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Abstract

We make the case for a technology-enabled approach to Smart Specialisation policy making in order to foster its effectiveness by proposing a novel type of economic impact assessment. We use the RHOMOLO model to gauge empirically the general equilibrium effects implied by the Smart Specialisation logic of intervention as foreseen by the policy makers designing and implementing the European Cohesion policy. More specifically, we simulate the macroeconomic effects of achieving the R&D personnel targets planned by a set of Southern European regions. We discuss the implications of the proposed methodology for future assessments of Smart Specialisation.

Economic modelling to evaluate Smart Specialisation: an analysis on research and innovation targets in Southern Europe

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Disclaimer: 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.

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1. Introduction

The 2014-2020 European Cohesion policy cycle aims at promoting smart, sustainable and inclusive growth in all regions of the European Union (EU), with a particular focus on the less developed ones. According to the European legislation (European Union, 2013a), EU countries and regions must formally adopt a Research and Innovation Strategy for Smart Specialisation (RIS3) in order to access funding for research and innovation (R&I) investment through the European Regional Development Fund (ERDF), which is the main fund to support European economic development.

Smart Specialisation characterises the EU approach to regional innovation policy and aims at strengthening the place-based nature of Cohesion policy (Barca, 2009). Smart Specialisation was implemented shortly after its theoretical framework was developed (Foray et al., 2009 and 2011), and became a pillar of the reformed Cohesion policy for the 2014-2020 funding cycle. Due to its quick incorporation into actual policy, some scholars consider it as an ambitious experiment (Kuznetsov and Sabel, 2017; Morgan, 2017). More importantly for our purposes, there is a widespread need for an appraisal of its achievements (Gianelle et al., 2019), with calls for a technology-enabled approach to RIS3 policy making in order to foster its effectiveness.

In an increasingly complex, intertwined and uncertain world, policy makers responsible for the design and implementation of innovation policy need to base their decisions on well-informed projections about the future states of the world. In a highly experimental context such as innovation policy for Smart Specialisation, those projections are systematically incorporated in the policy logic of intervention and ought to be subsequently compared with actual outcomes and updated accordingly, in a continuous process of policy learning. Thus, the effective design and the implementation of the policy should rely crucially on the use of data and advanced computational capacities to simulate scenarios. However, how is it possible to conjugate ICTs and modelling tools with the principles underlying RIS3? How may this help policy makers with the ongoing and future implementation of RIS3 in European regions?

In this paper, we propose a novel approach for the ex-ante economic evaluation of the Smart Specialisation policy impact. To do so, we focus on the R&I numerical targets declared in the multiannual planning documents governing the funding of Smart Specialisation strategies in the framework of the European Cohesion policy. This exercise gauges empirically the general equilibrium effects implied by the logic of intervention of the Smart Specialisation policy according to the interpretation and expectations of the policy makers as expressed in the planned targets.

We perform our analysis using the RHOMOLO model, which is a dynamic multi-regional computable general equilibrium (CGE) model developed by the Joint Research Centre of the European Commission (Lecca et al., 2018). Although RHOMOLO has been extensively used for policy impact assessment, this is its first application for the purpose of evaluating RIS3 of European regions. The model is particularly suitable for this objective, given that it can provide sector (ten NACE rev.2 sectors)-, region (NUTS-2)- and time-specific simulations to support the EU policy on investments as well as reforms covering a wide array of objectives. In this paper, we focus on the implementation of RIS3 in Southern European regions (in Greece, Italy, Portugal, and Spain) where policy intervention in support of innovation and research investment is most needed due to their relatively poor innovation performance compared to their Northern counterparts of the EU. The so-called North-South innovation divide (Veugelers, 2016) was, and still is, a topic of high policy interest and, to some extent, Smart Specialisation is expected to mitigate it.

We investigate the potential macroeconomic impact of the changes induced by the achievement of the targets established for the result indicators related to the Thematic Objective "Strengthening research, technological development and innovation" (TO1) of the ERDF Operational Programmes (OPs) elaborated by the regional and national policy makers for the period 2014-2020. Within the current European Cohesion policy cycle, the ERDF TO1 budget is legally bound to finance national/regional RIS3, hence we assume that the target values attached to the ERDF TO1 result indicators provide a realistic representation of the policy makers' expectations regarding the effects of the Smart Specialisation logic of intervention. This working assumption appears plausible also in light of the close scrutiny that the European Commission performed over the

ERDF OPs and RIS3, as per Cohesion policy regulations (European Union, 2013b, Art. 29).

The analysis shows overall positive effects of the Smart Specialisation policy on all main economic indicators and sectors in the regions under scrutiny, with a peak in economic activity reached at the end of the ERDF financial period, when the policy objectives are fully accomplished. Our analysis offers a sort of upper bound estimate of what could happen if the logic of intervention postulated in the ERDF OPs was fully reflected in the real world and the policy makers' targets were achieved, thus quantifying the potential scope of the Smart Specialisation policy. We argue that ex-ante evaluations of the type we propose, albeit admittedly challenging from a technical point of view, should be more systematically used by policy makers in the design phase of Smart Specialisation strategies and R&I policies in general.

The reminder of the paper is organised as follow. The next section illustrates the Smart Specialisation approach in the context of the European Cohesion policy and advocates for the need of more systemic ex-ante impact assessments. The methodology and data section briefly describes the strategy used to estimate the macroeconomic effects of the achievement of the OPs targets related to R&I; this section illustrates separately the first econometric step and the RHOMOLO modelling strategy. Then we present the results of both parts of the analysis and, finally, we conclude.

2. Smart Specialisation in the EU cohesion policy and its impact assessment

2.1 European Cohesion policy and the challenges for the impact assessment of RIS3

Smart Specialisation is an R&I policy approach originally meant to tackle the transatlantic productivity gap (Van Ark et al., 2008). In its later and most widely accepted formulation, it advocates concentration of R&I funding on a limited number of emerging activities to avoid small-scale initiatives incapable of exploiting the full benefits of agglomeration economies (Foray and van Ark, 2007; Foray et al., 2009). Smart Specialisation became a fundamental component of the logic of intervention of the European Cohesion policy for the 2014-2020 financial cycle to provide principles to guide R&I investments.

This approach has two main characteristics: first, it focuses on specific economic activities (referred to as investment *priorities* or *priority areas*) rather than on horizontal policy actions. Second, the choice of the priorities relies on the interaction between entrepreneurial actors and policy makers. This so-called *entrepreneurial discovery* *process* (Foray et al., 2009) is a learning process by which (potential) entrepreneurial agents recognise new opportunities for socio-economic development, become aware of their capacity to engage in new activities, make themselves capable to articulate them into concrete actions and projects, and transmit this information to the policy maker (Hausman and Rodrik, 2003; Foray, 2018).

Formally, EU regions and countries must adopt a national or regional RIS3 guiding R&I investment according to the Smart Specialisation principles. This is an ex-ante conditionality, without which regions are not eligible to receive the ERDF TO1 funds (European Union, 2013a and 2013b). RIS3s are defined as "the national or regional innovation strategies which set priorities in order to build competitive advantage by developing and matching research and innovation own strengths to business needs in order to address emerging opportunities and market developments in a coherent manner, while avoiding duplication and fragmentation of efforts" (European Union, 2013b, Art. 2).

The implication is that the Smart Specialisation principles must be reflected in the regional and/or national ERDF OPs, which are the documents establishing the operational and financial details of ERDF interventions. The OPs are adopted after an iterative process involving on the one hand European countries, regions and relevant stakeholders (broadly defined entrepreneurial actors), and on the other hand the European Commission. This, in principle, ensures the consistency of RIS3 with the Smart Specialisation principles and the alignment between the OPs and the respective RIS3s. About 120 national/regional RIS3s were adopted for the 2014-2020 period, channelling an overall investment of more than €66 billion in R&I activities.

Notably, each of the objectives of the ERDF OPs must be linked to a set of result indicators measuring the intended change in a number of dimensions of wellbeing and economic progress (European Union, 2013a; European Commission, 2015). For each result indicator, the OPs must provide a baseline value using the latest available data, and a 2023 target value. Under the ERDF, the choice of the most appropriate result indicators and suitable targets is left to the national and regional administrations. The set of result indicators linked to the ERDF TO1 should capture the socio-economic effects of the Smart Specialisation policy. More precisely, the target values attached to those indicators represent the policy makers' expectations regarding the effects of the Smart Specialisation logic of intervention.

Although the ultimate objective of Smart Specialisation is to maximise the positive impact of R&I on growth and job creation, no specific methodologies exist to evaluate the expected effect of the RIS3 implementation in European regions. This is possibly due to the unresolved conceptual issues of the policy (Foray et al., 2011) as well as to the need for extending existing economic impact assessment models in order to integrate new dimensions related to Smart Specialisation (Varga et al., 2020). In addition, in most cases it appears difficult to identify clearly the RIS3 specific objectives to be measured through definite indicators, and to identify the intervention areas and the target populations that policy interventions are meant to affect. This is also reflected in some authors' criticism of Smart Specialisation (Balland et al., 2019; Santoalha, 2019).

For instance, the priority areas identified in the RIS3 documents are often very broad, covering large portions of the economic system, with policy measures simultaneously addressing several priorities at once (Iacobucci and Guzzini, 2016; D'Adda et al., 2019; Gianelle et al., 2019). This makes it difficult to select quantitative indicators to measure the specific results that the EU regions expect to achieve by implementing the policy. Although more than one decade ago David et al. (2009) stressed the importance of shifting the Smart Specialisation discussions from policy conceptualization to empirical evidence, this remains an unresolved issue, especially in what concerns impact assessment. Thus, policy evaluation with robust impact assessment models may not be an easy task and the question of how to measure the impact of R&I underlying RIS3 in European regions remains unanswered.

2.2 Smart Specialisation impact assessment tools: modelling, ICTs, and others

The methodologies and attempts to carry out impact assessments of the RIS3 of European regions have been scant so far. This may seem surprising considering the importance attached to these strategies in the EU policy discourse over the past years, as well as the increasing amount of resources and funding allocated to those same strategies. For instance, the share of EU Structural Funds dedicated to innovation-related policy measures increased "from just 8% of total regional policy expenditure in the 1988-1994 programming period…to nearer a third of the total in the 2014–2020 period" (Morgan, 2017, 569).

There are exceptions, though, as in the recent years new approaches have been developed in this direction. For instance, the European Committee of the Regions (2017) describes the use of the ESPON Territorial Impact Assessment (TIA) tool to evaluate the expected impact of the implementation of RIS3 in European regions. This goes beyond a simple economic impact assessment, as it considers different regional dimensions that range from the economy to governance, including also environmental and societal aspects. This ICT tool provided and managed by ESPON combines qualitative expert judgments on the potential impact of RIS3 on specific variables in each region with data on the sensitivity of regions to these indicators.

The outcome of this exercise is a set of maps that use a qualitative scale to show the potential (and expected) impact of RIS3 implementation in the EU at the NUTS-3 level. Although this is a relevant initiative, it also comes with important limitations such as subjectivity, the impossibility to quantify the actual impacts of the policy, as well as limited insights on the mechanisms through which RIS3 influences specific regional dimensions such as economic development. Moreover, in an increasingly dynamic and uncertain world, it might be necessary to update quickly these impact assessment exercises. On the one hand, the fact this is an ICT tool facilitates this process. On the other hand, updating (primary) data on expert judgement might be challenging, costly and time consuming. In this sense, policy makers would experience some concrete limitations should they intend to use this method routinely.

These limitations can be mitigated using more quantitative approaches based on indicators embedding certain proposed orienting principles for Smart Specialisation. For instance, Rigby et al. (2019) build on the Smart Specialisation framework proposed by Balland et al. (2019) and use patent data statistics and econometric methods to investigate whether the principles of technological relatedness and complexity lead to GDP growth and employment creation in a set of EU cities. Using a modelling perspective, Varga et al. (2020) develop an extension of the GMR-Europe (geographic, macro and regional) model that includes entrepreneurship (measured by the Regional Entrepreneurship and Development Index) and integration in knowledge collaboration networks (measured by regional participation in EU Framework Program network). According to the authors, these two dimensions should guide the RIS3 of the European regions.

While those approaches are flexible because they allow investigating the impact assessment of any dimension potentially relevant for Smart Specialisation, they come with three main limitations. First, the definition of the orienting principles may be controversial, as they may not fit the strategies of all regions. While these principles may seem adequate for some regions, probably they are not in line with the strategies defined by others. Second, regions may not have targets regarding indicators that embed and measure those principles. As such, it would be necessary to simulate different possible (and ideally realistic) targets for each region. However, there is no guarantee that the targets used to simulate such counterfactual scenarios mirror the expectations and targets of the region for the indicators under investigation. Third, this strategy can be regarded as a top-down (and one-size-fits all) Smart Specialisation impact assessment, which is clearly opposite to the bottom-up design that underpins this policy.

The examples above confirm that the economic impact of RIS3 has gained increasing interest in the recent years, though using a wide variety of different methods, reasoning and orienting principles. Not surprisingly, ICTs and modelling tools have been vitally important for these developments. However, it is necessary to go one-step forward and think of an impact assessment method of RIS3 that could support effectively policy decisions in the EU, but at the same time, be more in line with the specificities and expectations of each region regarding this policy.

2.3 Towards a new approach to RIS3 impact assessment: combining modelling tools and policy-makers expectations

In this paper, we put forward a new type of Smart Specialisation ex-ante economic impact assessment. We investigate the potential macroeconomic impacts of the changes induced by the achievement of the targets established for the result indicators related to the ERDF TO1 funding stream aimed at "Strengthening research, technological development and innovation", as detailed in the OPs of the regions for the period 2014-2020. In particular, we use the ERDF TO1 targets that are expressed in terms of shares of R&D personnel. This indicates the regions' expectations regarding their capacity to improve the innovation performance of the economy, which shall have substantial repercussions on growth potential both in the short and long run. We assume that the target values attached to the ERDF TO1 result indicators provide a realistic representation of the policy makers' expectations regarding one of the results they expect to achieve through the implementation of a sound RIS3. This indicator is also convenient because data on R&D personnel are available from official statistics (Eurostat) for all the regions considered in our sample, which makes the analysis more transparent and replicable.

By introducing the policy-maker outlook in the scenario analysis of the RHOMOLO model, we gauge the effects that the EU regions expect to achieve by following the implementation of RIS3. Differently from other types of RIS3 impact assessments, our approach is "agnostic" with regard to the specific strategic choices made by policy makers, in the sense that we do not impose or test principles such as relatedness, complexity or entrepreneurship as the objectives of a Smart Specialisation process. We simply evaluate the macroeconomic impacts of the achievement of the specific targets that regions expect to achieve (and to which they are committed). This is the main advantage of our analysis: we use the objectives that are defined by local policy makers based on their expectations arising from their specific knowledge of their regions. Moreover, it is likely that these expectations embed and reflect the principles underlying a sound RIS3: drafting, discussing and approving an OP is a long iterative process involving various different actors (regional, national and European Commission's), which reduces the likelihood of biased standpoints or misinterpretations. In spite of this, one important caveat is the following: since we do not investigate the process leading to the setting of the OP targets, it is not possible to guarantee the quality and consistency of this process in every region. Moreover, our analysis does not make predictions on the likelihood of the achievement of those targets.

Briefly, the main objective of our approach is not to identify economic sectors and industries that benefit from the increase of the R&D personnel in the region, or whether those sectors are in line with the Smart Specialisation priorities defined in the OPs. What we evaluate is the following: what would be the macroeconomic effects of reaching the targets contained in the OPs? The implicit assumptions in our impact assessment exercise are that RIS3s truly reflect the Smart Specialisation principles, and that the policy makers and stakeholders implement the policy in a consistent way. Thus, we presume that the improvements in R&D personnel are allocated to the activities defined according to a sound and well-implemented entrepreneurial discovery processes. Putting it simply, we assume that the targets set in the ERDF OPs for TO1 can be achieved by following closely the Smart Specialisation logic of intervention that is through support granted selectively to priority areas identified through an entrepreneurial process of discovery.

Similarly to Varga et al. (2020), our approach relies strongly on modelling. However, our methodology for impact assessment differs from theirs for three main reasons. First, on the econometric side, we estimate the R&I effects on productivity using a *stochastic frontier* approach instead of the residuals of an aggregate production function. Second, Varga et al. (2020) combine simulations using a dynamic macroeconomic model at country level and a regional spatial computable general equilibrium model, iterating until the solutions of the two models converge. In our case, we are able to perform the simulations in a more consistent way by using one single spatial computable general equilibrium model defined over the EU NUTS-2 regions. Third, our policy simulations are based on achieving the targets established in the OPs, while Varga et al. (2020) simulate an increase in the number of cooperative projects without any specific policy target.

3. Methodology and data

We analyse a scenario in which we assume that the Southern European regions under scrutiny achieve their ERDF TO1 targets in terms of R&D personnel by 2023. The numerical targets contained in the regional OPs are firstly translated into productivity improvements thanks to an econometric model, and then those productivity improvements are introduced into the RHOMOLO model in order to simulate their effects on GDP, employment, and other macroeconomic variables. Due to the high R&I content of the policy intervention, productivity improvements are assumed to last beyond the end of the policy compliance period. Therefore, we consider the policy-induced productivity improvements to be maintained, although at a decreasing rate, even in the absence of continuous policy implementation/achievement of R&I policy targets.

We use data for Greek, Italian, Portuguese, and Spanish regions and we adopt a two-step procedure. In the first step, we use a stochastic frontier approach to estimate the effect of changes in R&D personnel on regional technical inefficiency. In the second step, we simulate the general equilibrium effects of achieving the R&D personnel targets assumed in the ERDF OPs using the RHOMOLO model. The model covers all EU regions at the NUTS-2 level, which allows for geographical disaggregation of country-wide policy impacts and also for evaluation of policies implemented at regional level (see Supplementary Appendix A for a description of the model).

3.1 Step 1 - Estimation the link between R&D personnel and technical inefficiency

We estimate a panel data stochastic frontier model with output-oriented technical inefficiency (Greene, 2005). The model is expressed as follows:

$$\begin{gathered} \ln y_{it} = \beta_0 + \beta_1 \ln k_{it} + \beta_2 \ln l_{it} + \mu_{it} - u_{it} + v_{it} \\ u_{it} \sim N^+(0, \sigma_u) \\ v_{it} \sim N(0, \sigma_v) \end{gathered} \quad (1)$$

where y_{it} is the gross value added for region i at time t, k_{it} is the capital stock, l_{it} is the employment stock, μ_{it} are region-specific fixed effects, u_{it} is the inefficiency term, and v_{it} is a random noise component that affects the production process.

The inefficiency term $u_{it} \geq 0$ captures the difference between the maximum potential output that can be achieved given the technological frontier, and the observed output. The stochastic frontier model estimates both the parameters of the production function, β_1 and β_2, and the inefficiency of each observation.

Regions operate under different conditions that might explain the differences in the inefficiencies of the production processes. Regional R&D capabilities is one of the factors that can explain those differences. We can express this as follows:

$$ln\, \sigma^2_{u,it} = \gamma_0 + \gamma_1 \ln RnDper_{it} \quad (2)$$

where $\sigma^2_{u,it}$ is the variance of the inefficiency term u_{it}, $\ln RnDper_{it}$ is the log of R&D personnel in the region, and γ_0 and γ_1 are the parameters to be estimated.

Both equations (1) and (2) are estimated in a single-step procedure to avoid bias in the estimation of the inefficiency (Battese and Coelli, 1995; Wang and Schmidt, 2002). We use a balanced panel of observations that includes all Greek, Italian, Portuguese and Spanish regions for which there are data available in Eurostat. We use annual observations that cover 60 regions over the period 2000-2015.[1] We collect data on gross value added, gross fixed capital formation, employment, and R&D personnel. Regional capital stocks are constructed using the perpetual inventory method: we use data on gross fixed capital formation as a proxy of investment and we assume a depreciation rate of 0.15.

Notably, in contrast to the growth accounting literature in which total factor productivity is estimated as the residual of an aggregate production function and might potentially include noise, our approach separates the efficiency term from the noise term.[2]

3.2 Step 2 - The macroeconomic impact of the efficiency gains implied by the policy makers expectations following the RIS3 implementation

The spatial CGE model RHOMOLO allows for a geographical disaggregation of country-wide policy impacts and for the evaluation of EU regional policies. General equilibrium models like RHOMOLO are used to uncover the economic mechanisms leading an economic system to a new equilibrium after the introduction of a shock, which is typically policy-driven. The simulation results can help identifying the territories where the benefits or losses are concentrated, and permit to gauge the importance of both the direct effects of policy interventions and of their spillover effects. This analysis can be used as guidance to identify priority areas for investment and policy interventions and can provide a basis for comparing net welfare benefits with prospective investment costs. The RHOMOLO model is routinely used for ex-ante impact assessments of European policies (see for instance Christensen et al., 2019) and it has also been used for a number of other applications such as migration studies (Kancs and Lecca, 2018; Di Comite et al., 2018) and the analysis of spillover effects of demand-side shocks (Lecca et al., 2020).

RHOMOLO is calibrated using data organised in a multi-regional system of Social Accounting Matrixes (SAMs) of EU NUTS-2 regions disaggregated in ten economic sectors[3] for the year 2013. All regions are inter-connected via trade and production

[1] If data is missing or not available for a given region in a given year, we follow an imputation procedure. See Supplementary Appendix B for details.

[2] Here we contribute to mitigate one of the limitations of Varga et al. (2020): although the authors estimate total factor productivity as the residual of an aggregate production function, they acknowledge it to be a shortcoming, as it might lead to imprecise measures of productivity.

[3] Agriculture, Forestry and Fishing (A), Energy Sector (B_D_E), Manufacturing (C), Construction (F), Trade and Transport (G_I), Information and Communication (J), Financial Activities (K-L), Scientific and Technical Activities (M_N), Public Services (O-Q), and Other Services (R-U).

factor flows. Trade is modelled following the Armington (1969) approach. The EU regions are treated as small open economies that accept non-EU prices as given, consistently with the regional scope of the model. Households, governments, and industries (sectors) consume goods and services. The 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. A consequence of the myopic expectations is that within the recursive framework, the policy shocks act as surprise-announcements of policy changes, which can result in steep economic adjustment paths. For this particular exercise, the model was run assuming perfect competition, imperfect factor mobility, return-optimising investments, and a labour market governed by a wage curve (for more details, see Lecca et al., 2018).

Following the econometric strategy described in the previous section, the second step of our analysis involves simulating in the RHOMOLO model the macroeconomic impact of achieving the R&D personnel targets. We only include in the analysis those regions in Greece, Italy, Portugal, Spain whose OPs contain TO1 targets expressed in terms of R&D personnel (23 regions in total).[4] The impact of TFP gains on selected macroeconomic variables (like GDP, employment, imports, etc.) is presented as percentage deviations from the baseline scenario in which regions do not implement any R&I policy.

As the data collected from the ERDF OPs for the reference year diverges from Eurostat regional statistics for the same year (see reference values in the Supplementary Appendix C), we recomputed the targets of the regions departing from the reference value of the Eurostat regional statistics for each indicator.[5] In order to do so, we assume that between 2013 and 2023 the selected indicators for each region grow at the same rate as foreseen by policy makers due to the implementation of RIS3. Thus, the growth rates anticipated by the policy makers for each indicator in each region are used to revise the levels for the regional targets (when we depart from the reference value of the Eurostat regional statistics for each indicator). In the ERDF OPs, targets are expressed in three different ways: R&D personnel in the business enterprise sector; R&D personnel excluding the business enterprise sector; or as total R&D personnel. We converted all targets to their equivalent in terms total R&D personnel in order to homogenise the data for our analysis. Those updated targets, based on Eurostat regional

[4] The regions are the following: North Aegean (EL41), Western Macedonia (EL53), Central Greece (EL64), Piemonte (ITC1), Liguria (ITC3), Abruzzo (ITF1), Campania (ITF3), Calabria (ITF6), Sardegna (ITG2), Emilia-Romagna (ITH5), Toscana (ITI1), Norte (PT11), Algarve (PT15), , Centro (PT16), Área Metropolitana de Lisboa (PT17), Alentejo (PT18), Principado de Asturias (ES12), Aragón (ES24), Castilla-La Mancha (ES42), Extremadura (ES43), Illes Balears (ES53), Región de Murcia (ES62), and Canarias (ES70).

[5] This procedure seems more adequate than using ERDF Operational Programmes data, due to two main reasons. First, Eurostat regional statistics database is revised and updated more often than the ERDF OPs. Second, in section 3.1 we also use Eurostat regional statistics in order to implement the econometric analysis.

statistics and on the percentage changes anticipated by policy makers for TO1 result indicators, are presented in Table 1.

Table 1: R&D personnel targets and estimated TFP shocks

Region	Baseline R&D personnel	Target R&D personnel	Target % increase
North Aegean (EL41)	743	750	0.94%
Western Macedonia (EL53)	473	578	22.15%
Central Greece (EL64)	1,030	1,132	9.86%
Piemonte (ITC1)	28,247	35,309	25.00%
Liguria (ITC3)	7,411	7,890	6.47%
Abruzzo (ITF1)	2,920	4,884	67.26%
Campania (ITF3)	14,692	16,009	8.97%
Calabria (ITF6)	1,895	2,694	42.17%
Sardinia Sardegna (ITG2)	3,747	4,223	12.70%
Emilia-Romagna (ITH5)	24,576	41,894	70.47%
Toscana (ITI1)	15,136	17,550	15.95%
Norte (PT11)	14,913	16,020	7.42%
Algarve (PT15)	762	830	8.87%
Centro (PT16)	9,192	13,024	41.69%
Área Metropolitana de Lisboa (PT17)	20,158	21,260	5.47%
Alentejo (PT18)	1,028	1,248	21.37%
Principado de Asturias (ES12)	3,372	3,570	5.88%
Aragón (ES24)	5,534	7,137	28.97%
Castilla-La Mancha (ES42)	2,777	3,204	15.38%
Extremadura (ES43)	2,126	4,252	100.00%
Illes Balears (ES53)	1,956	2,290	17.07%
Región de Murcia (ES62)	5,290	6,677	26.21%
Canarias (ES70)	3,308	4,153	25.53%

Source: Eurostat (baseline R&D personnel) and own calculations based on OPs targets.

4. Results

4.1 The econometric results

The estimation results of models (1) and (2) are presented in Table 2. Columns (I) and (II) are estimated as a pool of observations, ignoring the unobserved heterogeneity across regions, while columns (III) and (IV) correspond to the Greene (2005) true fixed effects model. Columns (II) and (IV) include R&D personnel as an exogenous determinant of regional inefficiency.

Table 2. Stochastic frontier regression results

	(I)	(II)	(III)	(IV)
Frontier - eq. (1)				
Log of Capital	0.748**	0.804**	0.745**	0.685**
	(32.09)	(37.73)	(26.44)	(31.94)
Log of Labour	0.293**	0.212**	0.266**	0.459**
	(12.25)	(9.34)	(5.11)	(11.17)
Intercept	0.477**	0.375**	0.824*	0.0975
	(4.44)	(4.08)	(2.18)	(0.33)
Inefficiency: $\ln \sigma_u^2$ - eq. (2)				
Log of RnD personnel		-0.571**		-2.995**
		(-9.36)		(-10.79)
Intercept	-3.209**	0.903*	-4.393**	25.500**
	(-19.47)	(2.18)	(-40.58)	(9.26)
Error: $\ln \sigma_v^2$				
Intercept	-4.204**	-4.254**	-6.366**	-7.346**
	(-30.02)	(-45.33)	(-34.36)	(-61.28)
Fix Effects	No	No	Yes	Yes
Observations	960	954	960	954
Log-likelihood	338.34	396.16	1,112.76	1,449.26

Note: t-statistics in parenthesis. ** and * denote statistical significance at $p<0.001$, and $p<0.05$ level, respectively.

The estimates indicate that both capital and labour positively determine the production frontier at statistically significant levels. In all models, the sum of the estimated coefficients for capital and labour is statistically equal to 1, revealing the prevalence of constant returns to scale in production. As for model (2), and according to our expectations, an increase in R&D personnel is negatively associated with technical inefficiency, which means that it is positively associated with improvements in technical efficiency.

We take this into account and assume that efficiency gains due to an increase in R&D personnel are equivalent to a positive shock on total factor productivity (TFP). We use the estimation results of model (IV) – the full model with fixed effects and inefficiency determinants – to compute the technical inefficiency (and thus, the TFP levels) for the given target value of the indicators (see Table 1). This allows us to translate the regional achievements expressed in terms of result indicators of R&D personnel, into TFP shocks in RHOMOLO. Table 3 reports the estimated cumulative TFP change in each region in 2023 (that is when regions achieve the target in terms of R&D personnel expected by policy makers as consequence of the implementation of RIS3). According to the empirical estimates and the policy makers' targets, the biggest TFP improvements are supposed to happen in Extremadura (ES43), Emilia-Romagna (ITH5), Western Macedonia (EL53), Calabria (ITF6), and Centro (PT16). Since the RHOMOLO model is calibrated using 2013 data, the achievement of the targets is assumed to start in 2014 and be completed by the end of the programming period in 2023. Thus, in order to plug these TFP improvements into the model, we smooth the shocks over time: between 2013 and 2023 we assume that yearly improvements in technical efficiency are gradual (see Appendix D for more details).

Table 3. Estimated TFP shocks

Region	**Cumulative TFP shock (%)**	**Region**	**Cumulative TFP shock (%)**
North Aegean (EL41)	0.05	Algarve (PT15)	0.05
Western Macedonia (EL53)	0.57	Centro (PT16)	0.41
Central Greece (EL64)	0.07	Área Metropolitana de Lisboa (PT17)	0.02
Piemonte (ITC1)	0.29	Alentejo (PT18)	0.11
Liguria (ITC3)	0.18	Principado de Asturias (ES12)	0.13
Abruzzo (ITF1)	0.35	Aragón (ES24)	0.10
Campania (ITF3)	0.11	Castilla-La Mancha (ES42)	0.12
Calabria (ITF6)	0.56	Extremadura (ES43)	1.48
Sardinia Sardegna (ITG2)	0.12	Illes Balears (ES53)	0.27
Emilia-Romagna (ITH5)	1.02	Región de Murcia (ES62)	0.29
Toscana (ITI1)	0.22	Canarias (ES70)	0.02
Norte (PT11)	0.07		

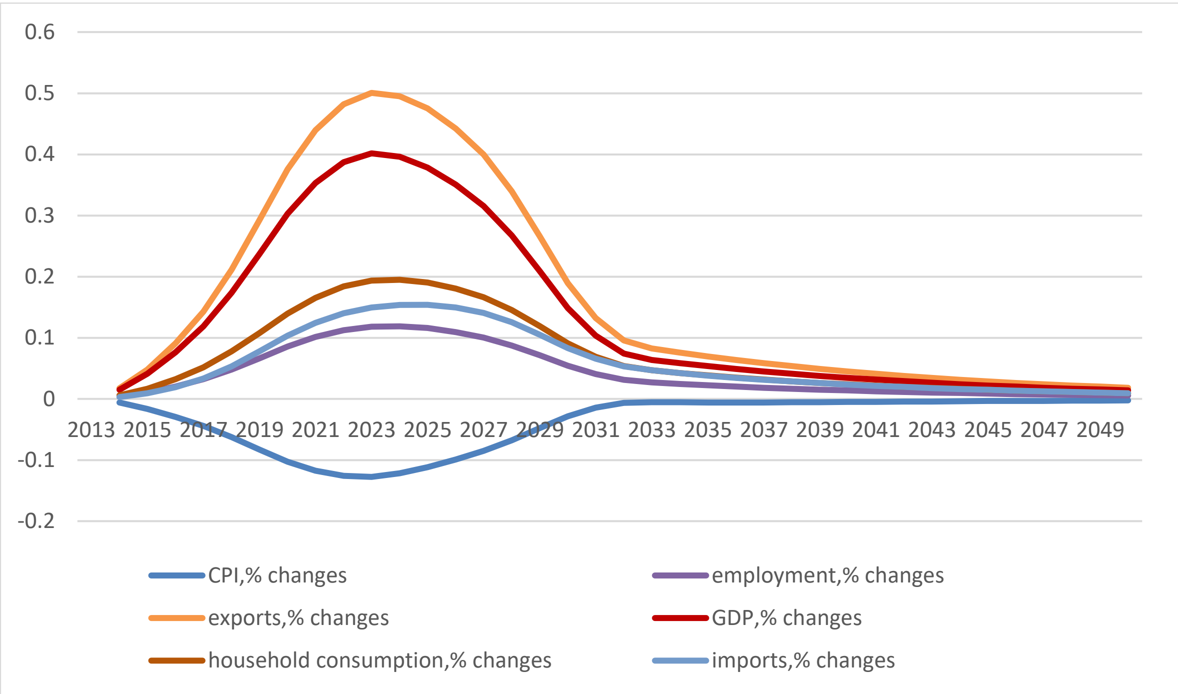
Source: Own estimates.

4.2 Modelling results

This section illustrates the macroeconomic effects of the simulated achievement of the ERDF TO1 targets in terms of R&D personnel increase in the 23 regions of Southern Europe under analysis (three regions of Greece; eight regions of Italy; five regions of Portugal; and seven regions of Spain). All results are presented as percentage deviations of selected variables from their baseline values which represent the "business as usual" evolution of the economies in the absence of policy perturbations. Figure 1 reports the evolution of GDP, household consumption, imports and exports, employment, and the consumer price index (CPI) for all the regions included in the analysis. Table 4 contains the region-specific results for the same variables up to the end of the programming period in 2023, expressed as cumulative changes. The first column also reports the cumulative TFP shock in order to facilitate comprehension, as there is a clear positive correlation between the degree of ambition of the regional policy makers and the expected expansion of GDP and competitiveness gains

TFP improvements allow to produce more output with the same amounts of labour and capital, thus increasing regional competitiveness with positive effects on exports. Given that the rental rate of a factor is equal to its marginal product, the decreased demand of labour and capital per unit of output rises both wages and the rate of return of capital, with a positive impact on household income. Overall, the strength of the direct policy impacts depends on how ambitious the regional R&D targets are, which in turn determine the intensity of the TFP shocks. Due to the high innovation content of the policy under scrutiny, productivity improvements are assumed to last beyond the end of the policy funding period, although their effects are assumed to decline gradually over time.

Figure 1. Macroeconomic impacts of TO1 targets' achievement in the 23 analysed regions, % deviations from the baseline



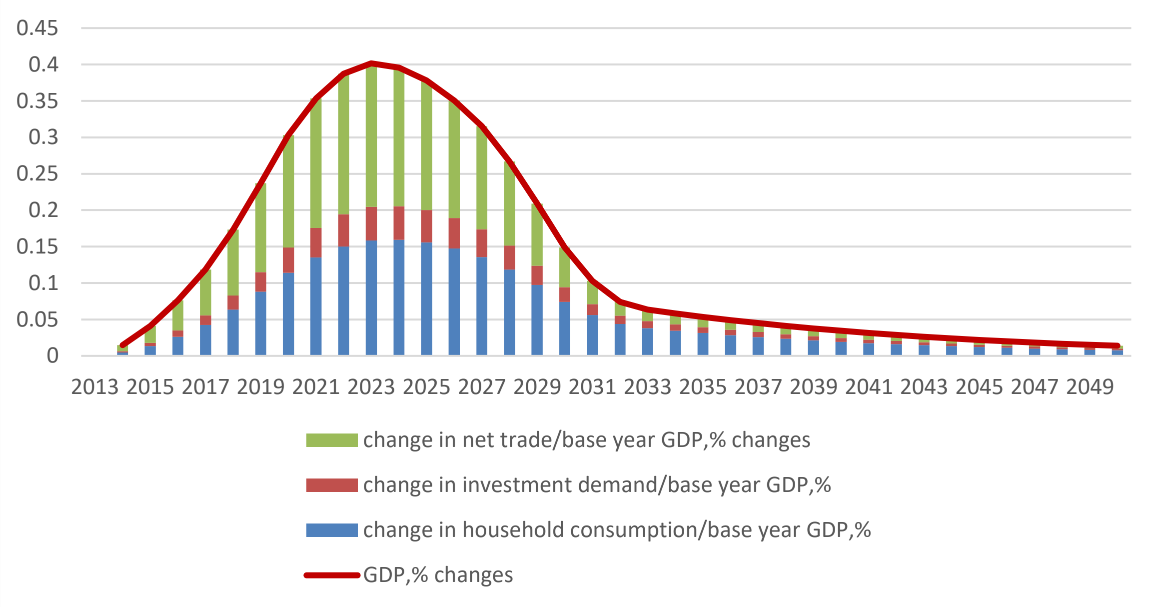
Source: Computer simulations with the RHOMOLO model.

Table 4: Macroeconomic impacts of TO1 targets' achievement in the 23 analysed regions, % deviations from the baseline projections (cumulative changes 2014-2023)

Region	**TFP shock**	**GDP**	**Household consumption**	**CPI**	**Employment**	**Net trade**
North Aegean (EL41)	0.05	0.03	0.01	-0.01	0.01	0.01
Western Macedonia (EL53)	0.57	0.39	0.22	-0.05	0.24	2.16
Central Greece (EL64)	0.07	0.05	0.03	-0.01	0.03	0.13
Piemonte (ITC1)	0.29	0.16	0.05	-0.10	0.01	0.17
Liguria (ITC3)	0.18	0.07	-0.01	-0.07	-0.01	0.12
Abruzzo (ITF1)	0.35	0.17	0.02	-0.10	0.00	0.21
Campania (ITF3)	0.11	0.03	-0.03	-0.06	-0.02	0.08
Calabria (ITF6)	0.56	0.28	0.10	-0.10	0.03	0.25
Sardinia (ITG2)	0.12	0.03	-0.03	-0.05	-0.02	0.09
Emilia-Romagna (ITH5)	1.02	0.56	0.31	-0.11	0.14	0.79
Toscana (ITI1)	0.22	0.12	0.07	-0.05	0.04	0.13
Norte (PT11)	0.07	0.05	0.03	-0.02	0.02	0.22
Algarve (PT15)	0.05	0.04	0.03	-0.02	0.02	0.08
Centro (PT16)	0.41	0.27	0.14	-0.06	0.11	0.60
Área Metrop. Lisboa (PT17)	0.02	0.02	0.01	-0.02	0.01	0.44
Alentejo (PT18)	0.11	0.08	0.05	-0.03	0.04	0.04
Principado Asturias (ES12)	0.13	0.10	0.06	-0.03	0.05	1.28
Aragón (ES24)	0.10	0.08	0.05	-0.03	0.04	0.56
Castilla-La Mancha (ES42)	0.12	0.09	0.06	-0.03	0.05	0.37
Extremadura (ES43)	1.48	1.06	0.72	-0.26	0.62	1.52
Illes Balears (ES53)	0.27	0.20	0.13	-0.05	0.12	0.79
Región de Murcia (ES62)	0.29	0.22	0.15	-0.06	0.13	2.50
Canarias (ES70)	0.02	0.01	0.00	-0.02	0.00	0.13

Not surprisingly, the achievement of regional targets related to the ERDF TO1 has a positive impact on all economic indicators in the selected regions, as it stems from TFP improvements in all sectors. The peak in economic activity is achieved in 2023 when the policy objectives are fully accomplished. In terms of demand components determining the positive impact on GDP, Figure 2 below suggests that both household consumption and net trade explain most of the positive effects of achieving the policy objectives (public consumption is kept fixed in the model for the closure of the model). The role of trade can be explained as follows: since policy-driven TFP improvements decrease expenditures on labour and capital per unit of output, producers gain comparative advantages in terms of pricing for the increased competitiveness of their exports, thus bringing about sizable net trade advantages in the selected regions. Smaller contributions come from household consumption and investments.

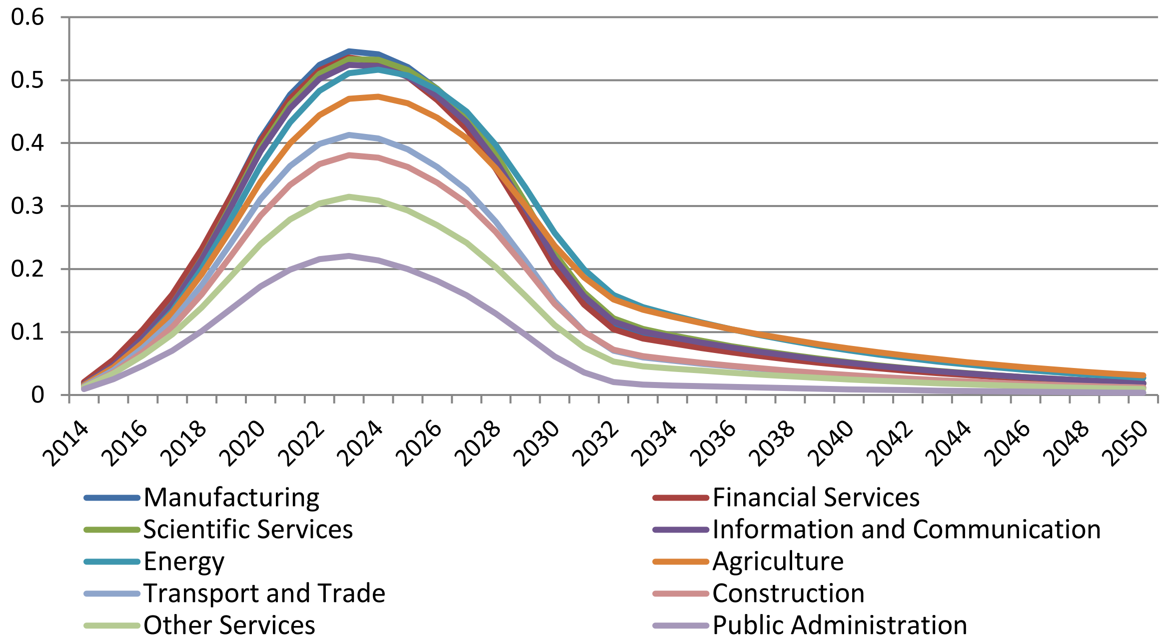
Figure 2. GDP decomposition by demand components in the 23 analysed regions, % deviations from the baseline



Source: Computer simulations with the RHOMOLO model.

The cumulative sectoral impacts of achieving the OPs TO1 targets in the selected regions of Greece, Italy, Portugal and Spain are illustrated in Figure 3. As it can be seen, all sectors in the selected regions benefit from the achievements of ERDF TO1 R&D personnel targets. Due to the accumulation of direct policy intervention and price and demand effects, the agricultural, financial, and Information & Communication sectors experience the most pronounced growth.

Figure 3. Sectoral impacts of TO1 targets' achievement in the 23 analysed regions, % deviations from the baseline



Source: Computer simulations with RHOMOLO model.

5. Conclusions

In this paper, we illustrate an ex-ante economic impact assessment of the Smart Specialisation policy. Specifically, we focus our evaluation exercise on the TO1 targets contained in the ERDF OPs. These targets are considered to reflect the policy makers expectations following the implementation of RIS3, according to the Smart Specialisation logic of intervention. Thus, our study evaluates the potential effects that policy makers may expect in regional economies by the end of the funding and policy period. We employ the RHOMOLO model to estimate the impact of achieving the targets for regional R&D personnel by 2023 in the group of NUTS-2 regions of Greece, Italy, Portugal, and Spain whose OPs contain TO1 targets under scrutiny.

The model simulations show overall positive effects of the Smart Specialisation policy on all the main economic indicators and sectors in the regions under scrutiny, where a peak in the economic activity is reached at the end of the ERDF financial period, when the policy objectives are fully accomplished. Our analysis does not evaluate the likelihood of the policy targets to be met. Rather, it offers an upper bound estimate of what could happen if the policy intervention is fully accomplished in the group of regions considered in the exercise. Thus, our analysis offers a quantification of the potential scope of the Smart Specialisation policy.

Regional economics and (evolutionary) economic geography scholars have developed "some of the smart specialization debates' main notions while at the same time being more consciously sensitive to the potential diversity of regional contexts" (Kroll, 2015, 2080). In this vein, on the one hand, compared to other ex-ante policy impact assessments, ours has the important advantage of evaluating the region-specific policy objectives made by the local policy makers. Therefore, one of the main strengths of this perspective is that it respects the place-based principle of Smart Specialisation as a regional innovation policy and identifies the regional and territorial effects of policy intervention (at the NUTS-2 level of detail). However, on the other hand, one potential limitation is that we use an impact assessment based on a general equilibrium approach, which might have limited capacity to capture some of the evolutionary features of the Smart Specialisation concept. Future research will need to develop models that approach regional economies as evolutionary systems (for example with agent-based models). Another limitation of our approach is that we do not take into account the distributional dimension of the policy intervention over specific sectors. This is part of the authors' future research agenda.

We claim that ex-ante evaluations of the type we propose, albeit admittedly challenging from a technical point of view, should be more systematically used by policy makers in the design phase of Smart Specialisation strategies and R&I policies in general. We propose the RHOMOLO web tool (https://rhomolo.jrc.ec.europa.eu/) as an entry point in order to engage fruitfully in this endeavour, and to build the necessary skills. The tool allows to carry out ad hoc, basic simulations dealing with changes in TFP, labour productivity, and trade costs, which can be made increasingly tailor-made to the specific needs of individual regions. We see the RHOMOLO model and its web tool as an essential step towards a broader use of ICT solutions to support the development of sound RIS3s and to facilitate the establishment of a virtuous policy learning cycle.

To conclude, we think that there is great potential in the use of macroeconomic impact assessment models for the ex-ante evaluation of innovations such as Smart Specialisation in the logic of intervention of the European regional policy. There are some crucial elements to consider in order to develop meaningful models leading to estimations that can be a realistic benchmark against which to compare the reality of the intervention once data are available. The evaluator needs first of all a clear comprehension of the logic of intervention of Smart Specialisation, both in general terms, and with reference to the specific situation of the countries/regions under scrutiny. Such an understanding should be reflected in the definition of the objectives and related socio-economic indicators that will be evaluated. Finally, the evaluator should make explicit the assumptions underpinning the modelling choices and the possible limitations that may affect the results of the simulations. We provide in this paper an example of how to implement in practice such guidelines.

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Appendix A. Spatial Computable General Equilibrium analysis: the RHOMOLO model

Computable general equilibrium (CGE) models have become a standard tool to analyse the welfare and distributional impacts of policies whose effects are transmitted through multiple markets. The key feature of such models is that they provide a systematic representation of inter-related markets in the economy.

The main database of a CGE model is a so-called "Social Accounting Matrix" (SAM), which represents a snapshot of economic transactions between sectors and agents (households, firms and government) of an economy in a particular year, so that all markets are equilibrium[6]. CGE models represent a decentralised market economy based on the assumption that agents make optimal choices given a system of resource constraints, preferences and technology. In other words, 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. Substitution elasticities are employed in functional forms describing agents' technology and preferences in order to define how easily different goods can be replaced with each other when their prices change. The model is calibrated to replicate the base year data when no shocks are introduced to the model. Introduction of policy shocks leads to a new, counterfactual equilibrium, which can also be organised in the form of a SAM. Analysis of results is based on comparison between the values of same variables before- and after- shocks are introduced. The simulations associated with a policy shock can be defined as a "counterfactual scenario", whereas the reproduction of the initial equilibrium in the economy can be referred to as "benchmark scenario". Therefore, simulating a policy change in a CGE model is a "what if" comparison of two equilibrium states of the economy. It is usually emphasized that CGE models are not the tool for forecasting, even though in the recent time advancements were made to link the both approaches.

Spatial CGE models have been acknowledged as key instruments to examine geographic features of economic activity (e.g. factor mobility, transport and transaction costs, regional price differentials), which influence the speed and extent of economic development. These models allow for geographical disaggregation of country-wide policy impacts and also for evaluation of policies that are implemented at regional level. Model results help to identify the territories where the benefits or losses will be concentrated, and clarify which impacts can be attributed to specific policy interventions, and which

[6] In multi-regional models, regional SAMs are complemented with the matrixes of bilateral trade and factor flows.

were attained 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.

The statistical units of the multi-regional CGE model employed in this study are NUTS-2 regions, since they are the basic administrative entities identified for the application of regional policies in the EU. Regional SAMs are complemented with the matrixes of trade and transport flows 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 from the work by Persyn et al. (2019).

The model settings follow closely Lecca et al. (2018). The industry structure in the SAMs is represented by ten NACE Rev. 2 sectors.[7] Goods are consumed by households, governments and firms. Industries can function in perfectly or monopolistically competitive settings. Labour is disaggregated by high-, medium- and low skilled groups. Unemployment is modelled through a wage curve (Blanchflower and Oswald, 1995) that negatively relates real wages to the unemployment rate.

Due to the high dimensionality implied by its extensive regional disaggregation, the dynamics of the model are 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.[8]

This model setting was selected as the instrument for ex-ante economic impact assessment of ERDF TO1 result indicators in Greek, Italian, Portuguese, and Spanish regions, because of the importance of modelling explicitly spatial linkages, interactions and spillovers between regional economies.

[7] The further disaggregation of RHOMOLO model would increase its computational complexity and hinder its use (the so-called "dimensionality curse") because of a persistent trade-off between the number of statistical units, agents, sectors, periods of analysis and so on.

[8] In contrast, forward-looking CGE models are solved simultaneously for all periods, as agents optimize intertemporally, which works 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 smooth adjustment trajectory.

Appendix B. Eurostat regional statistics missing observations

Eurostat Regional Statistics involve some missing values for several years in certain regions. To overcome this data shortcoming, whenever possible we compute missing values using one of the following procedures, in the following order:

- For a given NUTS-2 where data are missing for year t, we compute the ratio between the value for the nearest year before or after t (t+/-x) for which data are available at NUTS level and the NUTS-1 value for that year (t+/-x). This ratio is then multiplied by the NUTS-1 value for the year (t) for which NUTS-2 data are missing;
- For a given NUTS-2 where data are missing for year t, we compute the ratio between the value for the nearest year before or after t (t+/-x) for which data are available at NUTS-2 level and the NUTS-0 value for that year (t+/-x). This ratio is then multiplied by the NUTS-0 value for the year (t) for which NUTS-2 data are missing;
- For a given NUTS-2 where data are missing for t, we attribute the same value as the nearest year before or after t (t+/-x).

Appendix C. R&D personnel result indicators collected from the ERDF Operational Programmes

Region	R&D personnel indicator	Unit	Baseline	Target
North Aegean (EL41)	Total	Number	743	750
Western Macedonia (EL53)	Total	Number	614	750
Central Greece (EL64)	Total	Number	1247	1370
Piemonte (ITC1)	Total	%	6.4	8
Liguria (ITC3)	Business Enterprises	%	0.37	0.42
Abruzzo (ITF1)	Business Enterprises	%	0.1	0.3
Campania (ITF3)	Business Enterprises	%	0.3	0.37
Calabria (ITF6)	Business Enterprises	%	0.05	0.32
Sardinia Sardegna (ITG2)	Business Enterprises	%	0.04	0.12
Emilia-Romagna (ITH5)	Business Enterprises	%	0.35	0.76
Toscana (ITI1)	Business Enterprises	%	0.23	0.33
Norte (PT11)	Excluding Business Enterprises	%	5	5.6
Algarve (PT15)	Excluding Business Enterprises	%	3	3.3
Centro (PT16)	Excluding Business Enterprises	%	4.8	8
Área Metropolitana de Lisboa (PT17)	Excluding Business Enterprises	%	9.9	10.7
Alentejo (PT18)	Excluding Business Enterprises	%	1.8	2.4
Principado de Asturias (ES12)	Total	%	1.7	1.8
Aragón (ES24)	Total	%	1.07	1.38
Castilla-La Mancha (ES42)	Total	%	0.78	0.9
Extremadura (ES43)	Total	%	0.63	1.26
Illes Balears (ES53)	Total	%	0.41	0.48
Región de Murcia (ES62)	Total	%	1.03	1.3
Canarias (ES70)	Total	%	0.47	0.59

Appendix D. Estimated gradual TFP policy shocks when regions achieve their targets

Region	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
North Aegean (EL41)	0.00%	0.01%	0.01%	0.02%	0.03%	0.03%	0.04%	0.04%	0.05%	0.05%
Western Macedonia (EL53)	0.02%	0.07%	0.13%	0.21%	0.30%	0.38%	0.45%	0.52%	0.56%	0.57%
Central Greece (EL64)	0.00%	0.01%	0.02%	0.03%	0.04%	0.05%	0.06%	0.07%	0.07%	0.07%
Piemonte (ITC1)	0.03%	0.08%	0.12%	0.16%	0.19%	0.22%	0.25%	0.27%	0.28%	0.29%
Liguria (ITC3)	0.01%	0.02%	0.03%	0.05%	0.07%	0.11%	0.14%	0.17%	0.18%	0.18%
Abruzzo (ITF1)	0.02%	0.05%	0.09%	0.14%	0.20%	0.25%	0.30%	0.33%	0.35%	0.35%
Campania (ITF3)	0.00%	0.01%	0.02%	0.03%	0.04%	0.06%	0.08%	0.10%	0.11%	0.11%
Calabria (ITF6)	0.03%	0.07%	0.13%	0.19%	0.28%	0.38%	0.46%	0.52%	0.55%	0.56%
Sardinia Sardegna (ITG2)	0.00%	0.01%	0.02%	0.03%	0.05%	0.07%	0.09%	0.11%	0.12%	0.12%
Emilia-Romagna (ITH5)	0.03%	0.10%	0.18%	0.29%	0.45%	0.63%	0.81%	0.94%	1.01%	1.02%
Toscana (ITI1)	0.01%	0.02%	0.04%	0.06%	0.09%	0.13%	0.17%	0.20%	0.21%	0.22%
Norte (PT11)	0.00%	0.01%	0.01%	0.02%	0.03%	0.04%	0.05%	0.06%	0.07%	0.07%
Algarve (PT15)	0.00%	0.01%	0.01%	0.02%	0.03%	0.04%	0.05%	0.05%	0.05%	0.05%
Centro (PT16)	0.02%	0.04%	0.08%	0.13%	0.20%	0.27%	0.33%	0.38%	0.40%	0.41%
Área Metropolitana de Lisboa (PT17)	0.00%	0.00%	0.01%	0.01%	0.01%	0.02%	0.02%	0.02%	0.02%	0.02%
Alentejo (PT18)	0.00%	0.01%	0.02%	0.04%	0.05%	0.07%	0.09%	0.10%	0.11%	0.11%
Principado de Asturias (ES12)	0.01%	0.02%	0.03%	0.05%	0.07%	0.09%	0.11%	0.12%	0.13%	0.13%
Aragón (ES24)	0.00%	0.01%	0.02%	0.04%	0.05%	0.07%	0.08%	0.09%	0.10%	0.10%
Castilla-La Mancha (ES42)	0.01%	0.02%	0.03%	0.05%	0.06%	0.08%	0.10%	0.11%	0.12%	0.12%
Extremadura (ES43)	0.04%	0.13%	0.27%	0.44%	0.65%	0.90%	1.16%	1.35%	1.46%	1.48%
Illes Balears (ES53)	0.01%	0.03%	0.06%	0.09%	0.12%	0.16%	0.20%	0.24%	0.26%	0.27%
Región de Murcia (ES62)	0.01%	0.04%	0.07%	0.10%	0.13%	0.17%	0.22%	0.26%	0.29%	0.29%
Canarias (ES70)	0.00%	0.00%	0.00%	0.01%	0.01%	0.01%	0.01%	0.02%	0.02%	0.02%

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