Olga Diukanova, Giovanni Mandras, Francesco Di Comite

Modelling the Effects of RI and Low-Carbon European Structural Funds: The Case of Apulia, Italy

(doi: 10.14650/103213)

Scienze Regionali (ISSN 1720-3929)
Fascicolo Speciale, gennaio-aprile 2022

Ente di afferenza:
()

Modelling the Effects of R&I and Low-Carbon European Structural Funds: The Case of Apulia, Italy

Olga Diukanova, Giovanni Mandras, Francesco Di Comite

Received: 7/10/2020; Accepted: 5/10/2021

Abstract: The European cohesion policy is the main investment instruments targeting cities and regions at the European Union level and it targets all regions and cities in order to support job creation and economic and sustainable growth. For most regions, that policy is of the main tools to promote research and innovation and to facilitate the transition towards a low-carbon economy. This paper uses data for the Southern Italian region of Apulia to perform an ex-ante evaluation of the macroeconomic effects of the cohesion policy funds used to subsidize research and innovation and to support low-carbon investments. Both an input-output analysis and one carried out with the dynamic general equilibrium model RHOMOLO suggest that the European funds under analysis can exert substantial positive effects on the economy of Apulia.

Keywords: the EU cohesion policy, input-output analysis, CGE models.
JEL classification: O38, O44, C67.

1. Introduction

The ex-ante evaluation of the macroeconomic effects of public policies helps decision-makers to form sound expectations on how the effects of planned interventions could materialise within and beyond national and regional borders. Analyses based on well-defined and transparent analytical frameworks can support policy making at all levels and may either increase the benefits or mitigate the losses related to the policy interventions themselves[1].

The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

Olga Diukanova: European Commission, Joint Research Centre, Calle Inca Garcilaso 3, 41092 Sevilla, Spain. E-mail: Olga.Diukanova@ec.europa.eu, https://orcid.org/0000-0002-9611-8200, *corresponding author*
Giovanni Mandras: European Commission, Joint Research Centre, Calle Inca Garcilaso 3, 41092 Sevilla, Spain. E-mail: Giovanni.Mandras@ec.europa.eu
Francesco Di Comite: European Commission, DG Internal Market, Industry, Entrepreneurship and SMEs GROW.A1 – Economic Analysis/Chief Economist Unit, B – 1049 Brussels, Belgium. E-mail: francesco.di-comite@ec.europa.eu, https://orcid.org/0000-0003-2139-3715

[1] Ex-post analyses are equally important for policy makers (see, for example, Comi *et al.*, 2019; Caloffi *et al.*, 2019), as they can be used to evaluate the implementation of certain policies and guide similar future policy interventions.

ISSN 1720-3929

This paper concentrates on a specific Southern Italian region, Apulia, to perform an ex-ante evaluation of two broad types of policies which are particularly relevant in the current political scenario: subsidies to research and innovation (R&I), and low-carbon investments. With regards to the former, although there is consensus on the need of innovation to generate economic growth and employment (Acemoglu, 2012), the debate is ongoing on the effects of government actions promoting R&I investment (Aristei *et al.*, 2017; Davidson, Segerstrom, 1998). This type of interventions has been, and continues to be, at the core of the industrial policies of European countries, as well as of China and others, at least from the early nineties onwards (Acemoglu *et al.*, 2018; Aghion *et al.*, 2015).

As for low-carbon investments, policy makers worldwide are facing, and in some cases encouraging, a widespread push towards decarbonisation and a shift to low-carbon energy production and use (Goldthau, 2017; Carraro *et al.*, 2012). This is particularly relevant in the European Union (EU), as the so-called European Green Deal was launched at the end of 2019 and is supposed to characterise the whole mandate of the new Commission led by President von der Leyen (European Commission, 2019). Needless to say, this transition requires R&I investments and innovative solutions to favour decarbonisation (European Commission, 2017).

In the EU, most regions see the European cohesion policy as one of the main tools in order to promote R&I and, at the same time, accompany the low-carbon transition. Cohesion policy is the EU's main investment policy and it targets all regions and cities in the EU in order to support job creation, business competitiveness, and economic and sustainable growth. Among its objectives, the policy aims at achieving economic and social cohesion and to reduce the disparities between EU regions. For the 2014-2020 programming period (although the funds can be spent until 2022), the European cohesion policy is financed by the European Structural and Investment Funds (ESIF). The latter consist of five different funds, including the following: 1) the European Regional Development Fund (ERDF) supporting the development and structural adjustment of regional economies accounts for 43% of the whole ESIF; 2) the European Social Fund (ESF) contributing to the adaptability of workers and enterprises and dealing with labour market policies (Sakkas, 2018); and 3) the Cohesion Fund (CF) supporting less-developed European regions and countries.

More than € 460 billion of EU funds have been allocated for the 2014-2020 period, with more than half of the resources going to the less developed regions where GDP is less than 75% of the EU average. Italy receives almost € 45 billion in total, of which about € 33 billion are related to the ERDF and the ESF. Of those, € 5.7 go to Apulia, which is among the three regions receiving the most funds in the country together with Sicilia and Campania. The ERDF in particular supports eleven so-called Thematic Objectives (TOs) which include strengthening 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.

The release of these funds is inextricably linked to Smart Specialisation, which defines the EU approach to regional innovation policy and characterises the place-based nature of cohesion policy (Barca, 2008). Smart Specialisation is far from being a solely political concept, as proved by the recent literature review by Mora *et al.* (2019) on its scientific relevance. In particular, the ERDF budget related to TO1, the TO on strengthening research, technological development and innovation, is legally bound to finance national and regional Smart Specialisation strategies written by policy makers in close cooperation with other public and private stakeholders of their territories.

We focus our study on the Italian region of Apulia because it presents a number of characteristics that make it the perfect candidate for an interesting case study. First of all, as written above, it is one of the regions benefitting the most from the ERDF and from the European cohesion policy in general. Second, Apulia's Smart Specialisation strategy has attracted considerable attention and fits well within the logic of intervention of the policy (Fiore, 2016; Pancotti *et al.*, 2016; Grigolini *et al.*, 2015). And third, Apulia is one of the most dynamic Southern Italian regions in terms of industrial, environmental and economic in general, performance (De Marchi *et al.*, 2014).

There were several other important studies aimed at impact assessment of EU regional development policies on the economy of Apulia. Among them we can mention the study of Marinelli *et al.* (2018) of higher technical institutes and innovative industrial doctorates on Smart Specialisation and regional development. The study of Pesce and Barbieri (2015) focused on the ex-post evaluation of Cohesion Policy programmes 2007-2013. And the study of Kyriacou and Roca-Sagalés (2012) was dedicated to the impact assessment of EU regional funding. This study analysed the impact of the current economic crisis on the Apulia region and the role of the European regional development policies on local development and on the overcoming of the crisis. All these qualitative studies concluded an overall a positive impact of EU regional development programmes on Apulian economy, highlighting the importance of improving the coordination between the programs and policy makers.

In this paper, we quantify the macroeconomic impact of the European Regional Development Fund (ERDF) that is allocated to the Apulia region 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». We target innovation and low-carbon policies in Apulia because regional S3 priorities focus on blue and green economy, sustainable energy and innovation development. Apulia is, in fact, the leading region in the production of clean energy, holding first place in Italy in the production of wind and photo-voltaic energy and third in bio-energies. More than a half of region's electricity needs are already covered by renewable energy sources. Apulia also holds a propulsive role in realizing policies for innovation development thanks to its technology excellence poles, original R&I sectors, diversified services providers growth of informatics and research industry. Technological and business clusters support a close link between innovative and low-carbon policies: the business cluster «La Nuova Energia» supports energy production from renewable sources; the Apulian Sustainable Construction Business Cluster promotes sustainable construction in Apulia; the Apulian Environmental and Reuse Business Cluster favours industrial research and technological innovation with the objective of reducing waste generation and the use of polluting agents in production; National Energy Technology Cluster supports research in the energy field, favouring technology transfer between national and international actors to bridge research, enterprise and credit agencies (European Commission, 2020a).

For policy evaluation we first use a simple Input-Output (IO) framework to gauge the potential effects of a demand-side shock in the economy of Apulia. Then, we carry out an analysis using a dynamic spatial Computable General Equilibrium (CGE) model called RHOMOLO (Lecca *et al.*, 2018) in order to account for both demand-side, supply-side and spillover effects of the policy. RHOMOLO was created for providing the policy support with ex-ante evaluation of European regional policies on request of the Directorate General for Regional and Urban Policy (Di Comite *et al.*, 2018). The model is also used by the European Investment Bank for an assessment of the impact of EU investment support policies (EIB, 2018). The RHOMOLO model represents economies of all NUTS2 regions of the EU, which permits it to capture both the direct effect of policy interventions in Apulia and propagation of spillover effects to other NUTS2 regions that are interconnected with trade and factor flows. Model results help identifying the territories where the benefits or losses are concentrated, to select priority areas for policy interventions, and also provide a basis for comparing net welfare benefits with prospective investment costs.

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 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

2.1. Socio-economic profile

Apulia is a densely populated region (above the national average) characterised by a complex mix of urban and rural landscapes. Located in the

Table 1: Main socio-economic indicators in Apulia

	Apulia	Italy	EU28
GDP per capita (euro)	€ 17,400	€ 26,500	€ 27,500
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[2])	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

Note: [1] EAP-Economic Active Population. [2] Economic Active Population 15 to 24 years old.
Source: EUROSTAT (2016).

South-East of Italy, this region has slightly more than 4 million inhabitants living in a territory of approximately 19,000 km^2. Table 1 shows some socio-economic indicators which suggest that Apulia presents below-average country performances in several respects, something that should not be surprising given the well-known Italian North-South divide (Felice, 2011). Despite that, Apulia is very active in terms of policy experimentation and participation to EU-sponsored interventions (IPRES, 2015).

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).

Labour productivity varies much among sectors, being lowest in agriculture and highest in the service sector. Apulia has specialised in producing electricity both from 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 plants: Apulia does not have any hydroelectric installations due to its lack of rivers or lakes, but it hosts Italy's largest coal plants.

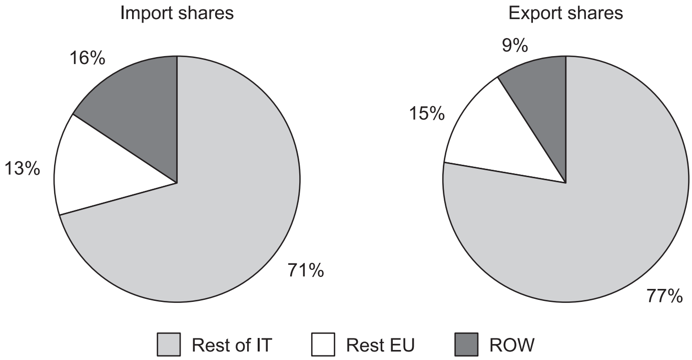

Figure 1: Apulia import and export shares by origin and destination (rest of Italy, rest of the EU, and rest of the world).
Source: Authors' estimations based on the data by Thissen *et al.* (2019).

Apulia is among the leading regions in Italy in renewable energy production. In 2018, its total installed capacity was 2.5 GW for wind, 2.6 GW for photo-voltaic energy, and 0.3 GW for biomass and waste energy, for a total of more than 5.5 GW. These were respectively 25%, 13%, and 8% of the national totals (GSE, 2019). 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).

Apulia is number 15 among the Italian regions in terms of international trade performance, with international imports and exports accounting for almost 25% of the regional GDP (ARTI Puglia, 2018). The regional dataset constructed by Thissen *et al.* (2019) permits to decompose the imports and exports according to their origins and destinations, respectively.

Not surprisingly, most of the commercial flows entering and exiting the region are related to national activities. In particular, 71% of the imports and 77% of the exports of the Apulia economy come from, and go to, other Italian regions. The importance of the rest of the EU for trade is comparable in imports and exports, and it is smaller than that of the rest of the world for imports (13% versus 16%), and larger for exports (15% versus 9%).

Small economies are normally more open than big ones, and single regions within a country are normally very open to national and international trade. 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. Thus, we can expect large inter-regional spillover effects from investments in the region under analysis.

2.2. Cohesion Policy interventions and Smart Specialisation in Apulia

In the 2014-2020 programming period, a total ERDF contribution of € 2,8 billion has been earmarked for Apulia to be invested in eleven TOs, which amounts to roughly 4% of regional GDP. 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)[2]. Low-carbon activities are the important 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.

The Regional Innovation Strategy of Smart Specialisation (RIS3) provides the framework to combine ERDF with other public and private investments[3]. 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 CO_2 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.

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 (EU, 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 optimising 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

[2] 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.

[3] 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.

gross final energy consumptions of 14.2% by year 2020 and creating new business opportunities for the regional companies through R&I. In fact, in 2018 already 16.5% of consumed energy excluding transport in Puglia was coming from renewable sources; Openpolis, 2020). A prominent policy in this field was creation of Puglia Active Network, an intelligent network covering the entire region that aims at integrating the energy generated by renewable plants distributed throughout the territory reducing network loses. It envisages the creation on a regional scale of public charging infrastructures for electric vehicles that are perfectly integrated into the electricity grid. Launched in 2014, it is a 170 million euro project, 50% co-financed by the European Union within a NER 300 programme (European Commission, 2020b).

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 comparison of the Regional Innovation Index for 2019 with the one for 2011 shows an increase of 5.3 points making Puglia be ranked as a moderate (with performance between 50% and 90% of the EU average) innovator according to the Regional Innovation Scoreboard 2019. The main weaknesses relate to business R&D expenditures in business sector (46% below the Italian average; 58% below the one for Europe), population who completed tertiary education (37% below the Italian average; 69% below the one for Europe) and EPO patent applications (52% below the Italian average; 67% below the one for Europe). However, the region is relatively strong in the field of the most-cited scientific co-publications and public R&D expenditures (European Commission, 2020a).

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 62946 projects, the largest share of Mezzogiorno cohesion policy interventions (IPRES, 2015) is concentrated in Apulia[4]. 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 programming 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 ERDF objectives have to be achieved by the end of the programming period 2014-2020, although the N+2 rule allows the funds to be spent until 2022. In Apulia, targets related to R&I include, among others: *a*) support of

[4] Mezzogiorno includes the Italian regions of Abruzzo, Apulia, Basilicata, Campania, Calabria, Molise, Sicilia, Sardinia, and part of Lazio.

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

Thematic objective	Amount, (M €)
O1 – 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
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
O4 – 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.

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 CO2eq[5].

[5] See the Open Data Portal for the European Structural Investment Funds maintained by the European Commission, DG REGIO.

Its rapid progress in innovation development, strategic role of green economy, strong business and public support of S3 and Cohesion policies make Apulia and important region for a case study.

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 use both IO and CGE modelling techniques.

The regional RHOMOLO-IO multiplier analysis utilises information about inter-industry relationships to highlight how the impact of demand (investment) changes on a particular industry spread to the rest of the sectors of the economy. The RHOMOLO-IO framework is equivalent to a standard IO model (for more details see Mandras *et al.*, 2019) and uses the dataset underlying the calibration of the CGE model called RHOMOLO (Lecca *et al.*, 2018). The former permits to analyse the data in a simple way and sets the stage for the more advanced analysis carried out with the CGE model accounting for complex behavioural relationships between the economic agents. This type of modelling permits 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 2013 regional SAMs whose construction is explained in Thissen *et al.* (2019). In particular, the inter-industry flows matrix (IO table) 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.

As explained by Mandras *et al.* (2019), a key output of the IO analysis is the calculation of the industry linkages (i.e., its multipliers[6]) 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

[6] 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.

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 for the ten sectors contained in the dataset[7]. The highest Type-I multiplier is associated with the financial, insurance and real estate activities sector (1.13), 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), the public sector is characterised by the highest multiplier (4.08) identifying where the additional effects of household income generation have the greatest impact on the economy.

To provide some guidance on the interpretation of the multipliers, consider an increase of € 1 in final demand of the agricultural sector. The Type-I multiplier for this sector shows that a change in final demand of € 1 induces an increase in total output of € 1.10. In other words, in order to produce an additional unit of output in the target sector, the national

[7] The sectors are the following (including the NACE 2 codes): A – Agriculture, forestry and fishing; B, D, E – Mining and quarrying + Electricity, gas, steam and air conditioning supply + Water supply, sewerage, waste management and remediation activities; C – Manufacturing; F – Construction; G-I – Wholesale and retail trade, repair of motor vehicles and motorcycles + Transportation and storage + Accommodation and food service activities; J – Information and communication; K-L – Financial and insurance activities + Real estate activities; M-N – Professional, scientific and technical activities + Administrative and support service activities; O-Q – Public administration and defence, compulsory social security + Education + Human health and social work activities; R-U – Arts, entertainment and recreation + Other service activities + Activities of households as employers, undifferentiated goods and services producing activities of households for own use + Activities of extraterritorial organisations and bodies.

Table 3: Type I and Type II IO multipliers – Apulia region

NACE 2 sectors	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
A	1	0.07	0.03	1.10	2.04	0.81	1.17
B_E	1	0.01	0.03	1.04	1.73	0.49	0.75
C	1	0.01	0.08	1.09	2.62	0.47	1.06
F	1	0.01	0.03	1.04	2.02	0.54	0.92
G_I	1	0.02	0.03	1.05	2.60	0.65	1.25
J	1	0.00	0.05	1.05	2.88	0.68	1.39
K_L	1	0.12	0.01	1.13	2.69	0.72	1.32
M_N	1	0.01	0.04	1.05	2.68	0.63	1.26
O_Q	1	0.01	0.02	1.04	4.08	0.77	1.94
R_U	1	0.02	0.02	1.04	3.15	0.74	1.55

Source: Authors' estimations based on the data by Thissen *et al.* (2019).

economy's output must increase by an additional € 0.07 in order to provide inputs to the agriculture sector itself, and in turn an increase of € 0.03 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 (0.07), and the industrial support effects (0.03). The sum of all these effects gives us the Type-I output 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 2.04.

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 € 1.17 (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 sector (for example, by purchasing machines for the local companies), then the local increase in total value added associated with this policy would total € 252 million over the years (using the type I value added multiplier), which is roughly 0.35% 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. Analysis of the RHOMOLO simulations

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 «baseline scenario». Therefore, simulating a policy change with a CGE model is a «what if» comparison of two equilibrium states of the economy.

All models are the stylised representation of reality featuring only the aspects that are the most relevant for a specific study. However, none of the existing models is able to capture better than CGE models the interconnectedness of economic sectors and the categories of final demand, accounting for both direct and spillover effects that ripple through the regions and sectors following changes in relative prices.

In this aspect, RHOMOLO is a unique model because of its very disaggregated regional structure which permits to trace how a policy shock applied to one region will spill over to other regions that are interconnected with trade and factor flows. 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 ten NACE Rev. 2 sectors. Currently, a very detailed regional disaggregation comes at a cost as due to the lack of statistic data, at the NUTS2 level the interregional trade flows are available only for ten 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 structure of the multi-regional CGE model RHOMOLO employed in this study closely follows Lecca *et al.* (2018). 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 constructed with EUROSTAT data and the data of the national statistic committees that permit the model to capture the unique structure of regional economies and transactions that take place within each region. The estimated matrices of trade and transport flows between regions are based on Thissen *et al.* (2019). Transport costs for trade between regions are of iceberg type and are sector- and region-pair specific. An asymmetric trade cost matrix was derived by Persyn *et al.* (2020).

Industries can function in either perfectly or monopolistically competitive markets (Dixit, Stiglitz, 1977). Labour is disaggregated into high-, medium- and low-skill groups. Unemployment is modelled through a wage curve (Blanchflower, 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 optimise 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 rather steep economic adjustment paths. In contrast, forward-looking CGEs are solved at once for the whole model horizon, which performs as a «prior announcements of policy changes», so that due to the rational expectations, economic agents can adjust to shocks before they happen, thus, producing a smoother adjustment trajectory. However, considering the gradual absorption of policy funding, the framework of myopic expectations better fits the S3 policy context.

The ability of modelling/capturing explicitly spatial linkages, interactions and spillovers between regional economies makes the RHOMOLO model an ideal tool for the ex-ante economic impact assessment of ERDF investments in Apulia.

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 62946 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 economic sectors of RHOMOLO. Taking into account the scope of TO1 investment funding, for this policy exercise the TO1 investments were translated into total factor productivity (TFP) improvements in all 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 (see Table 2 for the source of policy funding) enters the model as TFP improvements in all sectors. Although, R&D investments result also in production of a new and or improved products, this mechanism is not captured with RHOMOLO.

On the other hand, investments for «Institutional capacity of public administration» under the categories 013 and 068 (see Table 2 for the source of policy funding) are allocated as lump-sum transfers to the public sector (see the second row of Table 4).

Because of the highly aggregated production structure of RHOMOLO, caused by the lack of interregional trade flows data at detailed sectoral level for NUTS2 regions, at present energy sector cannot be disaggregated into fuel extraction, petroleum refinement, different electricity generation technologies, power transmission and distribution. For this reason, energy supply and demand flows are not explicitly represented in RHOMOLO, and, therefore, 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 (see Table 2 for the sources of policy funding) enter the model as a «Subsidy to the production of manufacturing sector» (see the last row of Table 4). This approach permits to capture the resource-saving and cost-reducing nature of these policy objectives.

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

Table 4: Translation of funding of TO1 and TO4 objectives into the model shocks

TOs' categories	Amount of policy funding (M €), 2014-2020	Model shock
O1 – 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 sectors in Apulia
O4 – 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 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.

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 (European Commission, 2021). This results in a low absorption rate in the first years which gradually increases to peak in the last year of the programming period (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 employed a working assumption that in the absence of continuous investment injections the policy-induced TFP improvements will gradually depreciate. 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 TO1 and TO4 investments during the ERDF programming period of 2014-2022. When the programming period is over, inter-regional investment transfers to Apulia cease, the *demand-side 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, exports, imports, wages, consumer price index (CPI) and employment in Apulia.

Not surprisingly, TO1 and TO4 policy funding has a positive impact on all the selected economic indicators in Apulia, increasing employment 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 GDP growth is achieved in 2022, when the ERDF programming period terminates with full absorption of policy funding. In particular, in 2022 we observe a 0.12% increase in GDP and a 0.07% 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 2050.

In order to illustrate the structural changes promoted by ERDF policies in the different sectors, in Figure 3 and Figure 4 we plot the percentage changes in output and employment relative to the baseline values over the whole simulation horizon (on both charts changes in output of manufacturing sector is depicted on the secondary axis).

As illustrated in Figures 3 and 4 all sectors in Apulia are positively affected by TO1 and TO4 investments. The regional Manufacturing, Research&Development, Business Services and Trade&Transport sectors benefit the most from TFP improvements that are generated thanks to the TO1 funding. Since the manufacturing 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

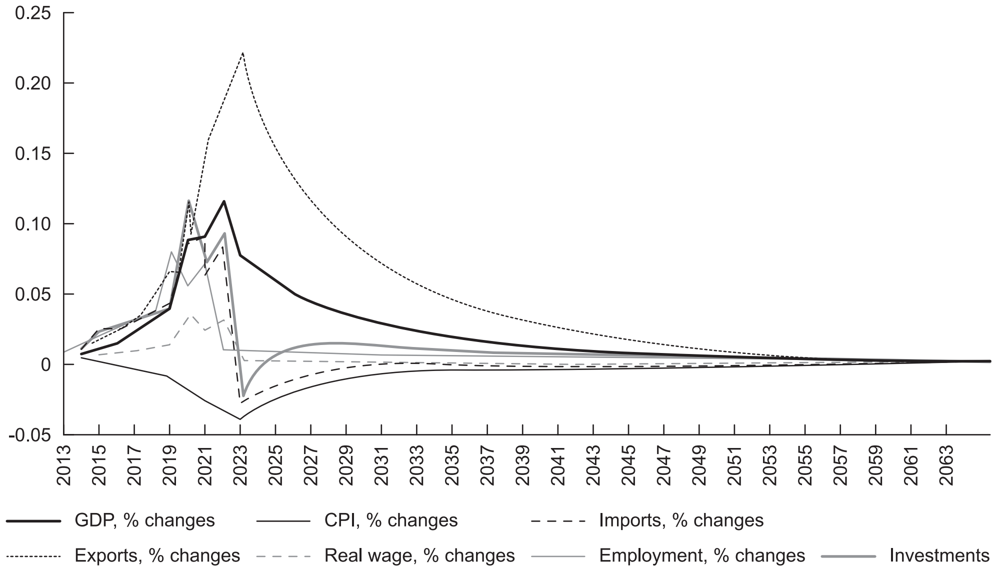

Figure 2: Impact of TO1 and TO4 policy funding in Apulia (percentage changes from baseline).
Source: Computer simulations with the RHOMOLO model.

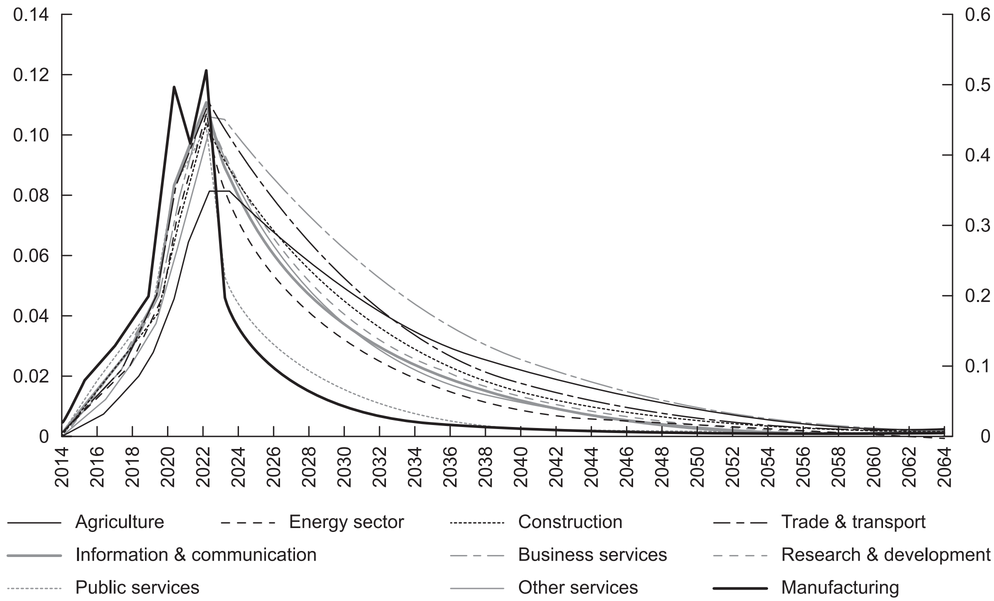

Figure 3: Impact of TO1 and TO4 policy funding on output per sector in Apulia (percentage changes from baseline).
Source: Computer simulations with the RHOMOLO model.

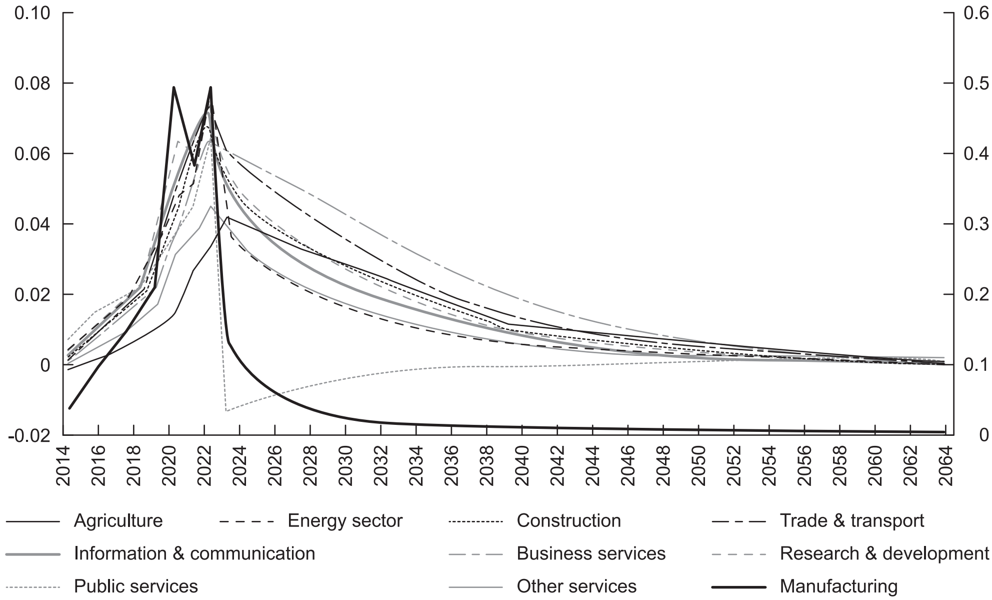

Figure 4: Impact of TO1 and TO4 policy funding on employment per sector in Apulia (percentage changes from baseline).
Source: Computer simulations with the RHOMOLO model.

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 TO1 and TO4 policies in Apulia on the GDP of all the NUTS2 regions of the EU in 2016, 2022, 2025, and 2030 is displayed in Figure 5.

The key observation arising from the maps in Figure 5 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 TO1 and TO4 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 ripple through 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 simulations. In a post-2022 period, Apulia still enjoys a comparative advantages gained through the lagged productivity effects that help it to take market shares of neighbouring Italian regions. Competitiveness improvements sustained until 2030 permit

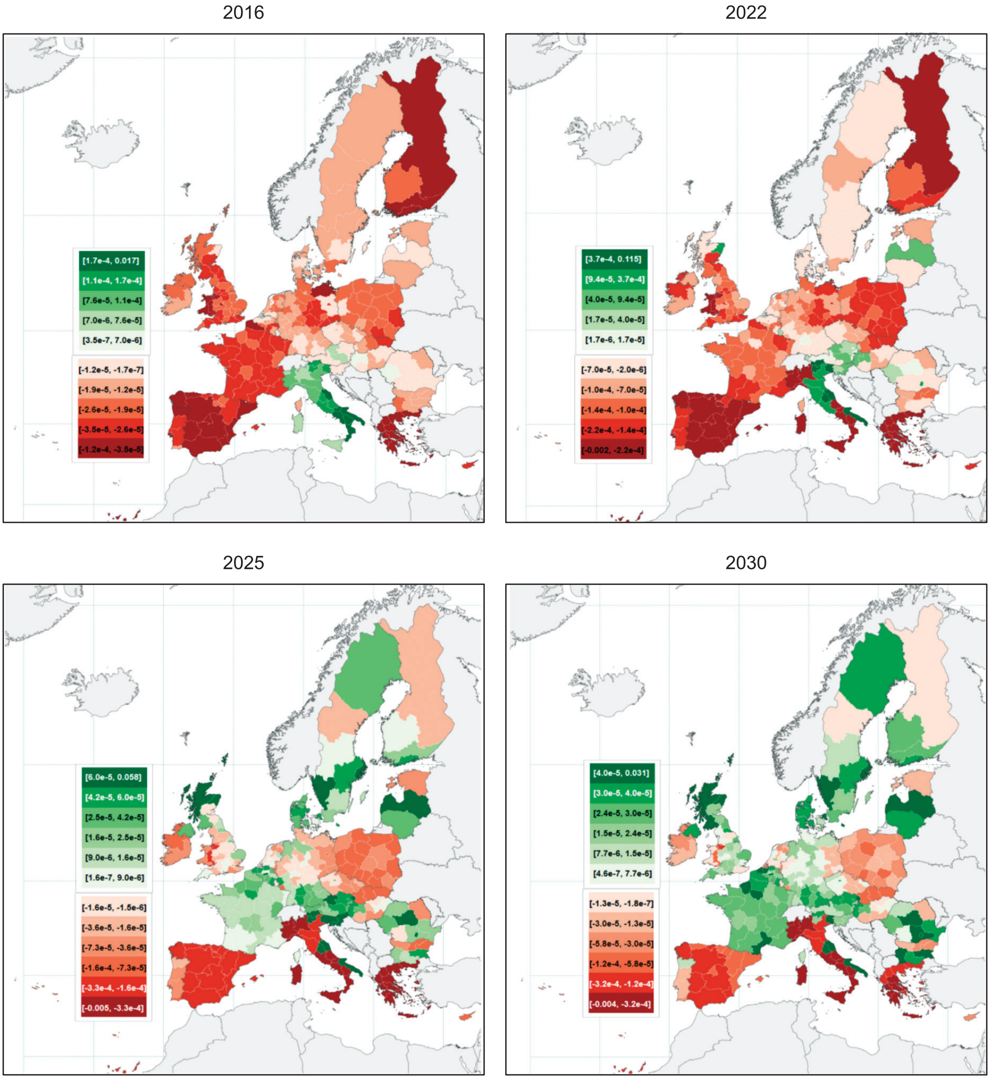

Figure 5: GDP changes in NUTS2 regions due to the policy funding in Apulia (percentage changes from baseline).
Source: Computer simulations with the RHOMOLO model.

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.

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.

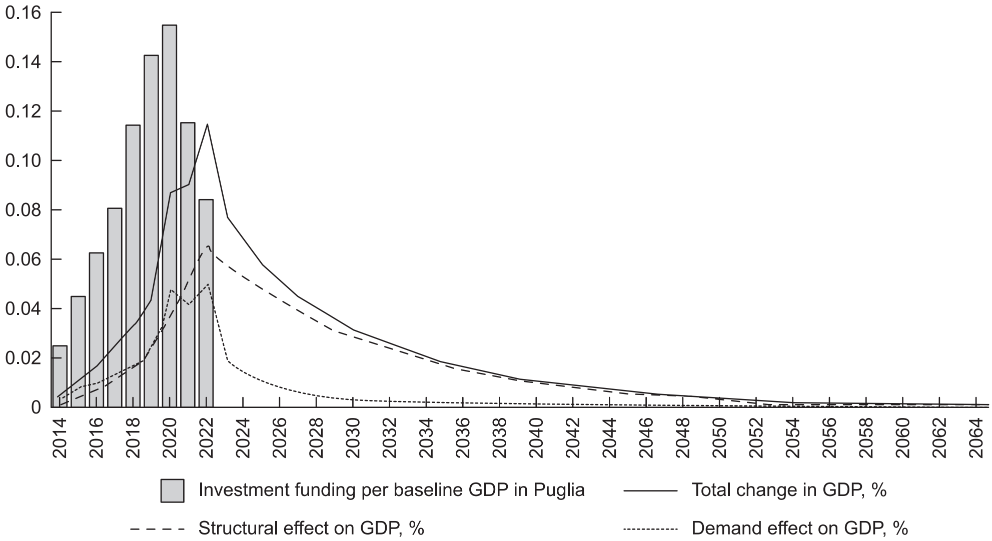

Figure 6: Demand-side and structural effects on GDP in Apulia (percentage changes from baseline).
Note: The intensity of policy funding is expressed as percentage of GDP.
Source: Computer simulations with the RHOMOLO model.

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 the key macroeconomic variables.

Figure 6 suggests that during the ERDF programming period the *demand-side* induced GDP growth amounted to roughly to the half 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 responds strongly 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 that lower the cost of domestic production would increase the volume exports and, therefore, have a positive impact on GDP. In order to better grasp such macroeconomic mechanisms, in Figure 7 we compare the policy impacts on Apulian

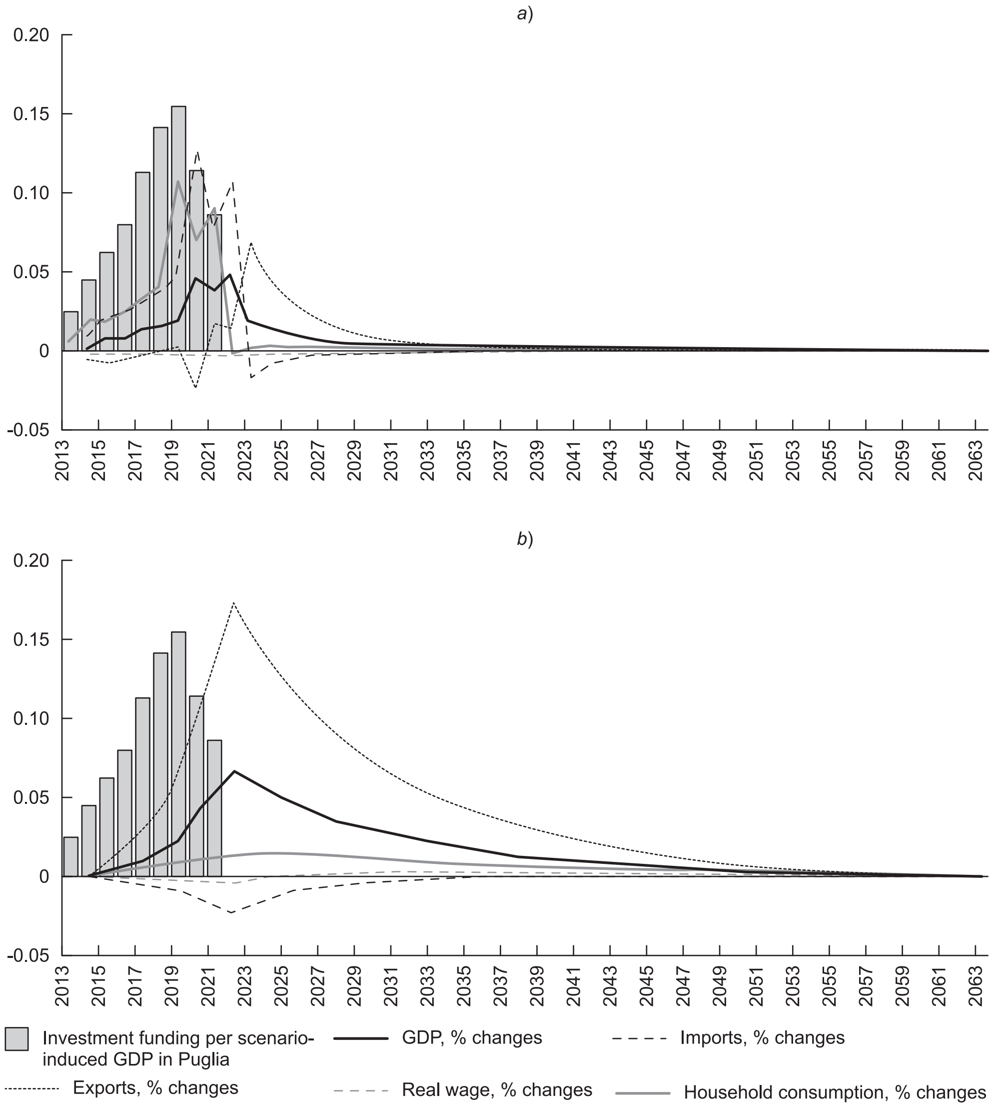

Figure 7: Demand-side *a*) and structural *b*) effects on key macroeconomic variables in Apulia (percentage changes from baseline).
Source: Computer simulations with the RHOMOLO model.

macroeconomic variables when demand-side (pane *a*) and structural (pane *b*) 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

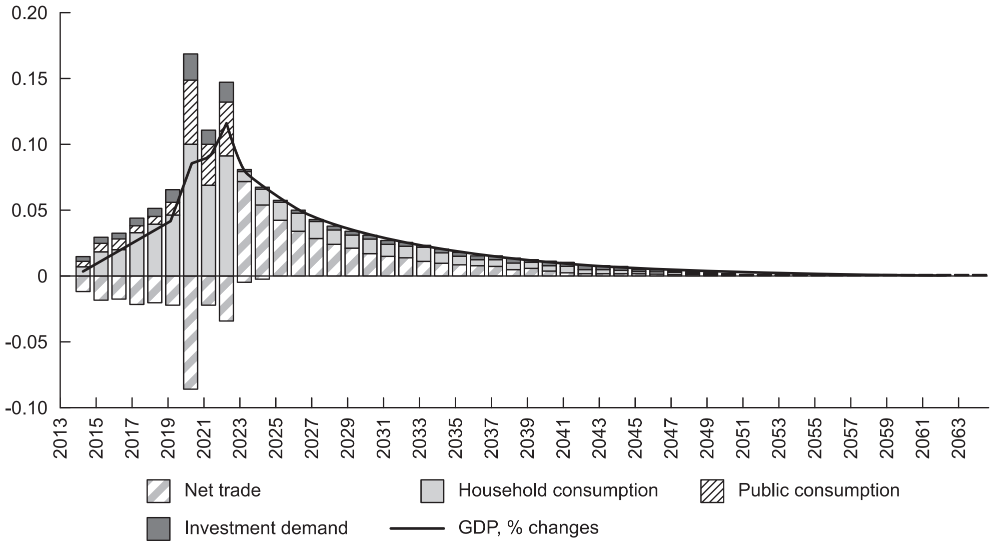

Figure 8: Decomposition of GDP growth in Apulia by component (percentage changes from baseline).
Source: Computer simulations with the RHOMOLO model.

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.

In order to further investigate deeper the difference between demand-side and structural effects, we decomposed GDP growth into the growth of its individual components in Figure 8.

During the ERDF programming period, household consumption plays a fundamental role in GDP growth, whereas public consumption and investments make smaller contributions, see Figure 7. 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 9 we show the GDP growth decomposition separately for the demand *a*) and the productivity shocks *b*).

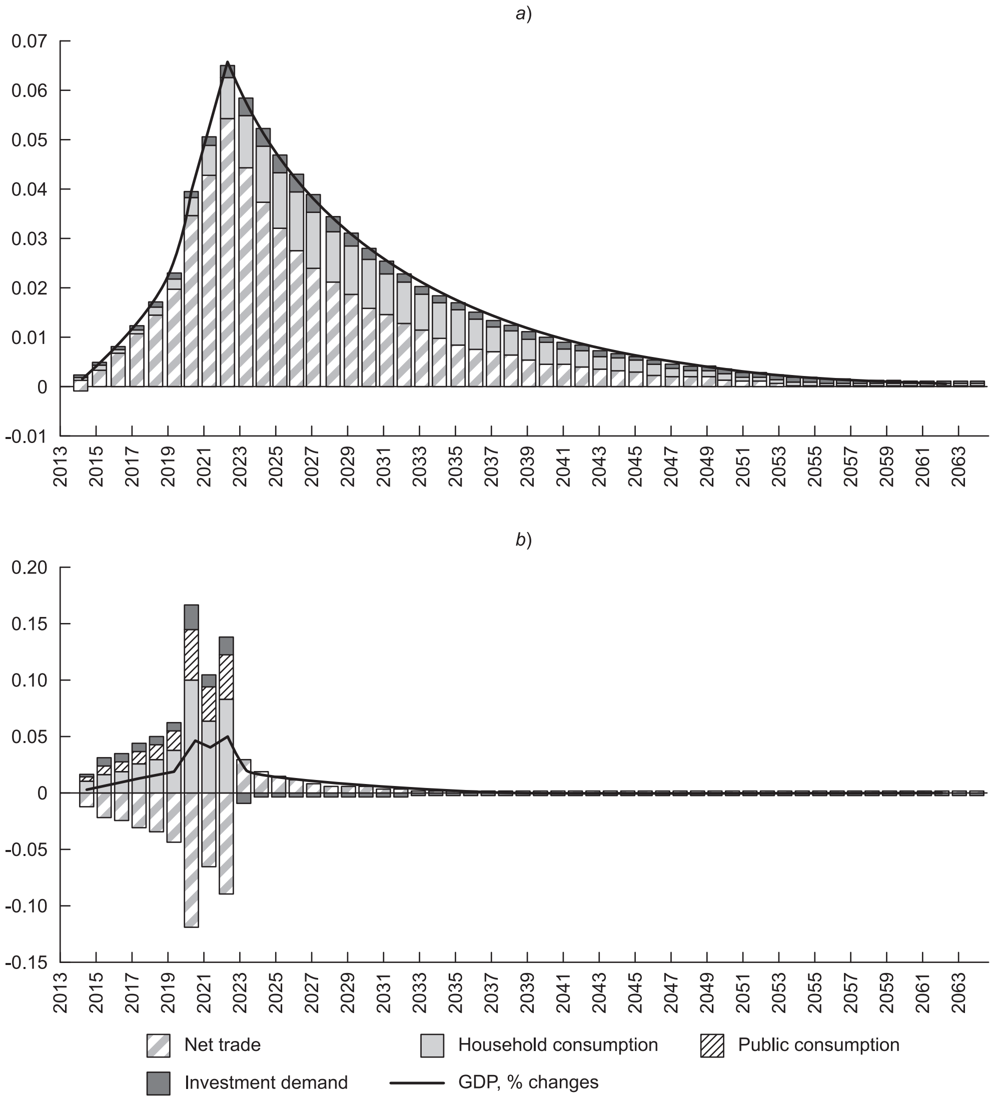

Figure 9: Decomposition of GDP growth in Apulia by component (percentage changes from baseline) – Demand *a)* and structural *b)* effects.
Source: Computer simulations with the RHOMOLO model.

Figure 9*a)* 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, net trade accounts for the major share of GDP growth, while household consumptions and investments constitute the remaining share.

In the case of a pure demand shock of Figure 9*b*), during the ERDF programming period a contraction in net trade almost entirely offsets the increase in household consumption, leaving public 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 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 paper contains an ex-ante economic macroeconomic 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 an IO framework as well as with the spatial dynamic CGE model RHOMOLO 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.

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 continuous 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 at a gradually slowing pace.

All sectors are positively affected by TO1 and TO4 investments, with manufacturing sector 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 emphasized that CGE models are not designed 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 could be enriched with a thorough research on the strength and duration of the policy-induced factor productivity long-lasting effects 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.

References

Acemoglu D. (2012), Introduction to Economic Growth. *Journal of Economic Theory*, 147, 2: 545-550. DOI: 10.1016/j.jet.2012.01.023.

Acemoglu D., Akcigit U., Alp H., Bloom N., Kerr W. (2018), Innovation, Reallocation, and Growth. *American Economic Review*, 108, 11: 3450-3491. DOI: 10.1257/aer.20130470.

Aghion P., Cai J., Dewatripont M., Du L., Harrison A., Legros P. (2015), Industrial Policy and Competition. *American Economic Journal: Macroeconomics*, 7, 4: 1-32. DOI: 10.1257/mac.20120103.

Aristei D., Sterlacchini A., Venturini F. (2017), Effectiveness of R&D Subsidies During the Crisis: Firm-Level Evidence Across EU Countries. *Economics of Innovation and New Technology*, 26, 6: 554-573. DOI: 10.1080/10438599.2016.1249543.

ARTI Puglia (2018), Le esportazioni pugliesi: un'analisi territoriale e settoriale. *Instant Report* n. 1. Available at: https://www.arti.puglia.it/wp-content/uploads/ARTI-PUGLIA-IT__Instant-report_01_2018.pdf.

Barca F. (2008), *An Agenda for a Reformed Cohesion Policy a Place-Based Approach to Meeting European Union Challenges and Expectations*. EERI Research Paper Series EERI_RP_2008_06. Brussels: Economics and Econometrics Research Institute (EERI).

Blanchflower D. G., Oswald A. J. (1995), An Introduction to the Wage Curve. *Journal of Economic Perspectives*, 9, 3: 153-167. DOI: 10.1257/jep.9.3.153.

Caloffi A., Rossi F., Russo M. (2019), The Network Effects of Regional R&D Collaboration Policy. *Scienze Regionali – Italian Journal of Regional Science*, 18, 2: 193-214. DOI: 10.14650/93647.
Carraro C., Favero A., Massetti E. (2012), Investments and Public Finance in a Green, Low Carbon, Economy. *Energy Economics*, 34, 51: 515-528. DOI: 10.1016/j.eneco.2012.08.036.
Comi S., Resmini L., Vittucci Marzetti G. (2019), The Impact of Regional Export Promotion Policies in Italy. The Case of Lombardy. *Scienze Regionali – Italian Journal of Regional Science*, 18, 2: 215-236. DOI: 10.14650/93648.
Davidson C., Segerstrom P. (1998), R&D Subsidies and Economic Growth. *The RAND Journal of Economics*, 29, 3: 548-577. DOI: 10.2307/2556104.
De Marchi V., Grandinetti R., Voltani R. (2014), How Are Italian Regional Economies Evolving? Comparing Veneto, Piemonte and Puglia. *Economia e Società Regionale*, 2: 126-160. DOI: 10.3280/ES2014-002009.
Di Comite F., Lecca P., Monfort P., Persyn D., Piculescu V. (2018), The Impact of Cohesion Policy 2007-2015 in EU Regions: Simulations with the RHOMOLO Interregional Dynamic General Equilibrium Model. Seville: European Commission. *JRC Working Papers on Territorial Modelling and Analysis* n. 03.
Dixit A. K., Stiglitz J. E. (1977), Monopolistic Competition and Optimum Product Diversity. *American Economic Review*, 67, 3: 297-308. DOI: 10.7916/D8S75S91.
EIB (2018), *Assessing the Macroeconomic Impact of the EIB Group*. Available at: https://www.eib.org/attachments/efs/assessing_the_macroeconomic_impact_of_the_eib_group_en.pdf.
EU (2013), Regulation (EU) No 1301/2013 of the European Parliament and of the Council of 17 December 2013 on the European Regional Development Fund and on Specific Provisions Concerning the Investment for Growth and Jobs Goal and Repealing Regulation (EC) No 1080/2006. OJ L 347 20.12.2013, p. 289, CELEX. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013R1301.
European Commission (2017), *Low-Carbon Research and Innovation – Building a Low-Carbon, Climate-Resilient Future*. Luxembourg: Publications Office of the European Union.
European Commission (2019), *Turning Challenge into Opportunity on the Course to Becoming the First Climate-Neutral Continent*. Brussels, European Commission, Announcement, 13 December.
European Commission (2020a), *Regional Innovation Monitor Plus. Puglia, Internal Market, Industry, Entrepreneurship and SMEs*. Available at: https://ec.europa.eu/growth/tools-databases /regional-innovation-monitor/base-profile/puglia.
European Commission (2020b), *NER 300 Programme. Energy, Climate Change, Environment Climate Action. EU Action Innovation Fund*. Available at: https://ec.europa.eu/clima/policies/innovation-fund/ner300_en#tab-0-0.
European Commission (2021), *EU Regional and Urban Development Regional Policy Policy How Does It Work*. Available at: https://ec.europa.eu/regional_policy/en/policy/how/principles/.
EUROSTAT (2016), *Regional Statistics by NUTS Classification*. Available at: https://ec.europa.eu/eurostat/web/regions/data/database.

Felice E. (2011), Regional Value Added in Italy, 1891-2001, and the Foundation of a Long-Term Picture. *Economic History Review*, 64, 3: 929-950. DOI: 10.1111/j.1468-0289.2010.00568.x.

Fiore A. (2016), A Three Dimensional Approach to Regional Smart Specialization Strategy: An Application to Puglia Region. *MPRA Working Paper* n. 83905.

Goldthau A. (2017), The G20 Must Govern the Shift to Low-Carbon Energy. *Nature*, 546, 7657: 203-205. DOI: 10.1038/546203a.

Grigolini M., Pancotti C., Sirtori E., Vignetti S. (2015), A Place-Based Strategy to Smart Specialisation: The Case of Apulia. CSIL Centre for Industrial Studies. *CSIL Working Paper Series* n. 01.

GSE (2019), *Rapporto statistico 2018 – Fonti rinnovabili*. Gestore Servizi Energetici. Available at: https://www.gse.it/documenti_site/Documenti%20GSE/Rapporti%20statistici/GSE%20-%20Rapporto%20Statistico%20FER%202018.pdf.

IPRES – Istituto Pugliese di Ricerche Economiche e Sociali (2015), *Rapporto Puglia 2015*. Bari: Cacucci Editore.

Kancs D., Siliverstovs B. (2016), R&D and Non-Linear Productivity Growth. *Research Policy*, 45, 3: 634-646. DOI: 10.1016/j.respol.2015.12.001.

Kyriacou A. P., Roca-Sagalés O. (2012), The Impact of EU Structural Funds on Regional Disparities within Member States. *Environment and Planning C: Government and Policy*, 30, 2: 267-281. DOI: 10.1068/c11140r.

Lecca P., Barbero J., Christensen M. A., Conte A., Di Comite F., Diaz-Lanchas J., Diukanova O., Mandras G., Persyn D., Sakkas S. (2018), *RHOMOLO V3: A Spatial Modelling Framework. JRC Technical Reports JRC111861, EUR 29229 EN*. Luxembourg: Publications Office of the European Union.

Mandras, G., Conte, A., Salotti S. (2019), The RHOMOLO-IO Modelling Framework: A Flexible Input-Output Tool for Policy Analysis. Seville: European Commission. *JRC Working Papers on Territorial Modelling and Analysis* n. 06.

Marinelli E., Cavicchi A., Fiore A., Paviotti G., Gerussi E., Iammarino S. (2018), *Higher Education Instruments and Smart Specialisation Innovative Industrial Doctorates and Higher Technical Institutes in Puglia*. Luxembourg: Publications Office of the European Union.

Mora L., Deakin M., Reid A. (2019), Exploring Current Trends in Scientific Research on Smart Specialisation. *Scienze Regionali – Italian Journal of Regional Science*, 18, 3: 397-422. DOI: 10.14650/94657.

OECD (2012), *Linking Renewable Energy to Rural Development, OECD Green Growth Studies.* Paris: OECD Publishing. DOI: 10.1787/9789264180444-en.

Openpolis (2020), *L'Italia è a buon punto sull'utilizzo di energie rinnovabili*. Available at: https://www.openpolis.it/litalia-e-a-buon-punto-sullutilizzo-di-energie-rinnovabili/.

Pancotti C., Sirtori E., Vignetti S. (2016), Smart Specialisation in a Lagging-Behind Region: The Case of Apulia. *Regions Magazine*, 301, 1: 25-28. DOI: 10.1080/13673882.2016.11720268.

Persyn D., Díaz-Lanchas J., Barbero J. (2020), Estimating Road Transport Costs between and within European Union Regions. *Transport Policy*, 13 April. DOI: 10.1016/j.tranpol.2020.04.006.

Pesce F., Barbieri D. (2015), Ex Post Evaluation of Cohesion Policy Programmes 2007-2013, Focusing on the European Regional Development Fund and the Cohesion Fund. *Work Package 9: Culture and Tourism – Case Study Puglia Region (Italy)*. Available at: https://ec.europa.eu/regional_policy/sources/docgener/evaluation/pdf/expost2013/wp9_case_study_puglia_en.pdf.

Sakkas S. (2018), The Macroeconomic Implications of the European Social Fund: An Impact Assessment Exercise Using the RHOMOLO Model. Seville: European Commission. *JRC Working Papers on Territorial Modelling and Analysis* n. 1.

Thissen M., Ivanova O., Mandras G., Husby T. (2019), European NUTS 2 Regions: Construction of Interregional Trade-Linked Supply and Use Tables with Consistent Transport Flows. Seville: European Commission. *JRC Working Papers on Territorial Modelling and Analysis* n. 01.