investments, employment, wages, net trade, prices (CPI) and unemployment in Apulia.

Figure 2. Impact of TO1 and TO4 policy funding in Apulia (percentage changes from baseline)

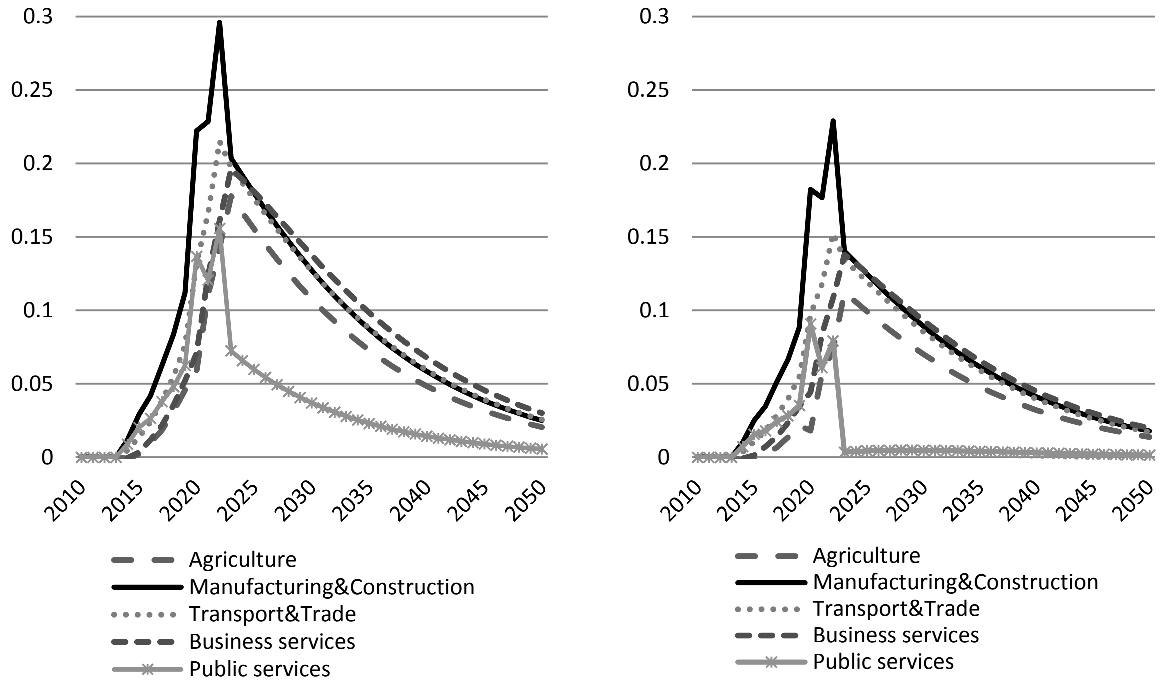


Not surprisingly, T01 and T04 policy funding has a positive impact on all the selected economic indicators in Apulia, reducing unemployment and lowering consumer prices. In fact, GDP, employment, wages, investments, and exports all grow in the medium-to-long run accompanied by an increase in competitiveness signalled by the decrease in CPI.

Reflecting the strength of the policy shocks entering the RHOMOLO model, the peak in economic activity is achieved in 2022, when the ERDF programming period terminates. In particular, in 2022 we observe a 0.2% increase in investments and GDP and a 0.19% growth in employment relative to the baseline values. All key variables continue to record a positive impact after policy funding is over because of two reasons. First, the capital stock built up during the policy support period increases the level of productive inputs in the region. Second, the long-run structural impacts associated of ERDF projects keep on providing a competitive edge to the region in the years after 2022. As we can see from Figure 2, the effects of the investment-induced structural phase last almost until the end of the simulation horizon in 2050.

In order to illustrate the structural changes promoted by ERDF policies in the different sectors, in Figure 3 we plotted the percentage changes in output (left pane) and employment (right pane) relative to the baseline values over the whole simulation horizon.

Figure 3. Impact of T01 and T04 policy funding on output (left pane) and employment (right pane) per sector in Apulia (percentage changes from baseline)



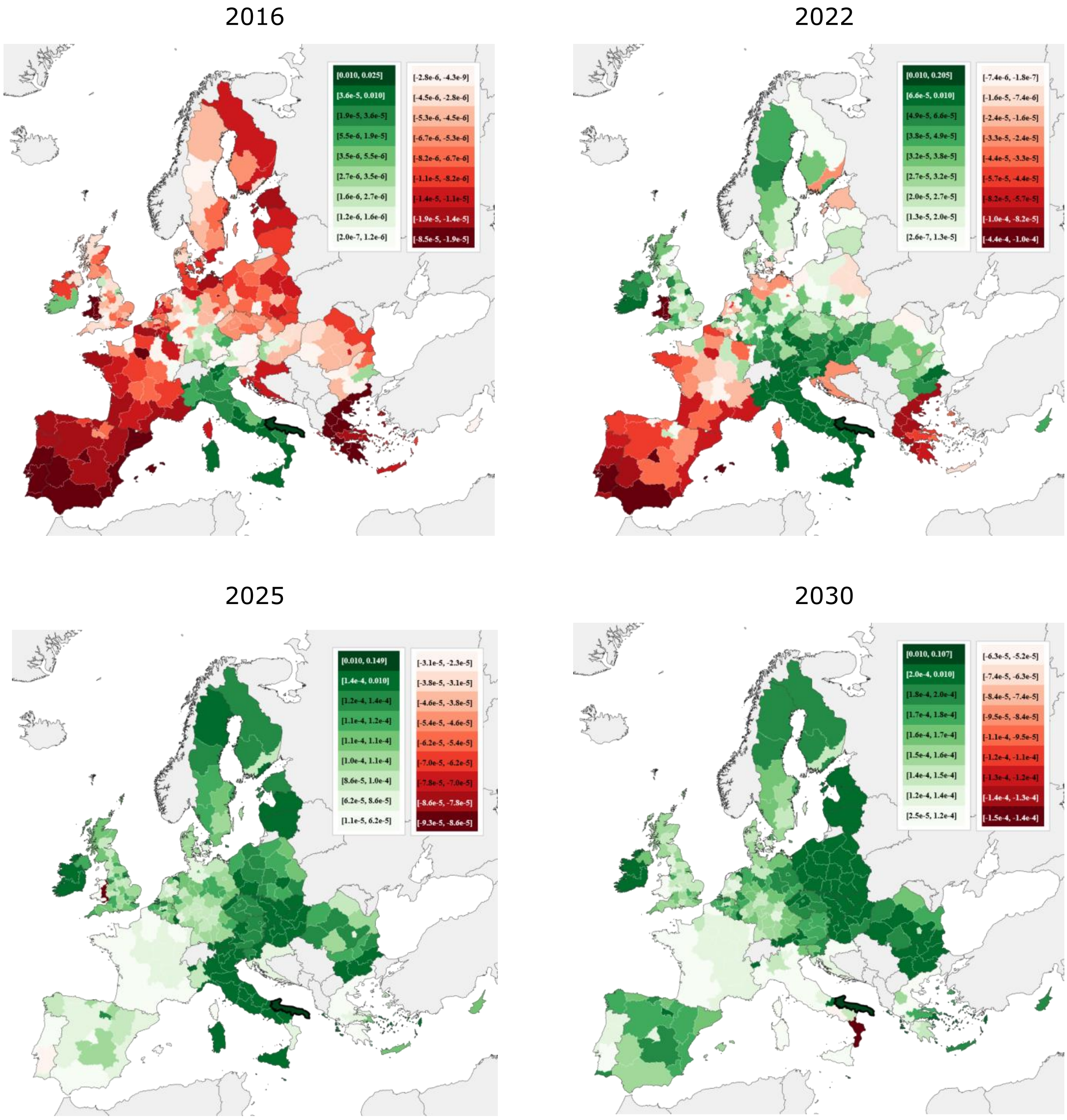
All sectors in Apulia are positively affected by T01 and T04 investments. The regional Agriculture, Manufacturing and construction, Transport and trade, Business services, and Public services benefit from TFP improvements that are generated thanks to the TO1 funding. Since the Manufacturing and construction sector receives additional subsidy support during the ERDF programming period, it experiences the most pronounced growth.

Depending on the extent of regional integration, income and price effects, the economic growth of one region can affect significantly the economies of its trading partners, causing spillover effects. Indeed, the model results show that the economic impacts of policy interventions in Apulia spread beyond the regional borders and affect the GDP of other regions as well. The impact of T01 and T04 policies in Apulia on the GDP of all the NUTS2 regions of the EU in 2016, 2022, 2025, and 2030 is displayed in Figure 4.

The key observation arising from the maps in Figure 4 is that the policy impacts are not only localized in the beneficiary region of Apulia, but spill over to other regions which are inter-connected with Apulia through the complex system of trade flows. During the ERDF programming period of 2014-2022, when T01 and T04 policy interventions in Apulia are financed by all NUTS2 regions, the positive spillover effects are mainly concentrated in Italy. Indeed, given that the rest of Italy is the main trading partner of Apulia, Italian regions benefit from improved productivity, competitiveness and terms-of-trade in Apulia.

Given that the rest of the NUTS2 regions spend quite a negligible share of national income to finance the policy interventions in Apulia, after 2022 the positive spillover effects gain momentum and affect the whole EU. Being the recipient of ERDF investment in this simulation exercise, Apulia is the region benefiting the most in the whole EU according to these simulaitons. Competeveness improvements sustained until 2030 permit Apulian firms to gain market shares at the expenses of other Southern Italian regions with a similar industrial structure and serving the same export markets.

Figure 4. GDP changes in NUTS2 regions due to the policy funding in Apulia (percentage changes from baseline)

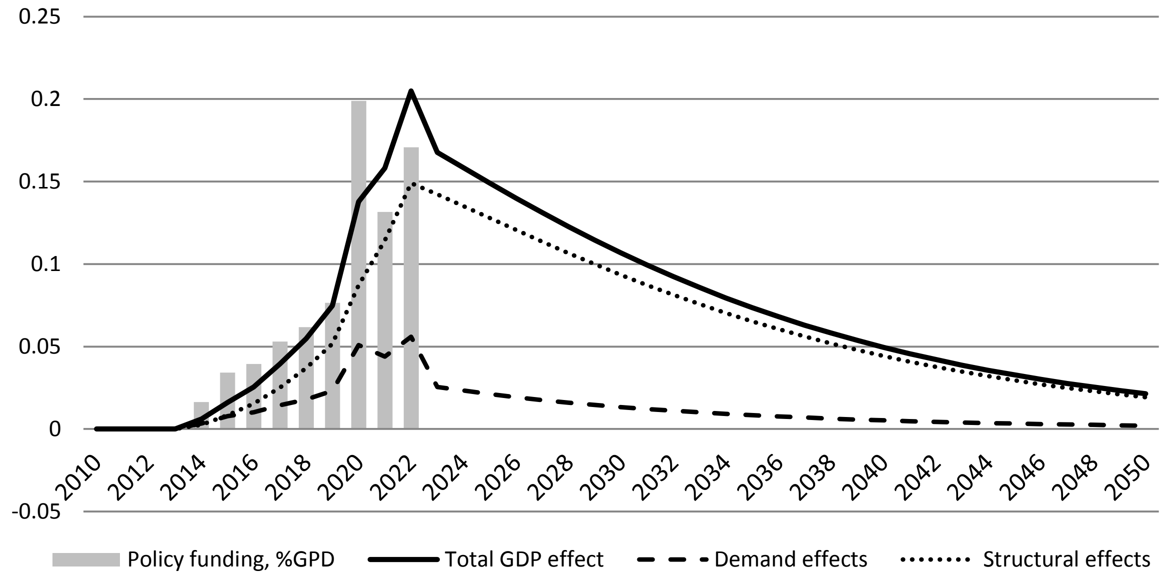


5 The importance of policy design

The RHOMOLO results presented above consist of a combination of short-run demand-side effects and long-run structural effects related to productivity. The former are the result of policy funding during the ERDF programming period. The latter effects are linked to the TFP growth resulting from the policy which continues to benefit the region even after the programming period, although fading out gradually.

We performed two additional sets of simulations in order to disentangle the demand-side effects from the structural effects on GDP growth and on the rest of the macroeconomic variables of interest.

Figure 5. Demand-side and structural effects on GDP in Apulia (percentage changes from baseline)



([1]) The intensity of policy funding funding is expressed as percentage of GDP.

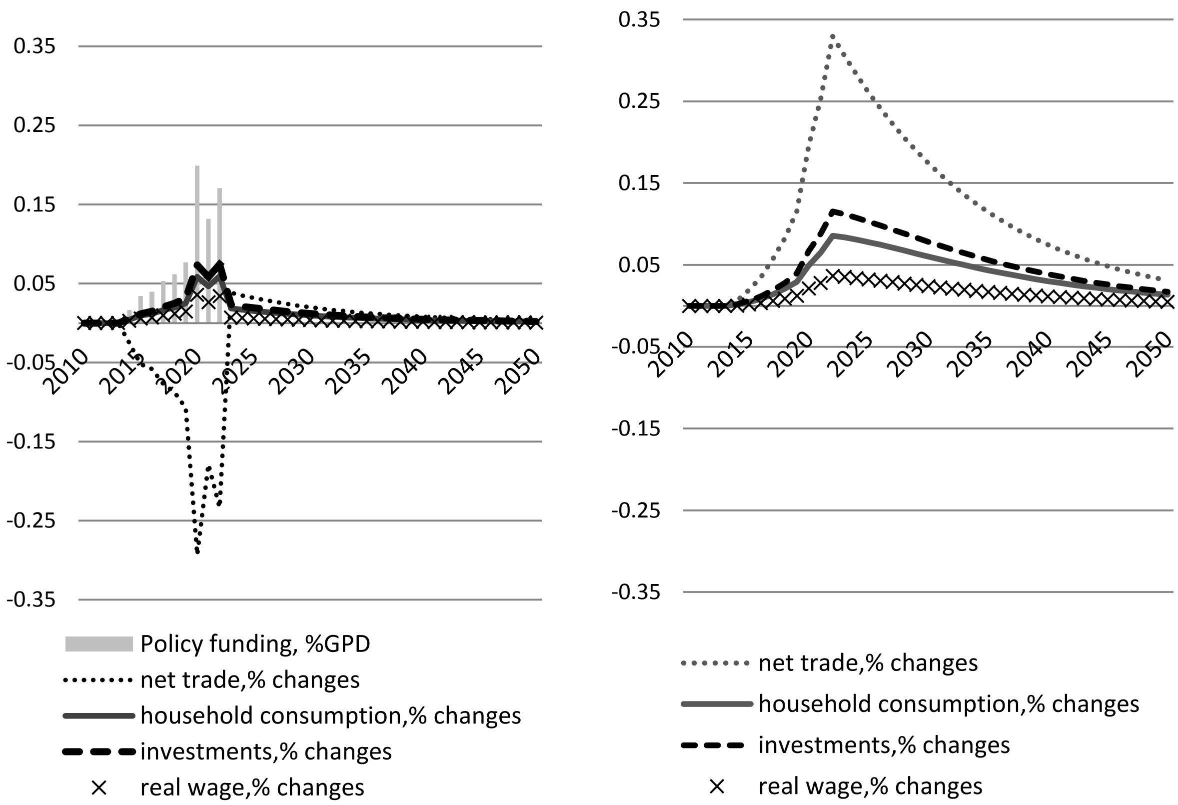
Figure 5 suggests that during the ERDF programming period the demand-side induced GDP growth amounted to roughly one fourth of the total GDP growth induced by the policy. The demand effects peak in 2020-2022 when the absorption of policy funding is at its highest, and sharply decreases afterwards when funding is over. After 2022, as explained above, the productivity improvements remain, although fading out at a constant rate. Thus, starting from the year 2023 onwards the structural effects become even more decisively the major determinant of GDP growth.

Given the high degree of economic openness in Apulia, the region's economy is bound to respond dramatically to changes in price competitiveness. For example, an increase in the cost of domestic production would cause the replacement of domestically-produced products with imports causing adverse effects on regional GDP. Conversely, productivity improvements lowering domestic production cost would positively affect net exports and GDP. In order to better grasp such macroeconomic mechanisms, in Figure 6 we compare the policy impacts on Apulian macroeconomic variables when demand-side (left pane) and structural (right pane) effects are considered separately.

A stark difference in the outcomes of the two sets of simulations emerges, demonstrating the different economic mechanisms behind the two types of shock operating on either the demand side or on productivity. Among the reported macroeconomic variables, only investments and real wages show similar trends. However, the mechanisms determining the results are drastically different. The pure demand shock boosts the demand of goods which is satisfied both with increased production of domestic goods and with imports, putting an upward pressure on prices.

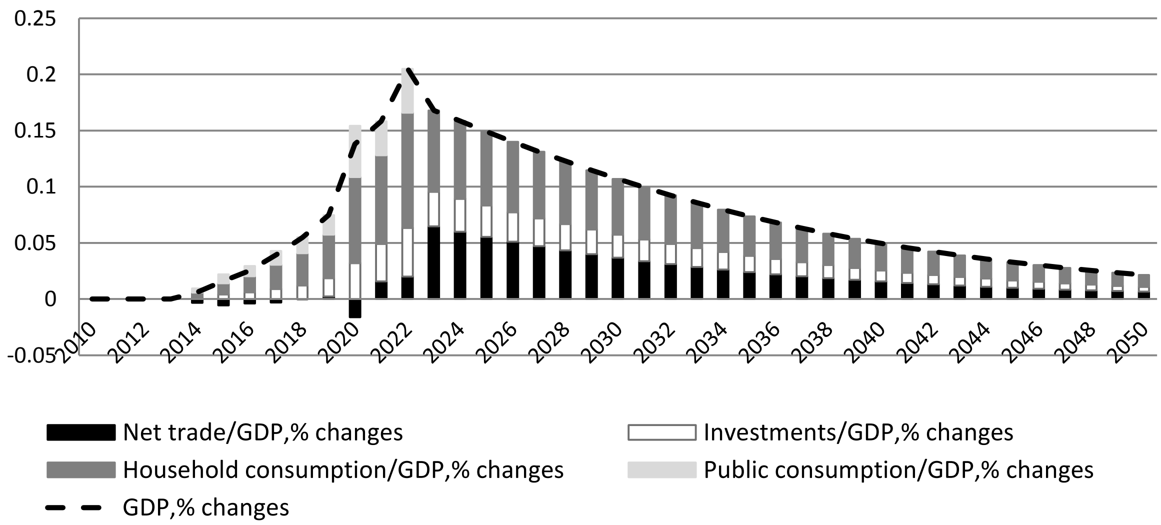
In the case of the pure structural shock associated with productivity improvements, Apulian goods gain competitiveness, permitting to expand market shares both domestically and abroad, with positive effects on income, investments, and consumption in Apulia. Thus, it seems that net trade dynamics is the main explanation behind of the differences between structural and demand effects.

Figure 6. Demand-side (left pane) and structural (right pane) effects on key macroeconomic variables in Apulia (percentage changes from baseline)



In order to investigate deeper the difference between demand-side and structural effects, we decomposed GDP growth into the growth of its individual components in Figure 7.

Figure 7. Decomposition of GDP growth in Apulia by component (percentage changes from baseline)

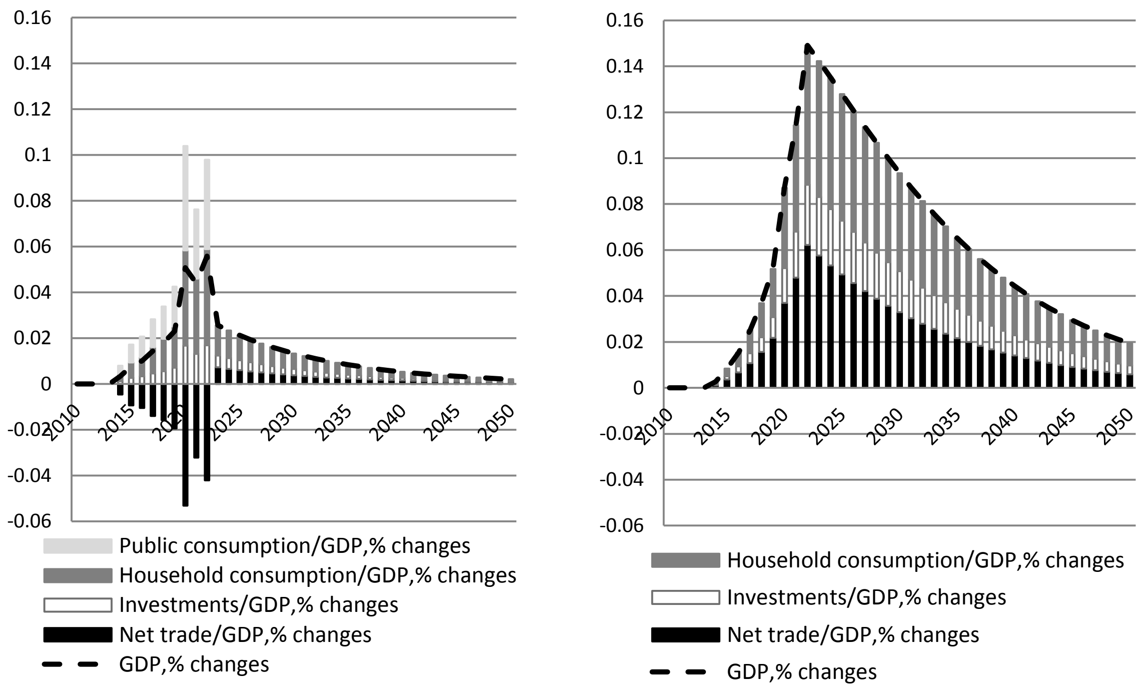


During the ERDF programming period, household consumption plays a fundamental role in GDP growth, whereas public consumption and investments make smaller contributions.

However, after 2022, the impact of public consumption on GDP declines while the contribution of the net trade on GDP sharply increases. These gains in net trade are achieved due to the competitiveness gains resulting from the TFP improvements and the capital stock increase.

In Figure 8 we show the GDP growth decomposition separately for the demand (left pane) and the productivity shocks (right pane).

Figure 8. Decomposition of GDP growth in Apulia by component (percentage changes from baseline) - Demand (left pane) and structural (right pane) effects



In the case of a pure demand shock (left pane of Figure 8), during the ERDF programming period a contraction in net trade almost entirely offsets the increase in public consumption, leaving household consumption and investments as the only sources of GDP growth until 2022. From 2022 onwards, growth in household consumption accounts for the major share of the GDP growth, with insignificant contributions of investments and net trade. The right pane of Figure 8 shows that along the model horizon structural shocks result in much higher rates of GDP growth and in a different composition of GDP growth compared with that resulting from a demand shock. After the productivity shock, investments and net trade together account for more than half of GDP growth, while household consumptions constitutes the remaining share.

The policy outcomes analysed in this chapter clearly show that in order for the benefits of the investment policy to be sustained over time it is important that the allocation of investments and the policy implementation were effective in raising productivity. Although investment injections boost demand, the structural effects heavily depend on the way policies are implemented. This highlights the importance of policy design to ensure that the policies yield the desired effects. Investment interventions have to be carefully designed in order to translate funding into long-lasting structural improvements capable of contributing to sustainable development. This observation calls for the setup of policy monitoring tools, midterm reviews, and impact assessment exercises based on empirical analyses (to complement model-based ex-ante and ex-post impact assessments).

6 Conclusions

This report documents the ex-ante economic impact assessment of ERDF investments related to R&I and sustainable energy in Apulia, a Southern Italian region. The assessment has been carried out with the spatial CGE model RHOMOLO (and its IO version, RHOMOLO-IO) which features the economic transactions in all NUTS2 regions of the EU and it is ideal to study the potential spillover effects resulting from the implementation of TO1 and TO4 investment projects in a specific region. Because of the high level of sectoral aggregation in RHOMOLO, policy evaluation was done at the macro-level, aggregating the funding of policy objectives into broad categories.

The key working assumption of the exercise is that productivity improvements achieved due to policy funding have a structural impact on the economy and are maintained even in the absence of investment monetary injections. The macroeconomic simulations show that policy funding of TO1 and TO4 objectives provides a large temporary stimulus during the ERDF programming period with positive effects on GDP, investment, exports, household consumption, and employment in Apulia. Due to the structural productivity effects, when policy funding is over the positive economic impacts continue in the long-run.

All sectors are positively affected by T01 and T04 investments, with Manufacturing and construction experiencing the largest positive effects as it benefits both from production subsidies during the programming period and from the long-lasting factor productivity improvements. The policy effects on Apulia and neighbouring regions are the strongest in the last years of ERDF programming period, when absorption of investment funding is at its peak and competitiveness-enhancing structural effects are fully in place. The strength of spillover effects decreases over time so that by 2030 the positive economic impacts are maintained primarily in Apulia.

It should be noted that CGE models are not used for forecasting economic development, rather they are the standard tool for a "what-if" type of analysis, providing insights about the sign and magnitude of economy-wide project impacts. Such an analysis is considered crucial to support public authorities for their policy design activities. The analysis presented in this report may be improved by working on the assumptions on the strength and duration of the policy-induced factor productivity long-lasting effects which could be updated should robust empirical estimates of the influence of R&D investments on regional productivity become available.

Our results demonstrate that investments in R&I and in shifts towards a low-carbon economy not only have positive effect on the directly affected region, but also generate positive spillover effects, improving the welfare of other regions that are connected through trade links with the recipient region. This outcome highlights the importance of interregional cooperation which is in fact featured in the Apulian smart specialisation strategy.

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