European Commission

JRC SCIENCE FOR POLICY REPORT

Smart Specialisation Strategies and Regional Productivity

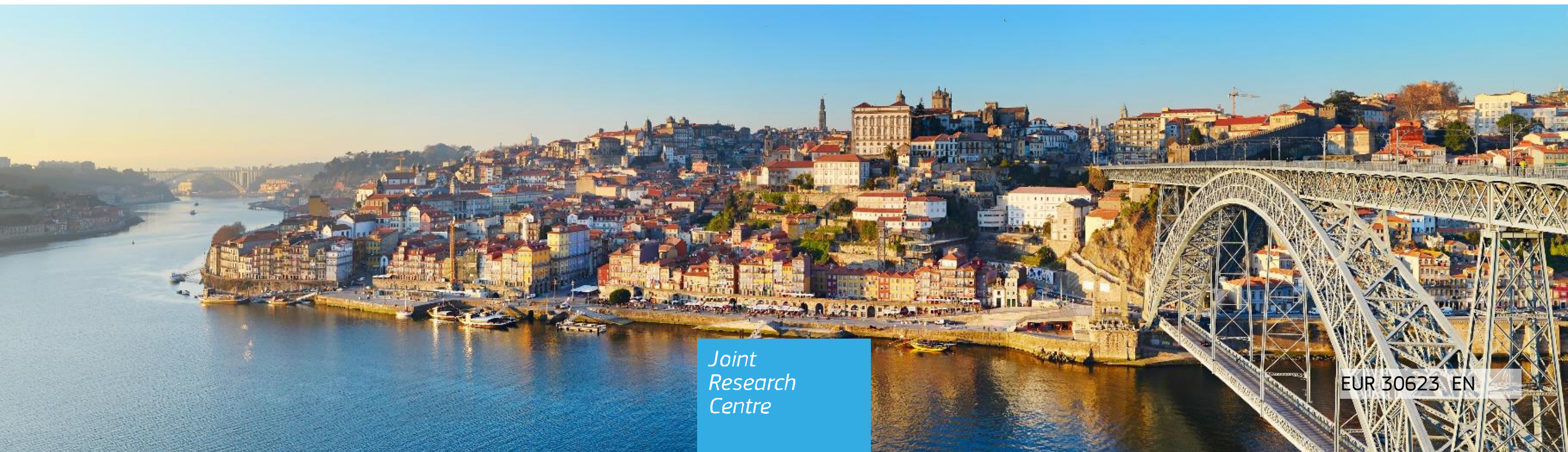
A preliminary assessment in Portugal

Marques Santos, Anabela

Edwards, John

Neto, Paulo

2021



Joint Research Centre

EUR 30623 EN

Contact information
Name: Anabela M. Santos
Address: Edificio EXPO, c. Inca Garcilaso 3, 41092 Sevilla, Spain
Email: anabela.marques-santos@ec.europa.eu

EU Science Hub
https://ec.europa.eu/jrc

JRC124389

EUR 30623 EN

PDF	ISBN 978-92-76-31375-5	ISSN 1831-9424	doi:10.2760/002330

Luxembourg: Publications Office of the European Union, 2021

How to cite this report: Marques Santos, A., Edwards, J., Neto, P, Smart Specialisation Strategies and Regional Productivity: *A preliminary assessment in Portugal*, EUR 30623 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-31375-5, doi:10.2760/002330, JRC124389

.

Contents

Abstract

Smart Specialisation is a place-based approach to innovation policy that underpins a significant amount of EU funding. The origins of the concept lie in the transatlantic productivity gap and a concern that previous investments in Research and Innovation (R&I) had failed to deliver commercial benefits. Following more than five years of implementation, this report contributes to the evaluation of the smart specialisation approach through quantitative analysis. As part of the Stairway to Excellence project, it is one of the first to assess its impact on regional productivity, based on the case of Portugal. This is done using the country's main instrument to support corporate Research and Development (R&D) that was launched in 2007 and adapted to accommodate smart specialisation in 2014.

An analysis of project characteristics reveals that during the programming period 2014-2020, financial support to corporate R&D investment aligned with S3 priorities has been more concentrated on cooperation between regions and sectors. A higher diversification of R&D and Innovation funds across sectors, regions and beneficiaries, in comparison with 2007-2013, is also observed. As more cooperation and diversification are two important features of smart specialisation, these findings suggest improved investment choices in the programming period 2014-2020. Furthermore, after controlling for the existence of potential geographical spillover effects by applying a spatial econometric analysis, the results display a positive effect on regional productivity from the R&D and Innovation subsidies over the last two programming periods. Furthermore, a higher rate of return of RDI subsidy in the second period is also observed, which suggests that smart specialisation was able to generate an additional effect in comparison with a situation without this place-based policy. Nevertheless, we also found that – in the case of Portugal - smart specialisation has only been able to generate this additional effect in regional productivity when the R&D funding instrument is combined with other types of innovation subsidies. This finding provides additional weight to the argument for broader and more integrated smart specialization policy mixes in the new programming period.

Keywords: Productivity; Innovation; Smart Specialisation Strategies; Portugal.

JEL Classification: O31; R11; H71

.

Acknowledgements

The authors are grateful to the *Comissão de Coordenação e Desenvolvimento Regional do Alentejo* (CCDRA) for the information provided in the framework of the activities developed by UMPP - *Unidade de Monitorização de Políticas Públicas*/Public Policy Monitoring Unit at the University of Évora. The authors also thank ANI for the data about PT2020, as well as Teresa Jorge (CCDR-Centro), Sophie Patricio (CCDR-Centro), Alexandra Gomes (CCDR-Centro), Carla Coimbra (CCDR-Centro), Alexandra Rodrigues (CCDR-Centro) and José Caldeira (INESC TEC) for clarifications about Portuguese financing instruments. Acknowledgement also goes to colleagues from DG REGIO (Richard Deiss) and JRC (Sara Amoroso, Peter Bauer, Mark Boden, Karel Haegeman, Carmen Madrid and Johan Stierna) for their valuable comments and suggestions. A very special thanks also to Michele Cincera (ULB), Pierre Mohnen (Maastricht University) and Attila Varga (University of Pécs) for their comments, as well as to Javier Barbero Jiménez (JRC) for his training and kind advice concerning spatial econometrics.

Authors

Anabela M. Santos
Joint Research Centre, European Commission

John Edwards
Joint Research Centre, European Commission (until August 2020), CICS-NOVA and Policy Experimentation and Evaluation Platform (from October 2020)

Paulo Neto
Universidade de Évora, Portugal

Executive summary

Policy context

A Smart Specialisation Strategy (S3) is an integrated, evidence- and place-based policy approach to concentrate knowledge and innovation resources in a limited number of priorities, which are selected because of their potential for regional competitiveness and structural transformation. Evidence is collected through analysis but more importantly through entrepreneurial discovery by innovation actors.

The concept of Smart Specialisation emerged in 2009, when the Knowledge for Growth (K4G) Expert Group advised the Commissioner for Research, Janez Potočnik, on how to reduce the productivity gap between Europe and the United States([1]). Policy recommendations from this expert group converged on the need for higher specialisation in R&D and Innovation, especially for territories that are not leaders in any of the major science and technology areas (**Foray et al., 2009**). Furthermore, they also agreed on the need to focus future investment on fields that can complement other territorial productivity assets for enhancing (or creating) critical mass (**Foray et al., 2009**).

Under the programming period 2014-2020, a regional (or national) S3 was established as an *ex-ante* conditionality for investments in R&I by the European Structural Investment Funds (ESIF). In this context, promoting synergies between different policies and funding instruments are important to enhance the added value of EU funds and within a limited budget.

Following more than five years of S3 implementation, and as part of the Stairway to Excellence project ([2]), this study attempts to evaluate the impact of S3 on regional productivity, based on the case of Portugal. It aims to assess whether the S3 approach has had a positive effect on productivity, including the effect of synergies between different R&I funding instruments.

Key conclusions

The results show that R&D and Innovation subsidies have a positive effect on regional productivity and its rate of return is higher in the programming period with S3 than in the previous one (without S3). Furthermore, a certain degree of dependence between funding instruments was found: corporate R&D subsidy alone appears not to generate any significant effect at the regional level, but when combined with the innovation subsidy, the overall net effect is higher than the individual effect. The findings of the present study also suggest that the benefit of smart specialisation in Portugal could be improved, if funding instruments were deployed in a more coherent and integrated manner.

Main findings

- Under the ESIF programming period 2014-2020, when the S3 approach was implemented, we observe a higher diversification of R&D and Innovation funds across sectors, regions and beneficiaries, in comparison with 2007-2013 ([3]). A higher amount of funding was also dedicated to R&D partnership projects and inter-regional collaboration within the country in the second period under analysis. This is in line with the S3 approach that emphasizes cooperation and related variety, suggesting improved spending of the ESIF in Portugal.

- A different innovation pattern between different funding instruments is observed in our analysis. For instance, knowledge-intensive services, high-tech and medium high-tech industries seem more likely to receive R&D financing, whereas low and medium-tech industries appear to have a higher propensity to receive other types of subsidies created to support non-R&D innovation.

- Competition between regions also seems to attract resources from one region (usually in a worse relative position) to another (better positioned), generating a negative spillover effect. Nevertheless, the total net effect of R&D and Innovation subsidy on regional productivity reveals to be positive and higher in the

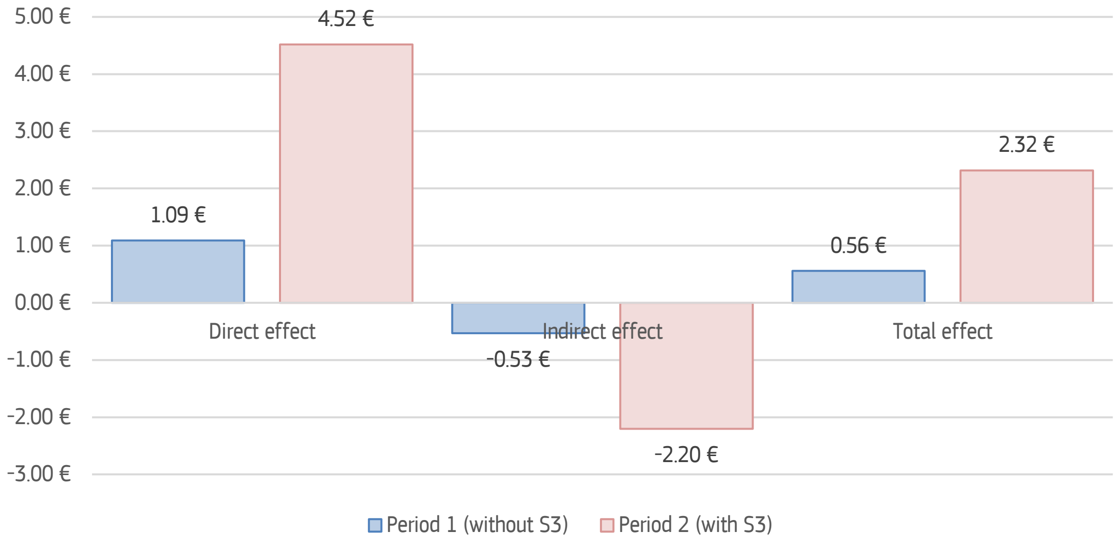
([1]) For more information about the K4G see: http://ec.europa.eu/invest-in-research/monitoring/knowledge_en.htm [Accessed on 29 October 2020].

([2]) The "Stairway to excellence" project was launched between 2014-2020 as a European Parliament pilot project executed by JRC together with DG-REGIO. It aims to support EU Member States and their regions in: (i) developing and exploiting the synergies between European Structural and Investment Funds (ESIF), Horizon 2020 (H2020) and other EU funding programmes and (ii) Assisting them in closing the innovation gap, in order to promote excellence in all regions and EU countries as well as (iii) Stimulating the effective implementation of national and regional Smart Specialisation Strategies. For more details see S3 Platform webpage: https://s3platform.jrc.ec.europa.eu/stairway-to-excellence.

([3]) Even if S3 is about the concentration of priorities for knowledge-based investment, it is also about diversification within priorities. However, in the present study, we are not analysing the description of the projects to make an analysis on the concentration of funds around specific priorities, since this is not its objective. In fact, this type of analysis may be the subject of another research.

second period under analysis (where S3 was implemented) and as we can see in Figure 1. For instance, an increase of one euro in R&D and Innovation funds stock per worker in the second period generates an additional productivity increase of 1.76 euros in comparison with the previous period. As differences between programming periods is used as a proxy to measure the effect of S3 in Portugal[4], this value can used as an approximation of the effect of S3 in Portugal.

Figure 1. Rate of return of R&D and Innovation subsidy stock per worker on regional productivity, by programming period



Source: Own elaboration based on results in Table 25 in Appendix.

Note: refers to the absolute change in regional productivity (production per worker) as a result of an increase of 1 euro in the stock of R&D and Innovation subsidies per worker

- However, the additional effect of S3 seems only to exist when R&D subsidies are combined with other innovation support. Such findings suggest that – at least in the Portuguese context - complementarities and synergies between financing instruments could be essential to enhance knowledge transfer. Indeed, absorptive capacity is crucial to help spill over the benefit of R&I created at micro-level to regional-level.
- Such findings are particularly interesting, because a pre-condition to access corporate R&D subsidies is alignment with an S3 priority, which is not the case for other corporate innovation support (alignment is only a criterion in the project assessment). Therefore, our results suggest that if they were to be combined strategically in the programming period 2021-2017, as a broader smart specialisation policy mix, the benefits could be substantial for S3 in Portugal. This supports findings of previous studies that show that support to R&D should be provided in all the phases of the innovation process. Research in other countries will be needed to further substantiate this argument under different conditions.

Related JRC work

The study complements other JRC work on Smart Specialisation Strategies in Portugal, namely with a focus on the assessment of S3 implementation (see **Laranja et al., 2020**), as well as the work of **Barbaro et al.** (2020) related to the ex-ante analysis of Smart Specialisation in Southern Europe.

(4) The present exercise is more assessing differences between periods. It implies first to assess if S3 was implemented and under which circumstances. In the present study, due data limitation, we decided to focus only on the key feature of S3 related to better investment choice.

1 Introduction

Smart Specialisation is a place-based approach to regional innovation policy where priorities for public investment are 'discovered' through analysis and dialogue with the innovation and entrepreneurial communities. The objective is to develop 'critical mass' around specific innovative activities that are based on regional strengths but benefit from the application of new knowledge and industrial methods. The rationale for Smart Specialisation as an EU policy was that it could improve the functioning of the single market by differentiating regions through these specific activities, avoiding the duplication of investment within the Union and the same Member State. However, the origin of the concept itself followed analysis of the transatlantic productivity gap, explained by the much more widespread application of general purpose technologies in North America compared to Europe (**McCann and Ortega-Argilés 2015**). After six years of Smart Specialisation underpinning spending on innovation by the EU's Cohesion Policy, this report aims to help assess the impact of the approach on productivity in one Member State, namely Portugal.

The EU operationalised Smart Specialisation by requiring Member States to have a Smart Specialisation Strategy (S3) at national or regional level as an 'ex-ante conditionality' for spending the European Structural and Investment Funds (ESIF) on the Thematic Objective for Research and Innovation (TO1) ([5]). Moreover, Member States have been required to use TO1 to implement the S3. While this is the legal requirement, the European Commission has also encouraged Member States to use other ESIF thematic objectives as well as other policies and sources of funding to implement the strategies (**European Commission, 2012**). In practice however, Member States have mostly relied on TO1 of the ESIF, and although evidence has showed that majority of the spending is formally linked to S3 priorities, there have been few specific S3 calls, for example those targeting single selected priorities (**Gianelle et al, 2019**).

This report attempts to assess the impact of S3 on regional productivity, based on the case of Portugal. However, two main challenges emerge in this exercise. First, in most EU Member States, S3 - as a policy approach promoting better governance - has lacked a specific funding instrument that can be analysed (**Neto and Santos, 2020**). Second, since S3 has been adopted by all the EU Member States as an 'ex-ante conditionality', there is no counterfactual situation - i.e. a similar situation without policy intervention - to perform such an analysis. To solve the first issue, we have used data from ESIF co-funded projects under TO1 and TO3, because in Portugal S3 were mainly implemented through these thematic objectives. As a comparison group we use the previous programming period of the structural funds from 2007-2013, for several reasons. Indeed, Portugal is a very interesting case study to conduct such an analysis because it launched the main funding instrument to support corporate Research and Development (R&D) and innovation in 2007 (for the programming period 2007-2013), which subsequently incorporated S3 criteria under the current period (2014-2020). The differences in the criterion to select investment projects are only related with the alignment of S3 priorities for the territories ([6]). Therefore the differences regarding the leverage effect of this direct public support can be considered as a proxy to measure the impact or added-value of S3 on regional competitiveness, measured by production per worker. For this purpose, we estimate an augmented version of the regional productivity function following **de la Fuente and Doménech** (2002), adding the stock of R&D and Innovation (RDI) funds. To control for the existence of potential geographical spillover effects we use a spatial econometric analysis. Aggregate corporate data at NUTS 3 level from 2008-2018 comes from the INE (National Statistics Office of Portugal). Information about regional ERDF funding flows to corporate RDI expenditures was calculated combining data provided by ANI (Portuguese Innovation Agency) with that extracted from Portuguese regional managing authorities' websites.

The main originality of this study lies on being the first to evaluate the effect of S3 based on data for the programming period 2014-2020. Indeed, more of the existing studies (see e.g. **Balland et al.**, **2019**; **Santoalha**, **2019a**, **2019b**; **Crescenzi et al. 2020**) have focused on assessing the effect of policy measures implemented in the period 2007-2013 with similar features to S3 to show under which circumstances S3 could produce an added value. More recently, **Barbero et al.** (2020) have also provided a simulation of the macroeconomic effects of achieving the R&D personnel targets planned by a set of Southern European regions, thanks to implementation of S3. Therefore, the present study aims to complement existing literature but using data on corporate S3 aligned RDI investment projects to assess its effect on regional productivity. We recognize that the whole period (2014-2020) is not covered and that probably some effect will only become visible in the medium and long-term. We also are aware that we are not assessing the effect of all the characteristics of S3, which is also due to data limitation issues. Therefore, faced with the information available, we decided to focus

([5]) The European Structural and Investment Funds (ESIF) implement the EU's Cohesion Policy and are composed of several different funds, but spending under TO1 is limited to the European Regional Development Fund (ERDF).

([6]) Nevertheless, as explained in section 3, this analysis must be preceded by an assessment of the characteristics of the selected investment projects, to see if they are aligned with the S3 principles: more diversification and collaboration.

on one of the main features that changed in the programming period 2014-2020, namely alignment of investment projects with S3 priorities. Despite the methodological limitations, the results still provide timely material to improve S3 design and update for the new ESIF programming period.

The document has six sections. After the introduction, section two provides an overview of the S3 approach adopted in Portugal, with regard to the selected priorities and main implementing funding instruments. Section three explains the methodological approach while section four describes and analyses the data. Section five reports on the results of the econometric estimations, allowing us to make conclusions and policy recommendations in a final section.

2 Smart Specialisation Strategies in Portugal

The smart specialization approach essentially has five main elements: a place-based approach; the entrepreneurial discovery process (EDP); choices for investment; a broad vision of innovation; and monitoring and evaluation, as described in the first two columns of Table 1. In Portugal, some of these elements had already been implemented in the policy cycle before the 2014-2020 framework programme. Column 3 in **Table 1** shows how they were covered in the previous period 2007-2013. The two differences lie in the involvement of innovation actors in policy design and implementation, as well as in better, more targeted investments. Concerning the first, **Laranja et al.** (2020) have already provided a detailed assessment of the implementation of the EDP in Portugal. Through group interviews with the most relevant actors of the regional and national innovation systems, this report demonstrated that until 2019, the implementation of EDP faced several challenges. Our empirical analysis complements this study using investment choice to assess the impact of S3.

Table 1. Elements of the S3 approach in the 2007-2013 framework programme in Portugal

S3' principles	Description [1]	Equivalent in 2007-2013 [2]
Place-based approach	• Based on resources available in regions • Targeted to specific socio-economic challenges	• Regional and national development strategies, based on SWOT analysis, with specific socio-economic targets for the territories
Entrepreneurial Discovery Process	• Stakeholders involvement to identify opportunities based on critical mass	• Involvement of innovation actors in policy design was weak or inexistent
Choices for investment	• Well-identified priorities for knowledge-based investments • Focus on competitive strengths and realistic growth potentials	• Alignment of investment to achieve a higher territorial competitiveness, however, not restricted to specific priorities
Broad vision of innovation	• Supporting technological and practice-based innovation	• Design of financing instruments for the different steps of the innovation phases (not only to support R&D)
Monitoring and evaluation	• Evidence-based, including a sound evaluation and monitoring process • Including a revision mechanism for updating the strategic choices	• Based on *ex-ante*, intermediary and *ex-post* analysis, mainly with a focus on the amount of funds allocated and jobs created

Source: Author's own elaboration based [1] **Neto and Santos** (2020) and [2] information collected on COMPETE website (http://www.pofc.qren.pt/).

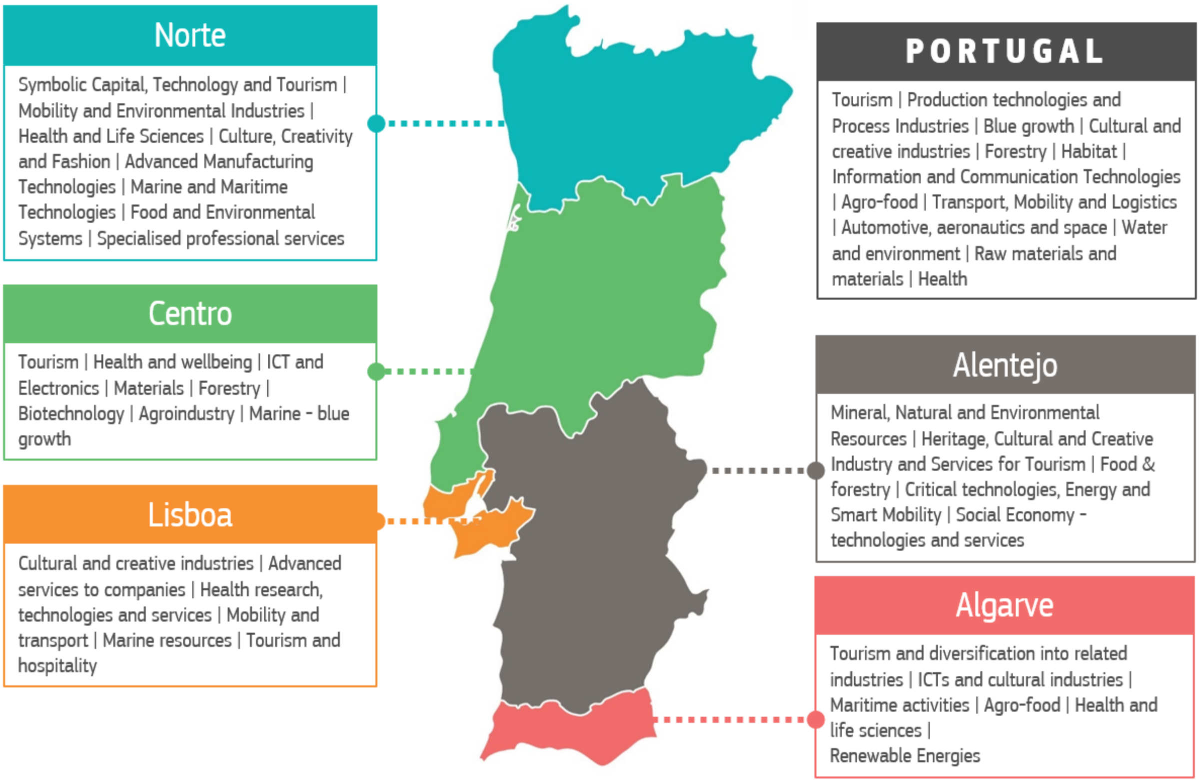
2.1 Description of priority domains

The exact nature of an S3 priority is not entirely clear and thus there is considerable variation across the EU. In the original literature, Dominique Foray refers to 'domains' (**Foray et al., 2009**) which can be defined as "an R&D or innovation area characterized by distinctive knowledge. It can be defined either in terms of capabilities or technology or product functionality" ([7]). However, most selected S3 priorities relate more to market sectors with varying degrees of granularity, while others are characterised more broadly as economic or social challenges[8]. The literature shows that innovation is often at the cross sections of related sectors (**Boschma, 2014**) while productivity benefits from the application of new technologies to existing markets (**McCann and Ortega-Argilés, 2015**). Finally, priorities are not always 'set in stone' and may be modified or re-characterised during the implementation of the strategy.
Portugal has adopted a multi-level approach to S3 that includes a national and seven regional strategies: five continental regions and two autonomous archipelagos of Azores and Madeira ([9]); and therefore, different priority domains by each of them. **Figure 2** and **Table 14** in Appendix shows the priorities selected in Portugal's

([7]) Definition taken from S3 Platform website FAQs : https://s3platform.jrc.ec.europa.eu/faqs-on-ris3 (Accessed on 31 January 2020).
([8]) Analysis of S3 priorities in the Eye@RIS3 tool on the S3 Platform website

national and regional S3. Although reading the actual strategy document ([10]) is necessary to understand their full meaning, according to **Laranja et al.** (2020) the priorities are very broad and not in keeping with the original understanding of a very specific knowledge domain or market niche. Although the word 'domain' translated into Portuguese is used, the titles of the priorities are similar to standard economic sectors ([11]). It is however difficult to narrow down priorities in less developed R&I systems and the Portuguese regions did not have fully fledged regional innovation strategies before (**Laranja et al, 2020**).

Figure 2. Priority domains of RIS3 in Portugal



Source: Author's own elaboration based on Eye@RIS3 tool of the European Commission's S3 Platform.

Portugal map from Adobe Stock: © WooGraphics_165710432.

2.2 Funding instruments under S3

In Portugal, S3 is implemented through four thematic objectives:

- TO1. Strengthening research, technological development and innovation;
- TO3. Enhancing the competitiveness of small and medium-sized enterprises;
- TO8. Promoting sustainable and quality employment and supporting labour mobility;
- TO10. Investing in education, training and vocational training for skills and lifelong learning.

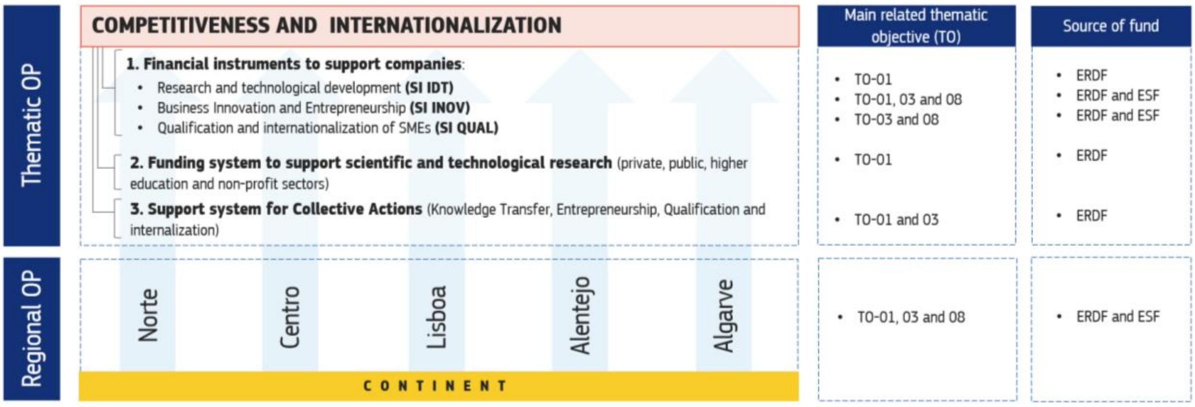
Such TOs are associated with both specific Thematic Operational Programmes (OP) and Regional Operational Programmes. For instance, the OP 'Competitiveness and Internationalization' includes financial instruments

([10]) See the national S3 in the COMPETE2020 website: https://www.compete2020.gov.pt/admin/images/RIS3_Nacional_ENEI_Especializacao-Inteligente.pdf [Accessed on 30 October 2020].

([11]) See the list of priorities domains of the national S3 in COMPETE2020 website: https://www.compete2020.gov.pt/admin/images/TabelaDominiosENEI.pdf [Accessed on 30 October 2020].

related to TO1, TO3 and TO8 (Figure 3). The actions associated to TO10 within S3 ([12]) are integrated in the OP 'Human Capital' ([13]), however, they represent only a small amount of the funds allocated to this OP and they are mainly targeted to higher education institutions and research centers. On the contrary, OP 'Competitiveness and Internationalization' contains a set of financial instruments to support private, public, higher education and non-profits sectors (Figure 3).

Figure 3. Portuguese agenda for 'Competitiveness and Internationalization' (CSF 2014-2020)



Source: Author's own elaboration based on Portuguese legislation - Decreto-Lei n.º 159/2014 of October 27 and Portaria n° 57-A/2015 of February 27.

Note: The regional OP of Azores and Madeira are not reported in the figure.

For the present study, since the Smart Specialisation 'ex-ante conditionality' only concerns TO1, we decided to focus essentially on funding instruments associated to this TO, i.e. within the OP 'Competitiveness and Internationalization'. Nevertheless, because funding instruments to support TO3 are strongly related to TO1, as we will explain later in this section, we also decided to include this TO in our analysis. Furthermore, we decided to restrict our analysis to corporate Research, Development and Innovation (RDI) financial instruments, which represents around 90% of the approved budget for TO1 and TO3 within this OP (Table 2), because for our analysis we use aggregate companies' data (as better explained in section 3).

Table 2. Contracted financing by Axis of the OP 'Competitiveness and Internationalization', 2014-2019

Axis of OP 'Competitiveness and Internationalisation'	Contracted financing	
	Million Euro	% Total
1. Financial instruments to support companies:	5,029	88%
Research and technological development (SI IDT)	691	12%
Business Innovation and Entrepreneurship (SI INOV)	3,396	60%
Qualification and internationalization of SMEs (SI QUAL)	942	17%
2. Funding system to support scientific and technological research	493	9%
3. Support system for Collective Actions	172	3%
TOTAL	5,693	100%

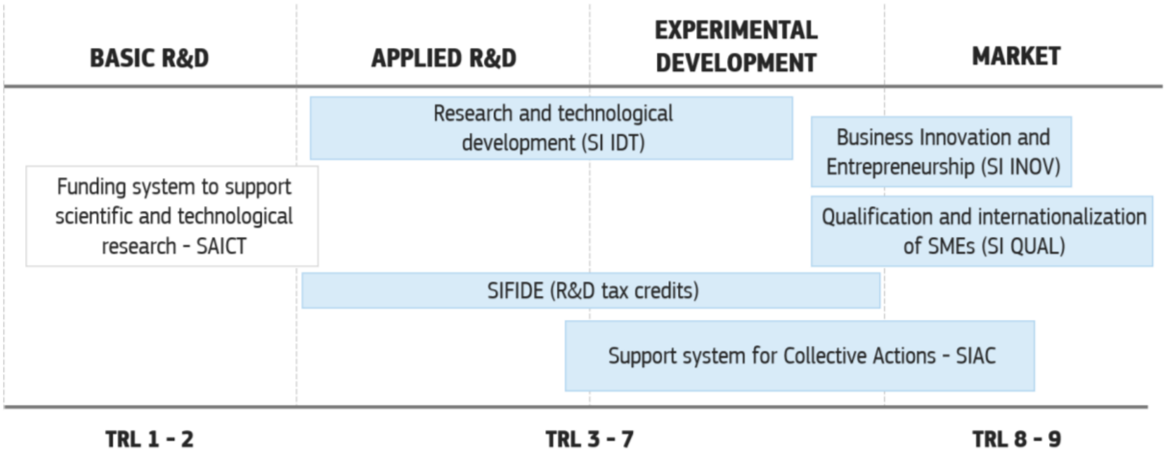
Source: Own elaboration based on data about projects contracted until 30/11/2019 provided by ANI.

([12]) Mainly doctorate programmes and post-doctorate grants, professional higher technical courses and technological specialisation courses.

([13]) For more details see OP Human Capital website: https://www.poch.portugal2020.pt/en/Pages/default.aspx [Accessed on 20 January 2021].

The main funding instrument to support companies under TO1 is the so-called SI IDT - Incentive System for Technological Research and Development (Figure 3). Other instruments to support corporate RDI are the SI INOV – Incentive System for Business Innovation and Entrepreneurship – and the SI QUAL – Incentive System for Qualification and Internationalization of SMEs. However, these last two are mainly under TO3, and depending on the size of the company (e.g. large) or the type of expenses, funding is provided under the TO1 and/or TO8. For instance, SI INOV is also under TO3 (Enhancing the competitiveness of SMEs) and TO8 (Promoting sustainable and quality employment and supporting labour mobility). R&D activity is not included in the SI INOV funding instrument, but supports innovation in the broadest sense. In line with to the definition provided by the OSLO manual **(OECD, 2005),** the concept of innovation behind the SI INOV corresponds to the introduction of a new (or significantly improved) product, process, organisational or marketing method. Regarding the SI QUAL, while under TOs 3 and 8 rather than TO1, it provides support for the last step of the innovation process, namely getting products to market. Figure 5 provides more details on Portuguese RDI funding instruments in each innovation phase.

Figure 4. Portuguese R&I funding instruments by innovation phase



Source: Adapted from **ANI** (2019).

Legend: Main beneficiary: companies; Main beneficiary: higher education and research center

Note: TRL = Technology Readiness Levels. All the instruments identified are funded by ESIF, except SIFIDE.

The SI IDT, SI INOV and SI QUAL were all launched in 2007 within the Portuguese Community Support Framework (CSF) for 2007-2013 (called QREN – *Quadro de Referência Estratégico National*). QREN represented a significant reform to incentive systems with a focus on business investment to achieve economic growth supported by innovation and knowledge ([14]). Within the Portuguese CSF 2014-2020 (called Portugal 2020 or PT2020), the instruments SI IDT, SI INOV and SI QUAL were adapted to match objectives of the Europe 2020 Strategy. As such, the criteria for selecting applications ([15]) includes the level of alignment with S3 priorities, which it is a requirement (mandatory condition) for investments under TO1 (namely SI IDT), and an evaluation criterion for TO3 calls. Table 3 describes the main characteristics of SI IDT in the last two CSF (2007-2013 *versus* 2014-2020). As we can see in Table 3, the main difference lies in the eligibility criteria: the economic activity of the project must be aligned with the S3 priority areas.

([14]) For more details see the “Portaria n° 1462/2007 of November 15” and “Resolução do Conselho de Ministros n° 86/2007 of July 3”.
([15]) For more details about the selection criteria in the QREN see **Santos et al.** (2019).

Table 3. SI IDT characteristics by CSF: 2007-2013 versus 2014-2020

	2007 – 2013	2014 – 2020
Objective	- Intensification of technological R&D and the creation of new knowledge aiming to increase the competitiveness of companies - Promoting the cooperation between companies and other entities of the Scientific and Technological System (STS)	- Increasing business investment in Research and Innovation, in line with the priority areas of S3 - Boosting the cooperation between companies and other entities of the National Innovation System - Enhancing knowledge-intensive economic activities and the creation of value based on innovation
Sectoral scope (by NACE code)	- Industry (10 to 37) - Energy (40 – only production) - Trade (50 to 52 – only SME) - Tourism (551, 552, 553, 554, 633, 711, 9232, 9233, 9261, 9262 e 9272, 92342, 93041 and 93042) - Transport and logistics (602, 622, 631, 632 and 634) - Services (72 to 74, 90, 921, 925, 9231, 01410, 02012 and 02020)	- All economic activities, excluding that covered by sectors subject to specific European State aid restrictions - The economic activity of the project must be within the S3's priority areas (project eligibility criteria)
Beneficiary	- Companies - Entities of the STS and business association (only for co-promotion project)	- Companies - Entities of the STS (only for co-promotion project)
Funding scheme	- Non-refundable and/or refundable subsidy depending on the amount of investment and type of beneficiary	- Non-refundable and/or refundable subsidy depending on the amount of investment and type of beneficiary

Source: Author's own elaboration based on Portuguese legislation: Portaria n° 1462/2007 of November 15, Decreto-Lei n.º 287/2007 of August 17 and Portaria n° 57-A/2015 of February 27.

Note: STS = scientific and technological system.

However, for convergence regions ([16]), depending on the size of the company and the geographical scope of the project, the matching with S3 priority areas, concerning the eligibility/admissibility process, is also different. For instance, projects led by micro and small-size firms must be framed by the regional S3 priority areas, depending on the region of implementation, and the allocation of funds comes from the Regional Operational Programmes (OP). In turn, projects promoted by medium and large-size firms or multi-regional must be aligned with the national S3 priority areas and are funded by the Thematic OP ([17]). Applications are mainly submitted under a tender procedure. Notices for submission of applications define the priorities of the call, and any possible restrictions about beneficiaries, activity sector or regions. Applications are analysed regarding the quality of the project and its impact on the company and regional/national competitiveness. In general, call for applications

([16]) PT11 - Norte, PT16 - Centro and PT18 - Alentejo.

([17]) However, these differences are only applicable in terms of financing sources and the analysis of the project admissibility. During the project evaluation phase, the attribution of project score (or merit) concerning its alignment with the S3 priority areas is made at regional level; whereas, for multi-regional projects (in convergence regions), the analysis of the project admissibility is carried out through the priority areas at national level.

to SI IDT cover a budget from the different Regional OP and the Thematic OP 'Competitiveness and Internationalization'. Entities from all regions and all sectors submit an application in the same call. There is no specific call by priority areas.

Evaluations have positively assessed the incentive system adopted in Portugal since 2007 (see e.g. **Santos, 2019**; **Santos et al. 2018**). However, it was only adapted slightly to account for smart specialisation in 2014 and being the main implementing instrument has limited the effectiveness of S3. The incentive system for R&D continued broadly unchanged after 2014, adapted to smart specialisation only by requiring project alignment with one of the national or regional S3 priorities. However, due to the broadly defined priorities, projects are unlikely to be much more targeted than would be the case through a different approach such as thematic calls in which the type of projects sought are clearly defined (**Gianelle et al, 2019**).

Therefore, the aim of the present study is to analyse the contribution of S3 to productivity gains, starting by understanding which projects the RDI funds were allocated to before assessing the cause-and-effect relationship.

3 Methodology and conceptual framework

3.1 Designing the framework

As highlighted previously, impact assessment of smart specialisation is very challenging, because all the Portuguese regions have an S3 to fulfill the 'ex-ante conditionality' (so there no counterfactual situation) and, it lacks a specific and newly created funding instrument or programme within the ESIF. Therefore, to assess impact we need to use a 'proxy' and to make some assumptions:

— Since S3 is related to TO1 financial support, we decide to focus on financing instruments related to this TO (SI IDT), and also that related mainly to TO3 (SI INOV and SI QUAL) because they are strongly associated with TO1 as we saw in **Figure 3**;

— As a benchmark or comparison group, we use the programming period 2007-2013 because, as we demonstrated in section 2, it included the same corporate RDI funding instruments; the main difference between the two periods being the alignment of investment projects with S3 priorities. Therefore, one could expect investment choices to better target regional competitiveness and growth.

Nevertheless, before performing such analysis, we need first to understand if there is any difference between the characteristics of projects financed between the two periods in line with the S3 principles. Indeed, in recent years, several studies (e.g. **Balland et al.**, **2019**; **Santoalha**, **2019a**, **2019b**; **Barbero et al.**, **2020; Varga et al. 2020; Crescenzi et al. 2020**) have emerged to provide empirical evidence on the benefit of the smart specialisation principles. Even if they were conducted using data covering periods before the emergence of S3, they provide useful evidence about the circumstances when the impact of S3 elements could be positive or where there is a potential risk of failure. Such research was essentially concentrated in two main areas: i) specialisation-diversification (see e.g. **Baland et al., 2019**; **Santoalha**, **2019b**); and ii) cooperation and knowledge transfer (**Crescenzi et al. 2020; Santoalha**, **2019b**; **Varga et al., 2020**). Therefore, we decided to carry out this first assessment according to these two criteria:

— Concentration-diversification of the allocated funds. Indeed, the S3 approach is not associated with regional specialisation in a particular set of industries, but seeks to 'discover' activities based on market opportunities, regional assets and competitive advantages (**Foray, 2013**). Even if territories can benefit from specialisation, through economies of scale and a higher resource efficiency, it also makes them more vulnerable to negative exogenous shocks (**Kaulich, 2012**). However, a certain degree of specialisation within diversification is also needed to get the full advantages of both (**Kaulich, 2012**). Furthermore, specialisation is interpreted as a way to provide more complex knowledge or technology resulting from the diversity of capacities (and their inter-relationship among them) existing in the territory (**Baland et al., 2019**). Such complexity, by being more difficult to imitate, confers a source of relative competitive advantage to a territory (**Baland et al., 2019**).

— Cooperation within and between Portuguese regions. Entrepreneurs should be supported in the 'discovery' process of such 'specialisation', sometimes under a new directionality able to generate structural change (**Crescenzi et al., 2020**; **Varga et al., 2020**). Related to entrepreneurs and knowledge transfer, cooperation - through research networks - plays an important role to enhance the knowledge creation (**Varga et al., 2020**) and to develop more complex technology.

To assess concentration-diversification of the allocated funds, we use information on the funded economic activities (NACE 5-digits) and beneficiaries (VAT number). To measure cooperation between actors, we use information on the investment projects conducted in partnership and their location regarding NUTS 2 level and districts. Additional sectorial analysis is also performed, grouping economic activities by technology level (low, medium-low, medium-high and high tech) for manufacturing industries and knowledge intensity for services_([18]), to evaluate whether there is any innovation pattern between the different financial instruments.

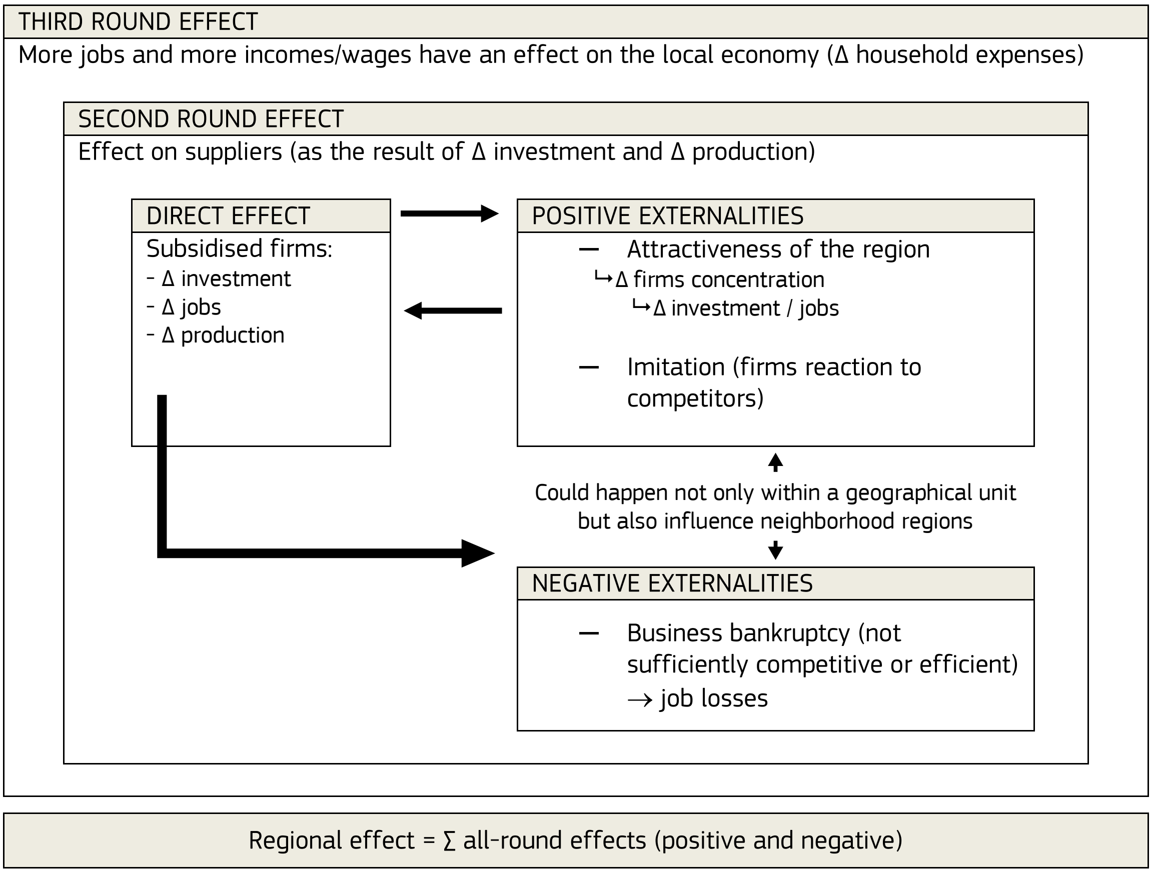
Once we have carried out this first preliminary analysis, and we have identified significant differences that are in line with the features of S3, we can move on to the second phase of our analysis. It is important to highlight that the current proposed methodology is more than assessing the difference between the effects in two periods

([18]) For more details see the EUROSTAT glossary for "high-tech classification of manufacturing industries" (https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:High-tech_classification_of_manufacturing_industries), as well as, that for "Knowledge-intensive services" (https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Knowledge-intensive_services_(KIS)).

of time; it implies first to understand if the S3 was implemented and under which circumstances. Indeed, according to **Varga et al.** (2020), EU regions can experience different impacts of S3 depending on the implementation of their strategies and the characteristics of their innovation ecosystem.

To quantify subsidy-productivity relationship, we decided to work with data at the regional level, instead of firm level, for several reasons. Indeed, when analysis is performed at firm level, we are only able to estimate the first and direct effect of incentives (i.e. effect on subsidised firms), whereas, as highlighted by **Guellec and van Pottelsberghe** (2000), with an analysis at country (or regional level) we can capture all the effects of public support in the economy – positive and negative, direct and indirect. Figure 5 gives an example of this reasoning and illustrates how the direct effect of subsidy can spill over to other sectors and actors that have not received funding. Furthermore, since the scope of S3 is at regional/national level, it seems more adequate to perform such an analysis using territorial data. In fact, S3 is not about the individual performance of firms, but about territorial competitiveness (**Foray, 2013**).

Figure 5. Different round-effects of public support at the aggregate level



Source: Authors' own elaboration.

Spillover effects can occur vertically (customer-supplier relationship) or horizontally (between competitors) in the value chain. For instance, if a company invests in R&D, it can push competitors also to invest in R&D to maintain their position in the market. On the other hand, innovation happening upstream in the value chain can stimulate innovation among suppliers to respond to new market needs. Similarly, innovation happening downstream (e.g. new input materials) can also enhance innovation upstream (e.g. production of new final products). However, to generate spillover effects the absorptive capacity of the different players in the territory plays a key role. Indeed, according to **Almudi et al.** (2020), the low productivity performance of an economy could be the consequence of a mismatch between the knowledge evolutions upstream and the downstream value chain. For instance, to absorb new technologies developed in high-tech industries (e.g. machinery), low-tech Industries (e.g. food producers or textiles) need learning capabilities that allow them to use them

productively (**Potters, 2009**). Under this assumption, one precondition to ensure an effective transfer and absorption of R&I knowledge are the skills of the labour force and the capacity to update or reshape these skills.

3.2 Econometric model

To assess the contribution of Smart Specialisation Strategies to regional productivity we use an augmented version of the **de la Fuente and Doménech** (2002) model ([19]). This model (1) is based on a regional production function, where the dependent variable corresponds to the output per worker ($Y_{i,t}$) in the territory i at time t. Inputs include the stock of physical capital per worker ($K_{i,t}$) and the qualification of human capital ($H_{i,t}$). In the present study, $Y_{i,t}$ refers to the real production value per worker, $K_{i,t}$ is the real capital stock per worker, estimated using Gross Fixed Capital Formation and the Perpetual Inventory method (PIM) with a depreciation rate of 8%. $H_{i,t}$ is proxied by the cost per worker, since this indicator is frequently used to assess the qualification/education level of human resources ([20]).

$$Y_{i,t} = f(K_{i,t}, H_{i,t}) \tag{1}$$

Before measuring the effect of smart specialisation, we will first start by understanding the relationship between productivity and RDI subsidies. Therefore, model (1) is augmented to include the stock of RDI funds per worker ($RDI_{i,t}$), as expressed in equation (2). To estimate the RDI funds stock we use the PIM and a depreciation rate of 15% ([21]). The equation (2) also comprises fixed regional effects (μ_i) and annual time fixed effects (τ_t), to control for all unobservable region-specific time invariant effects and specific common shocks, respectively. The i.i.d. error term of the specification is reported by the variable $u_{i,t}$.

$$Y_{i,t} = \beta_1 K_{i,t} + \beta_2 H_{i,t} + \beta_3 RDI_{i,t} + \tau_t + \mu_i + u_{i,t} \tag{2}$$

The next step lies on introducing in equation (2) a dummy variable ($S3_t$) to make a distinction between the two periods (before and after S3 implementation) and the interaction term between the previous variable and RDI funds stock. However, as the RDI funds stock variable in period 2 (with S3) also includes the net amount of RDI funds stock from the previous programming period (without S3 – period 1), we also need to isolate the amount of stock in period 2 coming from period 1 ($RDI\_R_{i,t}$). The equation (3) reports that changes in equation (2), where total RDI stocks ($RDI_{i,t}$) are divided in two variables: sum of RDI stock of period 1 until S3 implementation plus the stock in period 2 ($RDI\_S_{i,t}$) and the stock in period 2 coming from period 1 ($RDI\_R_{i,t}$). The coefficient of the interaction term ($S3_t.RDI\_S_{i,t}$) captures the proxy effect of S3 in productivity.

$$Y_{i,t} = \beta_1 K_{i,t} + \beta_2 H_{i,t} + \beta_3 RDI\_S_{i,t} + \beta_4 S3_t + \beta_5 S3_t.RDI\_S_{i,t} + \beta_6 RDI\_R_{i,t} + \tau_t + \mu_i + u_{i,t} \tag{3}$$

However, the baseline model in equation (3) ignores possible spatial effects, considering regions isolated economies. Studies (e.g. **de la Fuente et al., 2003**; **Ramos et al., 2010**) have demonstrated that spillover effects from neighbouring regions might be expected and ignoring them could bias the results of our analysis. Therefore, to capture the interaction between the different regions, equation (3) is augmented to include the spatial lags of the dependent variable, as expressed in (4); where δ is the spatial autoregressive coefficient and w_{ij} is each of the elements of the spatial weights matrix W_{ij} that defines the geographical distance between

([19]) This model has been used over the last years (e.g. **de la Fuente et al., 2003**; **Ramos et al., 2010**) to explain regional productivity.

([20]) Due to data limitation issues, we are not able to use the same indicator than **Fuente and Doménech** (2002) or **Ramos et al.** (2010) i.e. years of schooling.

([21]) Following **Hall and Mairesse** (1995) that used a depreciation rate for physical capital stocks of 8% and a value of 15% for R&D capital stock.

regions. The inverse distance matrix based on the great circle distance between region capitals is used to define the elements of W_{ij}.

$$Y_{i,t} = \delta \sum_{i=1}^{N} w_{ij} . Y_{j,t} + \beta_1 K_{i,t} + \beta_2 H_{i,t} + \beta_3 RDI\_S_{i,t} + \beta_4 S3_t + \beta_5 S3_t . RDI\_S_{i,t} + \beta_6 RDI\_R_{i,t} + \tau_t + \mu_i + u_{i,t} \quad (4)$$

To test if productivity of region i is also influenced by capital stock, human capital and RDI subsidy in neighbouring regions, equation (4) is enlarged to include the spatially lagged independent variables, as expressed in equation (5). This model is usually called Spatial Durbin Model (SDM), whereas equation (4) refers to the so-called Spatial Autoregressive Model (SAR).

$$\begin{aligned} Y_{i,t} = {} & \delta \sum_{i=1}^{N} w_{ij} . Y_{j,t} + \beta_1 K_{i,t} + \beta_2 H_{i,t} + \beta_3 RDI\_S_{i,t} + \beta_4 S3_t + \beta_5 S3_t . RDI\_S_{i,t} + \beta_6 RDI\_R_{i,t} \\ & + \gamma_k \sum_{i=1}^{N} w_{ij} . K_{j,t} + \gamma_h \sum_{i=1}^{N} w_{ij} . H_{j,t} + \gamma_r \sum_{i=1}^{N} w_{ij} . RDI\_S_{i,t} \\ & + \gamma_{sr} \sum_{i=1}^{N} w_{ij} . S3_t . RDI\_S_{i,t} + \gamma_{rr} \sum_{i=1}^{N} w_{ij} . RDI\_R_{i,t} + \tau_t + \mu_i + u_{i,t} \end{aligned} \quad (5)$$

When assessing causal inference a potential source of bias could be due to endogeneity issues. Endogeneity happens when an explanatory variable (x) in a regression model is correlated with the error term (u). This problem can occur for mainly three reasons: i) "simultaneity bias" when the dependent variable (y) is also a predictor of (x) and not a merely reaction to x; ii) "omitted-variable bias" when an important variable is missing in the model to explain y; iii) measurement error (**Baum, 2006**).

To deal with potential endogenous bias, the most known technique is to use instrumental variables estimation (**Baum, 2006**). However, the most challenging is the selection of appropriate instruments, exogenous variable(s) strongly correlated with the endogenous regressor and only able to influence the dependent variable through endogenous variables. Usually the first and/or second lag of the endogenous variables are used as instruments, however, this implies a loss of up to two years observations. Another alternative, as demonstrated by **Bellemare et al.** (2017), is to use the lagged explanatory variables which, under some conditions, are also appropriate responses to endogeneity concerns on estimation of causal effect. For instance, when there is no reverse causality ($Y \nrightarrow X$) and the causal effect operates with one period lag only ($X_{t-1} \rightarrow Y_t$ but $X_t \nrightarrow Y_t$).

In the present study, we decided to use the lagged explanatory variables for several reasons. First as shown by the Granger causality test in Table 20 (Appendix), only a unidirectional relationship between stock of RDI funds and productivity exists, and also with one period lag only. Second, to obtain valid instruments, as demonstrated in Table 21 (Appendix), we need to use the first and second lag of some endogenous variables. Losing one extra year of observations reduces the years available in the second period under analysis and makes it difficult to have enough observations in that period for comparison purposes. Third, the coefficients estimated using OLS regression with the lagged explanatory variables or instrumental variables are not statistically different from each other (Table 21 in Appendix), based on the estimation of equation (2). Furthermore, by including region-fixed effects and year-fixed effects in our model spatial regressions reduce the missing variables issues affected by unobservable factors. Moreover, in section 5 we also display the results of Ramsey test for omitted variables. All together this suggests that we try to control for any potential source of endogeneity bias, at least for our main variable of interest, namely the stock of RDI funds.

Equation (5) is rewritten in (6) to accommodate the lag of all explanatory variables, The SDM will coincide with a SAR if $\gamma = 0$ and $\delta \neq 0$. SAR and SDM are both estimated using Maximum Likehood (ML) procedures.

$$\begin{aligned} Y_{i,t} = {} & \delta \sum_{i=1}^{N} w_{ij} . Y_{j,t} + \beta_1 K_{i,t-1} + \beta_2 H_{i,t-1} + \beta_3 RDI\_S_{i,t-1} + \beta_4 S3_t + \beta_5 S3_t . RDI\_S_{i,t-1} \\ & + \beta_6 RDI\_R_{i,t-1} + \gamma_k \sum_{i=1}^{N} w_{ij} . K_{j,t-1} + \gamma_h \sum_{i=1}^{N} w_{ij} . H_{j,t-1} + \gamma_r \sum_{i=1}^{N} w_{ij} . RDI\_S_{i,t-1} \\ & + \gamma_{sr} \sum_{i=1}^{N} w_{ij} . S3_t . RDI\_S_{i,t-1} + \gamma_{rr} \sum_{i=1}^{N} w_{ij} . RDI\_R_{i,t-1} + \tau_t + \mu_i + u_{i,t} \end{aligned} \quad (6)$$

4 Data source, description and analysis

4.1 Data source

Data used in the study comes from several sources (for more details see Table 4). Aggregate corporate statistics at NUTS 3 level ([22]) (version 2013) were obtained from INE – Statistics Portugal. Information about regional ERDF funding flows to R&I expenditures was calculated based on data of investment projects funded by SI IDT, SI INOV and SI QUAL ([23]) between 2007 and 2018. This data was obtained by combining that provided by ANI - *Agência Nacional de Inovação* ([24]) - with that extracted from CCDRs ([25]), COMPETE ([26]) and PORTUGAL2020 websites. Information about Portugal 2020 refers to investment projects contracted until 31/12/2018.

Table 4. Data source and description

VARIABLES	DESCRIPTION	SOURCE	PERIOD
Production (€) of Enterprises by Geographic localization (NUTS - 2013)	Outputs or products created during the accounting period	INE – Integrated business accounts	2008 – 2017 and 2018e
Persons employed (No.) in Enterprises by Geographic localization (NUTS - 2013)	Persons who during the reference period participated in the business of the enterprise/institution, regardless of the duration of this participation	INE – Integrated business accounts	2008 – 2017 and 2018e
Gross fixed capital formation (€) of Enterprises by Geographic localization (NUTS - 2013)	Gross fixed capital formation consists of resident producers' acquisitions, less disposals, of fixed assets during a given period plus certain additions to the value of non-produced assets realised by the productive activity of producer or institutional units	INE – Integrated business accounts	2008 – 2017 and 2018e
Personnel expenses (€) of enterprises by Geographic localization (NUTS - 2013)	Personnel expenses comprise wages and salaries	INE – Integrated business accounts	2008 – 2017 and 2018e
Inflation rate	Annual growth rate of consumer price index in Portugal	INE, PORDATA	2007 – 2018
Funding contracted to companies under QREN 2007-2013 to enhance competitiveness and internationalization	Funding contracted to companies under QREN 2007-2013 by activity sectors (NACE 4-digits), geographical localization (municipalities) and financial instruments (SI IDT, SI INOV and SI QUAL).	ANI and COMPETE website	2007 – 2013
Funding contracted to companies under PT2020 to enhance competitiveness and internationalization	Funding contracted to companies under PT2020, until 31/12/2018, by activity sectors (NACE 4-digits), geographical localization (municipalities) and financial instruments (SI IDT, SI INOV and SI QUAL)	ANI, CCDRs website and PT2020 website	2014 – 2018

Source: Author's own elaboration based on metadata system from INE – Statistics Portugal.
Note: e = estimation by linear interpolation and extrapolation based on time trend of territorial units.

([22]) The choice of territorial unit NUTS 3 level is due to data availability. To the best of our knowledge, some aggregate corporate statistics are not available at a higher level of disaggregation, such as districts and municipalities level. Therefore, we use NUTS 3 level, the higher level of disaggregation available.

([23]) The main financial instruments to enhance competitiveness and internationalization in Portugal in the periods of 2007-2013 and 2014-2020.

([24]) Portuguese Innovation Agency, entity in charge of developing actions to support technological and business innovation in Portugal, contributing to the consolidation of the National Innovation System and to strengthening the competitiveness of the national economy in global markets.

([25]) CCDR-Norte: https://www.norte2020.pt/; CCDR-Centro: http://centro.portugal2020.pt/; CCDR-Alentejo: https://www.ccdr-a.gov.pt/; CCDR-Lisboa: http://www.ccdr-lvt.pt/pt/; CCDR-Algarve: https://www.ccdr-alg.pt (CCDR – Algarve) - data extracted on 19/12/2019.

([26]) http://pofc.qren.pt/ - data extracted on 2/10/2019.

Disaggregation of funds by years and territories in multi-regions projects follows the following assumptions, due to the lack of a more precise information:

- Disaggregation of funds by years was based on the duration of the project ([27]);
- Funding for investment project with several beneficiaries or/and located in several territorial units was imputed equally to each beneficiary and/or territory. The year-region funding data corresponds to the sum of the values of investment projects.

All monetary values are expressed in euros and transformed in constant prices (base 2018) to adjust for the effects of inflation. Even if regional deflators to measure differences of prices at regional level are not available, our model specification described in the next section includes fixed regional effects in order to control for unobserved characteristics. In this way, we reduce this data limitation as much as is possible.

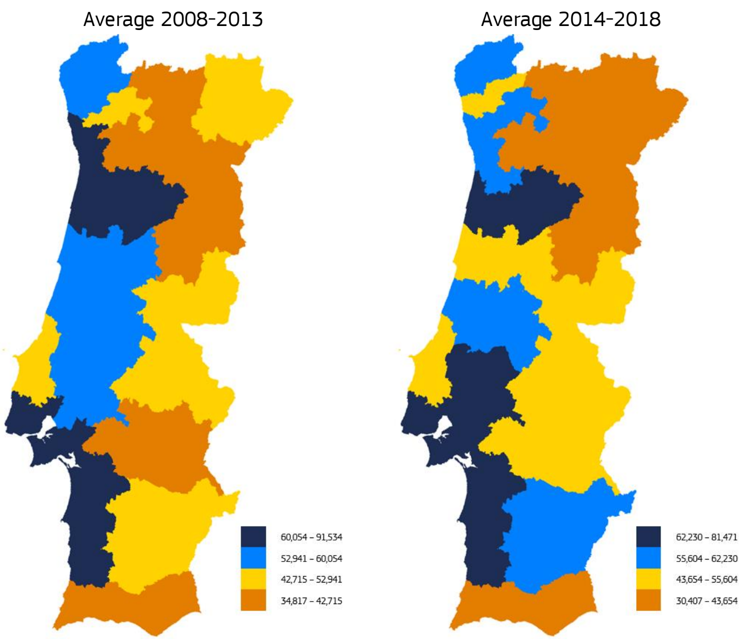
The summary statistics and the correlation matrix are reported in Table 15 in Appendix. The final panel has 230 observations, covering 23 regions over 11 years (2008-2018). We lose one year in the regression estimation due to the use of the lag of independent variables.

4.2 Data description and analysis

4.2.1 Regional productivity

Figure 6 details the average regional productivity for each region over the two programming periods under analysis: 2008-2013 and 2014-2018. Regions in blue indicate productivity level above the average and yellow-orange regions below. On average, coastal regions report higher values than inland regions. Of the 23 NUTS 3 level regions, four of them improved their relative positioning (PT184 - Baixo Alentejo; PT119 – Ave; PT187 - Alentejo Central; PT185 - Lezíria do Tejo), whereas productivity declines in four others (PT16E - Região de Coimbra; PT11E - Terras de Trás-os-Montes; PT112 – Cávado; PT11A - Área Metropolitana do Porto).

Figure 6. Regional production per employee, constant prices (base 2018), average by period, NUTS 3 level



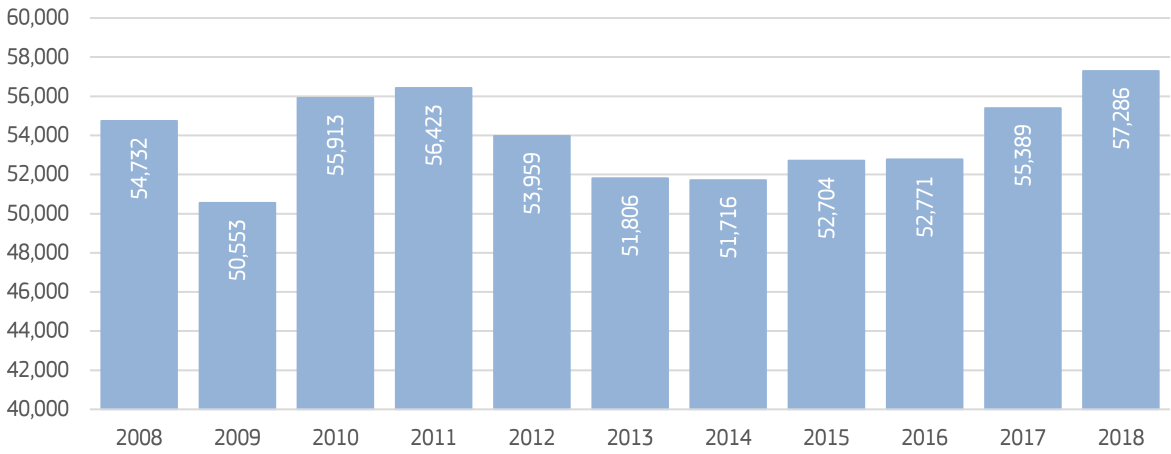
Source: own estimation based on INE data.

Over the period under analysis, regional productivity displays two breaks in the trends in 2008-2009 and 2012-2014 (Figure 7). The first drop in productivity level happens as the result of the global recession, and the second

([27]) For example, an investment project with a funding of 30.000Eur started in 2015 and with a duration of 3 years is imputed equally (10.000Eur per year) in the period 2015-2017.

to the financial crisis that hit Portugal and other Mediterranean countries, due to the excessive level of debt, still part of the previous crisis. Such trends reinforce the need to include time-fixed effect in our model, to control as much as possible for such shocks.

Figure 7. Evolution of average production per employee at constant price (base 2018), 2008-2018



Source: own estimation based on INE data.

4.2.2 R&D and Innovation funds

4.2.2.1 Geographical and annual distribution of funds

Figure 8, Figure 9, Figure 10 and Figure 11 displays the geographic distribution (% of the total) of the different types of RDI funding and the sum of these by region in the two programming periods. The amount of RDI funding is expressed in relative term (in percentage of the total). Darker the areas, higher concentration of funds in a region. On average, inland regions receive less funds than the coastal ones. Nevertheless, we can observe, based on the box plot reported in Figure 12, that in the programming period 2014-2020 the funds are on average less concentrated in comparison with the previous one.

Figure 8. Estimated geographical distribution of SI IDT funds by regions and programming period

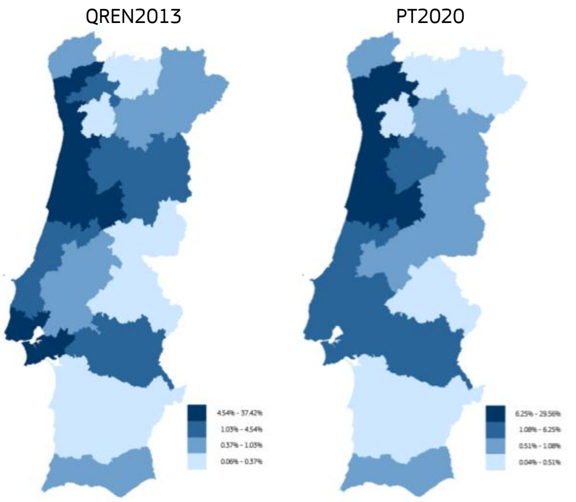


Figure 9. Estimated geographical distribution of SI INOV funds by regions and programming period

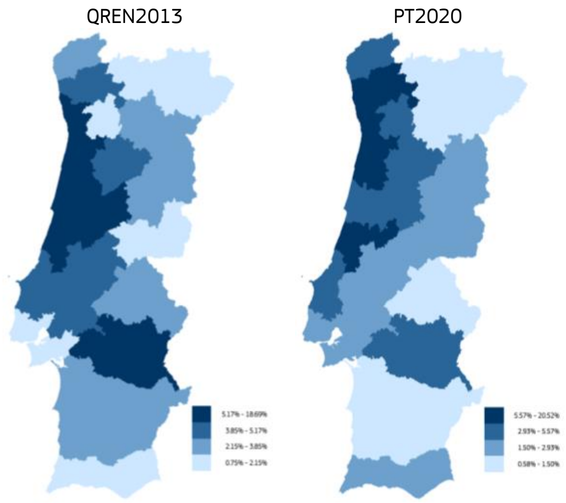


Figure 10. Estimated geographical distribution of SI QUAL funds by regions and programming period

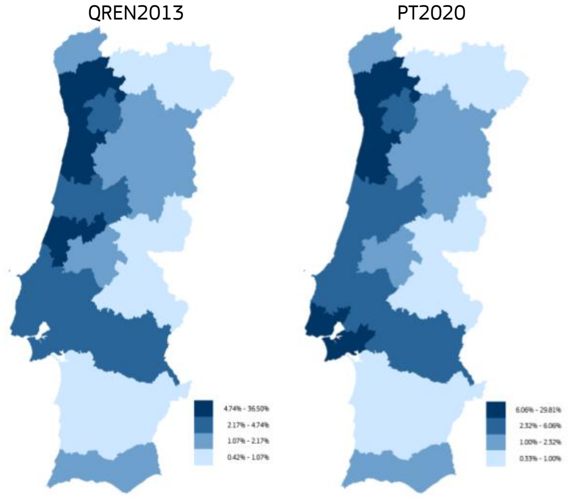
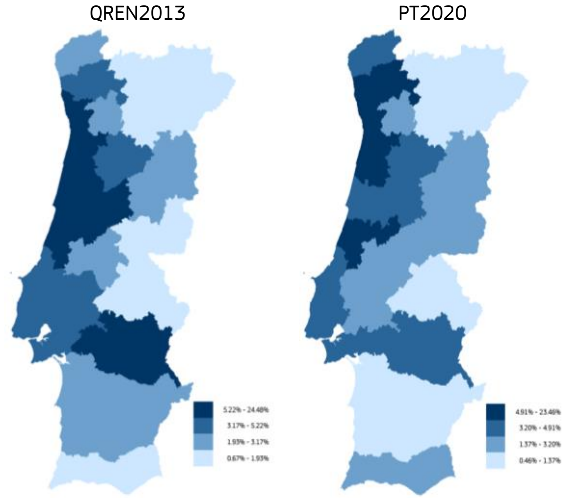
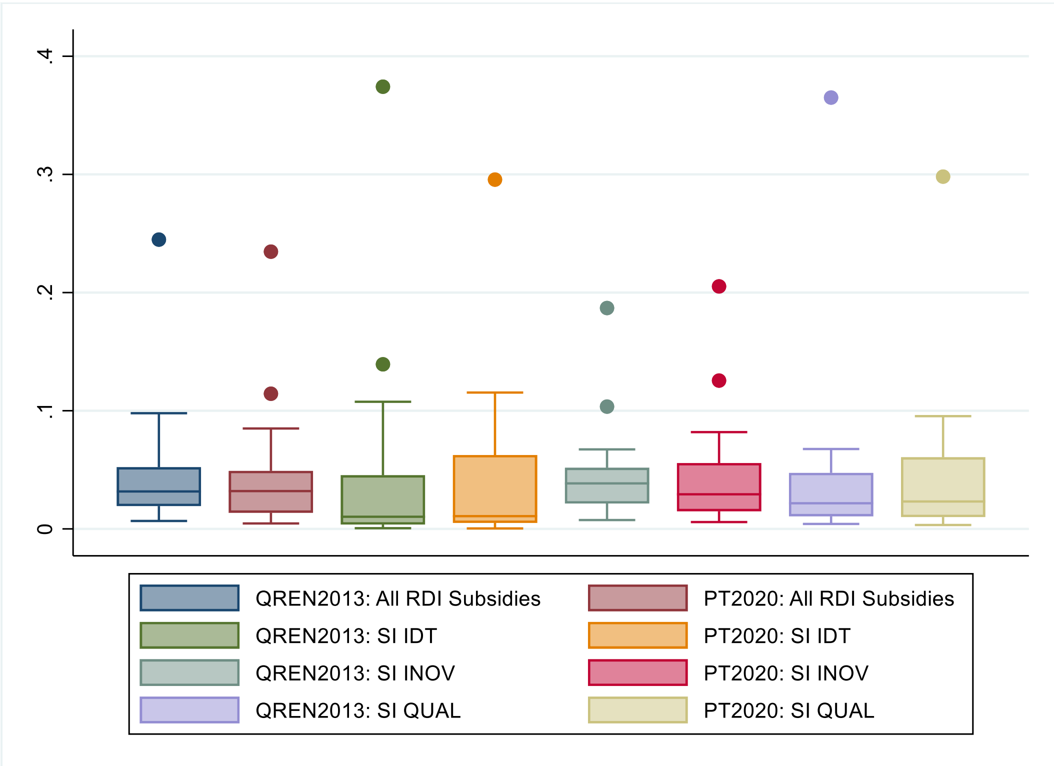


Figure 11. Estimated geographical distribution of all RDI funds by regions and programming period



Source: Own estimation based on data from ANI and COMPETE ([28]) and PORTUGAL2020 websites.

Figure 12. Box Plot geographical dispersion of RDI funds, by financing instruments and programming period



Source: Own estimation based on data from ANI and COMPETE ([29]) and PORTUGAL2020 websites.

The annual distribution of the flows of RDI funds and its estimated stock are displayed in Figure and Figure 14, respectively. As we can see, funding under QREN 2013 still had significant until 2015 (N+2) and even if PT2020 started in 2014, the first flow of funding only started in 2015.

([28]) http://pofc.qren.pt/ - data extracted on 2/10/2019.
([29]) http://pofc.qren.pt/ - data extracted on 2/10/2019.

Figure 13. Estimated Flow of RDI Subsidies (Million Euro, constant price – base 2018), by year

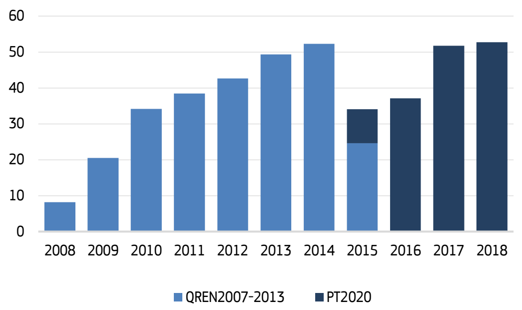
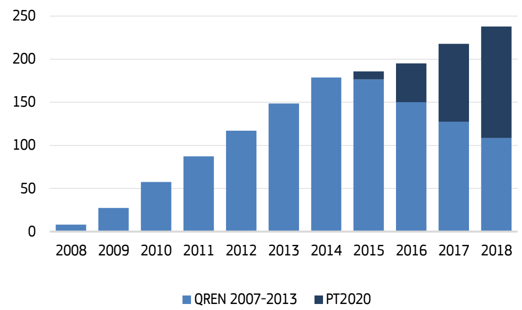


Figure 14. Estimated Stock of RDI Subsidies (Million Euro, constant price – base 2018), by year



Data of PT2020 refers to investment project contracted until 31/12/2018.

Source: Author's own elaboration based on data from ANI and COMPETE ([30]) and PORTUGAL2020 websites.

4.2.2.2 Characteristics of the projects and S3 features

Figure 15 shows the amount of R&D funds allocated (% total) to partnership and individual projects and Figure 16 the (average) number of different regions involved in partnership projects, by programming period. We can observe that, under the S3 programming period (PT2020), the percentage of subsidy for partnership projects is considerably higher (68%) in comparison with the previous programming period (42%). A higher level of inter-regional collaboration, at NUTS 3 and NUTS 2 level, is also detected under PT2020 framework programme.

Figure 15. Amount of R&D funds by type of projects and programming period: % Total – SI IDT (1)

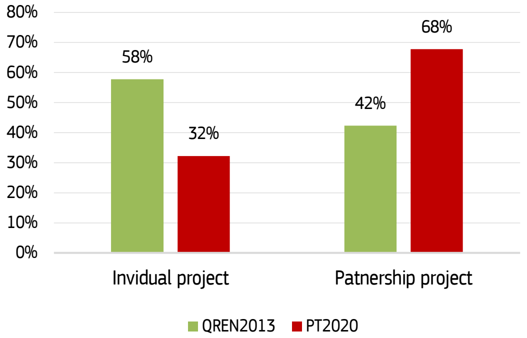
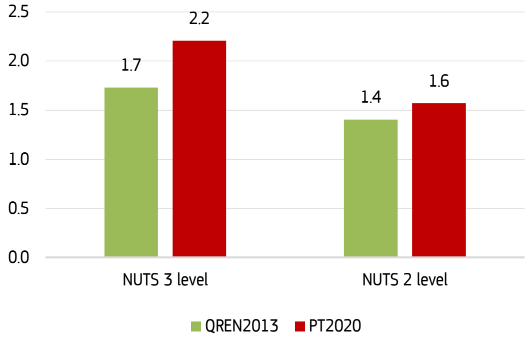


Figure 16. Inter-regional collaboration (SI IDT – project in partnership): average number of regions involved by project (2)



Source: Authors' own estimation based on data provided by ANI.

Note: PT2020 data refers to investment projects contracted until 31/12/2018. (1) Projects in partnership are funded by SI IDT (R&D) and SI QUAL (Innovation), however, since alignment with S3 priorities is only an eligibility condition in SI IDT, this financing instrument is analysed for comparison purposes only. (2) The regions involved in the project refers to the geographical location of the project beneficiaries.

A lower concentration of RDI subsidies in turn of the same beneficiaries (Figure 17 and Figure 18) and economic sectors (Figure 19 and Figure 20) can be observed, suggesting the entrance of new actors in the S3 ecosystem. Together with the previous findings, this provides evidence that the characteristics of RDI projects supported under PT2020 are aligned with key feature of S3: more inter-regional collaboration and more diversification.

([30]) http://pofc.qren.pt/ - data extracted on 2/10/2019.

Figure 17. Number of beneficiary participation in RDI projects (average)

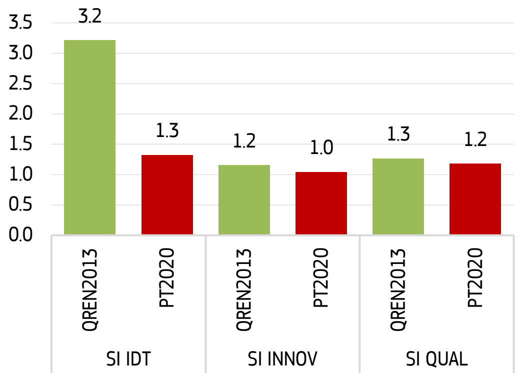


Figure 18. Subsidy concentration index – Beneficiary

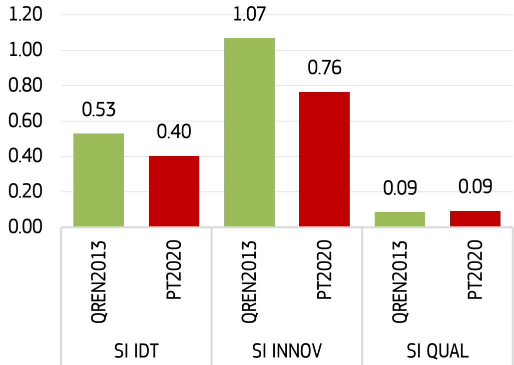


Figure 19. Average number of project by NACE Code (5-digits)

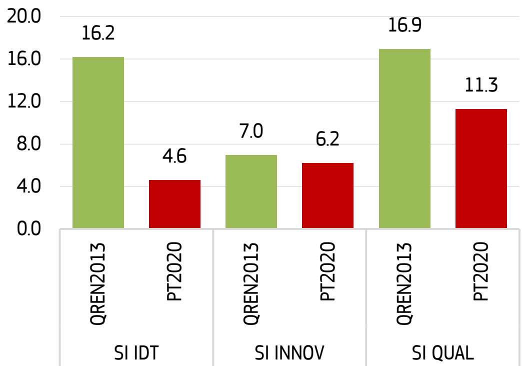
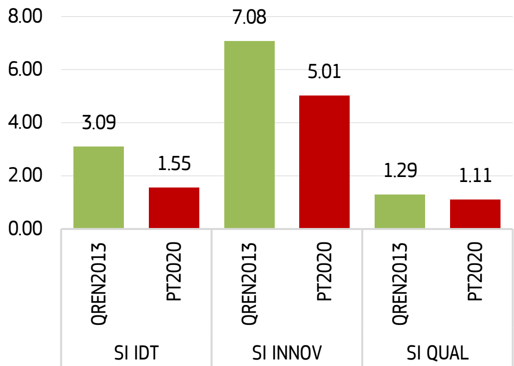


Figure 20. Subsidy concentration index - Economic activity (NACE code 5 digits)



Source: Authors' own estimation based on data provided by ANI.

Note: Data refers to projects contracted until 31/12/2018. (1) For projects in partnership, it refers to the project leader information (beneficiary and NACE code), due to data limitation. For QREN2013 information about projects includes only the name of project leader, even if the geographical localisation of all the beneficiaries is available.

4.2.2.3 Economic sector supported by RDI funds

Looking at the distribution of SI IDT funds by technology groups and reported knowledge intensity, Table 5 shows similar innovation patterns in both programming periods. About 70% of funds are concentrated in knowledge-intensive services (e.g. research centres and similar) or the so-called Knowledge Intensive Services (KIS). High and medium-high tech manufacturing industries account for about 15% of the funds. Low tech received 6% of the total SI IDT funds, which is even more than high tech sectors (3%-6%). This last finding is surprising because according to **Potters** (2009), R&D intensity in high tech companies could represent on average five times more than in low and medium-low-tech companies. In the present analysis this could suggest that low and medium-tech have a higher likelihood to request public R&D support than high-tech sector.

Table 5. SI IDT funds allocated by technology group and knowledge intensity

Sector	SI IDT (2007-2013)		SI IDT (2014-2018)	
	Euro	% Total	Euro	% Total
Technology groups (manufacturing)				
Low tech	16,974,610	6%	8,569,416	6%
Medium-Low tech	11,703,525	4%	9,310,099	6%
Subtotal: Low + Medium-Low tech	28,678,135	10%	17,879,516	12%
Medium-High tech	25,600,616	9%	17,285,839	12%
High tech	15,733,417	6%	4,179,898	3%
Subtotal: Medium-High + High tech	41,334,033	15%	21,465,738	14%
Knowledge intensive-services	191,000,789	70%	101,948,114	68%
Others	12,517,135	5%	8,872,811	6%
TOTAL	273,530,091	100%	150,166,179	100%

Source: Author's own elaboration based on data from Table 18 in Appendix.

As regards to the other innovation funding instruments (SI INOV and SI QUAL), we also observe a similar sectorial innovation patterns in both programming period (Table 6). However, if we compare the funds allocated by technology group and knowledge intensity under the different financing instruments (Table 5 and Table 6), we can see that SI INOV and SI QUAL funds are between 41% and 49% allocated to Low and Medium-Low tech industries. Also, under these financing instruments, KIS receive a small proportion of funds (11% - 13%) in comparison with SI IDT (68% - 70%). Regarding High and Medium-high tech, the funds allocated to those sectors are quite similar under SI IDT and SI INOV + SI QUAL (10% - 15%).

Table 6. SI INOV and SI QUAL funds allocated by technology group and knowledge intensity

Sector	INNOV + QUAL (2007-2013)		INNOV + QUAL (2014-2018)	
	Euro	% Total	Euro	% Total
Technology groups (manufacturing)				
Low tech	567,593,122	25%	487,475,956	25%
Medium-Low tech	363,065,828	16%	452,636,449	23%
Subtotal: Low + Medium-Low tech	930,658,949	41%	940,112,405	49%
Medium-High tech	237,456,082	11%	201,022,794	10%
High tech	18,421,947	1%	42,108,126	2%
Subtotal: Medium-High + High tech	255,878,029	11%	243,130,921	13%
Knowledge intensive-services	334,952,904	15%	195,821,796	10%
Others	739,772,266	33%	550,889,331	29%
TOTAL	2,261,262,148	100%	1,929,954,452	100%

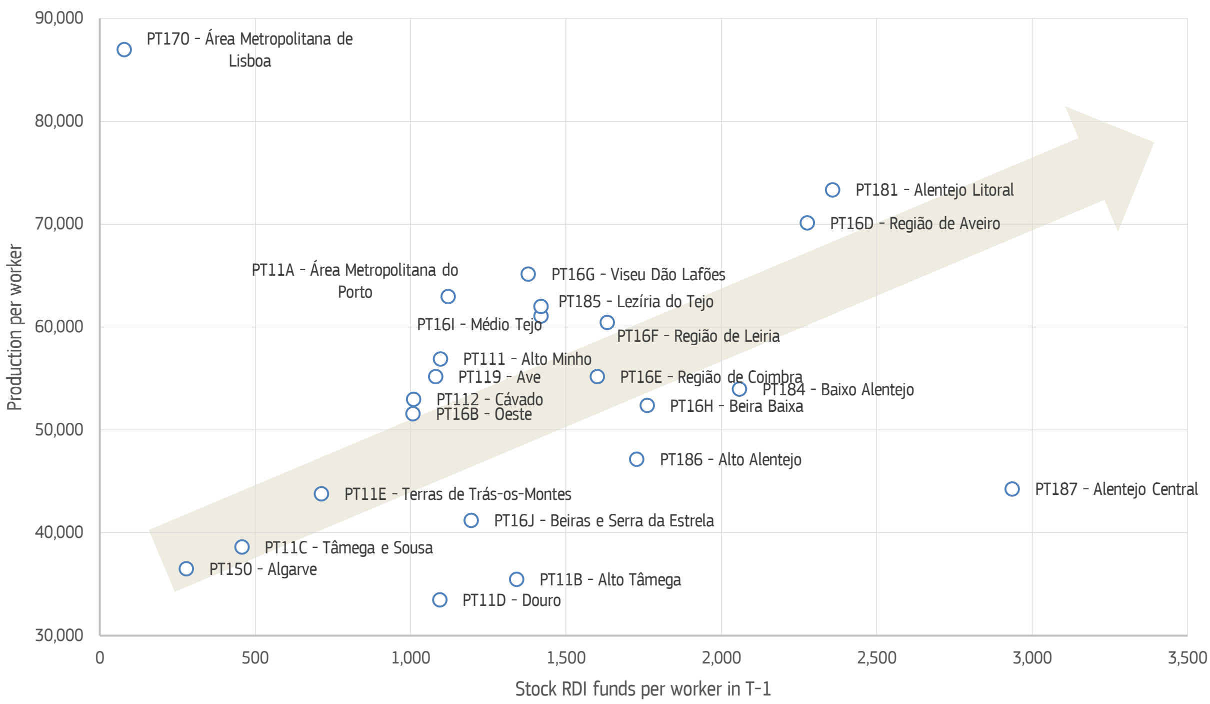
Source: Author's own elaboration based on data from Table 19 in Appendix.

Such findings regarding innovation patterns are particularly interesting if we take into account the Technology Readiness Levels (Figure 4) and the eligible expenditures (Table 17) of the different R&I financing instruments. From literature (see e.g. **Potters, 2009:9**) we know that firms in low-tech industries tend to invest in new equipment created by high-tech sectors rather than developing it by themselves. However, even if new technology tends to be diffused between sectors thanks to its acquisition, to use it knowledge transfer is also necessary (**Potters, 2009**). Such kind of support, can be observed if we take into account that low-tech and medium-low tech industries benefit more from SI INNOV and SI QUAL, where support for knowledge and technology transfer is provided.

4.2.3 Productivity and R&D funding relationship

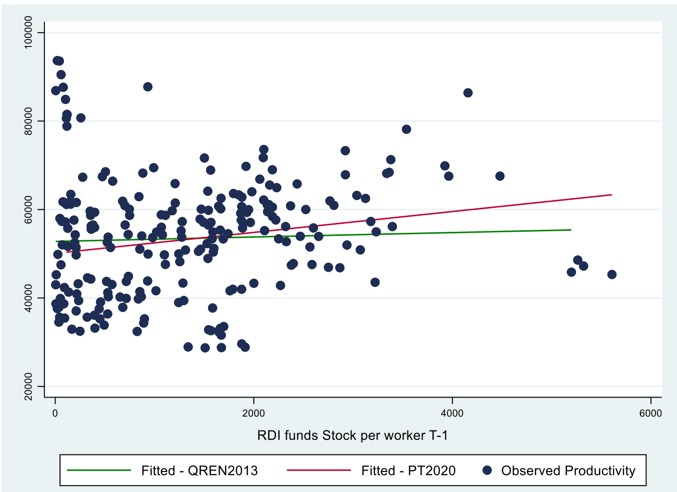
Figure 21 shows the positioning of each region in the productivity-RDI funding relationship and Figure 22 the scatterplot with all the year-regions observations, making a distinction between the defined periods (2008-15 *versus* 2016-18). Both figures illustrate a positive correlation between the productivity level and the stock of RDI funding coming from the previous year. It also seems that the relationship between the two periods under analysis is slightly different with the second one showing a higher leverage effect. However, further work is needed to evaluate if this correlation and differences are driven by other potential factors such as capital stock and human resources. The results of the analysis are displayed in the next sections.

Figure 21. Productivity and RDI funds Stock relationship by NUTS 3 level (2008-2018)



Source: Authors' own elaboration.
Note: Values refer to average between 2008 and 2018.

Figure 22. Productivity and RDI funds Stock relationship, by periods



Source: Authors' own elaboration.

5 Econometric results: effect of RDI subsidies in regional productivity

5.1 Results grouping all RDI subsidies

Table 7 presents the results of both spatial and non-spatial estimations without distinction between programming periods. Column (1) provides the estimation of a pooled OLS, which ignores spatial effects, for comparison purpose with the results of the Spatial Autoregressive Model (column 2) and Spatial Durbin Model (column 3). To assess whether spatial models are required we perform the Moran I test. The results reveal that spatial dependence exists and spatial models should be used. Furthermore, the productivity of neighbouring regions has a statistically significant effect in the productivity of region i using the SAR or SDM, confirming the previous findings.

Table 7. Regional production function, all programming periods (dependent variable: Production per worker)

Variables	OLS (1)	SAR (2)	SDM (3)
RDI subsidy stock per worker in T-1	1.377***	1.440***	1.426***
	(0.492)	(0.456)	(0.447)
Capital stock per worker in T-1	0.0971**	0.0968***	0.108***
	(0.0388)	(0.0360)	(0.0397)
Human capital in T-1	2.773***	2.571***	2.321***
	(0.811)	(0.754)	(0.789)
W*RDI subsidy stock per worker in T-1	-	-	2.879
	-	-	(3.143)
W*Capital stock per worker in T-1	-	-	0.000292
	-	-	(0.345)
W*Human capital in T-1	-	-	-17.14***
	-	-	(6.604)
W*Productivity	-	-0.951***	-1.035***
	-	(0.302)	(0.323)
Time fixed effect and regions NUTS 3 fixed effect	Yes	Yes	Yes
Constant	13,546	3,131***	3,051***
	(8,490)	(158.5)	(155.7)
Observations (23 regions x 10 years)	230	230	230
R-squared (or Pseudo R2)	0.423	0.655	0.341
Moran's test for spatial autocorrelation	1.322*	-	-
Log likelihood (LL)	-	-1,964.3	-1,959.6
Akaike's information criterion (AIC)	4,378.70	3,956.58	3,956.31
Wald test for joint significance	11.90***	176.53***	195.70***
Ramsey test for omitted variables (p-value)	3.34* (0.0690)	0.29 (0.5915)	2.49 (0.1149)
Wald test of spatial terms	-	9.92***	20.22***

Source: Authors' own elaboration.

Note: Standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05, * p<0.1.

Interestingly, results in Table 7 show a negative spatial dependence ([31]), as also demonstrated by **Le Gallo and Ertur** (2003) for Portuguese regions. A negative spatial autocorrelation means that neighbouring regions have opposite or divergent values. Nevertheless, as demonstrated by **Griffith and Arbia** (2010) it doesn't mean that in such cases a positive spatial autocorrelation doesn't exist, it could simply imply that a negative spatial autocorrelation is dominant. As explained by **Kao and Bera** (2016), it can express the persistence of a Myrdal's "backwash effect" (**Myrdal, 1957**) when more competitive regions attract resources from neighbouring regions

([31]) To confirm the presence of a negative spatial dependence we have analysed the direction of the relationship between productivity in region i and the average productivity in the neighbouring regions. The scatterplot and correlation coefficients reported respectively in Figure 23 and Figure 24 in Appendix confirm that a negative relationship exist.

and harmfully affect their growth potential. These authors also explicated that this situation is likely to occur when competition between regions exceeds cooperation.

As regards interpretation of the explanatory variable, all model specifications (Table 7) confirm that the stock of RDI funding per worker in one year is positively associated with higher productivity level in the next period. This conclusion is in line with **Santos et al.** (2019), who using Portuguese firm-level data covering the period 2007 to 2015, demonstrated a positive relationship between the propensity to receive an RDI subsidy and productivity (measured by labour productivity and total factor productivity). However, in the present study by showing that RDI subsidies attributed to specific companies is also able to enhance regional productivity, means that its result is not isolated at firm-level and have the capacity to transform a local impulse to a regional one (from firm-level to regional-level). Furthermore, the positive effect of European Structural funds on regional performance was also highlighted for several studies over recent years - see e.g. the survey of literature of **Dall'Erba and Fang Fang** (2017). Also, in line with scientific literature (e.g. **de la Fuente and Doménech, 2002**; **Brunow and Hirte, 2009**; **Ramos et al., 2010**), both capital stock and human capital display positive and statistically significant coefficients.

The results of SDM in column (3) of Table 7 show a limited statistical significant effect of the spatially lagged independent variables. Only human capital reports a significant negative geographical spillover effect. This negative spillover effect of labour force qualification is in line with the findings of **Brunow and Hirte** (2009) for German regions, **Ramos et al.** (2010) for Spanish regions and **Fischer et al**. (2009) for European regions. An explanation for such negative relationship, provided by **Fischer et al**. (2009), lies on the importance of human capital for productivity level. According to these authors, improving the average qualification of human capital in a region provides it with a relative advantage over its neighboring regions, if all other factors remain consistent. On the other hand, as human capital is a limited resource, regions also compete to attract highly qualified workers (**Ramos et al., 2010**).

To compare the models' performance (SAR *versus* SDM) in explaining regional productivity, we use the results of the test for model specifications (LL, Pseudo-R2 and AIC) in the bottom of Table 7. The higher the LL and Pseudo-R2 levels and the lower the AIC level, the better the data fits the model. The results of AIC and LL indicate that SDM is preferred over SAR, even if differences between the tests on both models are very small. Indeed, the test results differ only by 0.1%-0.2%. However, if we analyse the value of the Pseudo-R2, the SAR model (65.5%) explains the data much better than the SDM (34,1%). Therefore, considering that only small differences exist using AIC and LL, and since the Pseudo-R2 in SAR is almost double that of SDM, we use the SAR model to interpret the size of the effects.

To correctly interpret the size of the effects, it is necessary to calculate the direct and indirect effects associated with changes to the different explanatory variables on regional productivity, using the **LeSage and Pace** (2009) approach. Table 8 reports the estimated direct, indirect, and total effects. The direct effects refer to the effect of a specific explanatory variable in region i on the productivity level in region i. The indirect effect captures the effect of any changes happening in other regions on the productivity level in region i. The total effect is the sum of both direct and indirect effects on the productivity level in region i.

Table 8. Direct, indirect and total effects derived from Table 7

Estimated impacts	SAR		
	dy/dx	Std. Err.	P>z
Direct			
RDI subsidy stock per worker in T-1	1.50	0.476	0.002
Capital Stock per worker in T-1	0.10	0.037	0.007
Human Capital in T-1	2.67	0.780	0.001
Indirect			
RDI subsidy stock per worker in T-1	-0.76	0.285	0.008
Capital Stock per worker in T-1	-0.05	0.021	0.017
Human Capital in T-1	-1.35	0.454	0.003
Total			
RDI subsidy stock per worker in T-1	0.74	0.256	0.004
Capital Stock per worker in T-1	0.05	0.020	0.013
Human Capital in T-1	1.32	0.452	0.004

Source: Authors' own elaboration.

The total effect on regional productivity of RDI subsidy stock, capital stock and human capital is positive and significant. Despite the negative spatial dependence, the size of the positive direct effect is higher than the negative externalities from adjacent regions, generating in the end a net positive effect.

Since our model specification is on a lin-lin form, the estimated coefficients refer to the absolute change, meaning that we have the rate of return of each euro of RDI funds stock per euro change in production. Based on the estimated coefficients in Table 8, we found that an increase of one euro in RDI funds stock per worker increases regional productivity by 0.74 euro.

We also test the sensitivity of our results removing some control variables from the regression estimations (see Table 22 in Appendix). Firstly, since RDI subsidy can indirectly influence productivity through investment, which is included in the amount of capital stock, we re-estimate the regression without capital stock (column 1 in Table 22 - Appendix). Second, we re-estimate our model without the wages per employee (column 2). Results do not lead to any different conclusions, showing evidence that our results are robust and not biased.

5.2 Results by period: proxying S3 effect

The next step in our analysis consists of measuring differences regarding the rate of return of RDI subsidy between programming periods (with and without S3). Analysis performed in section 4.2 provides evidence that subsidised RDI projects have different characteristics in the two periods. Indeed, in line with the S3 principles, more cooperation, partnership, and diversification are observed. Furthermore, we know that the main difference regarding financing instruments to support RDI between the two periods is alignment of project objectives with S3 priorities ([32]). Based on these differences attributed to the implementation of S3, we can expect to proxy the effect of this place-based policy through the difference between the effects of RDI funds in the two programming periods.

Table 9 displays the results of the regional production function including an interaction term to measure the difference regarding RDI subsidy stock between programming periods and using the SAR. The results of SDM are reported in Table 23 (Appendix) for comparison purposes ([33]). The interaction term exhibits a positive and significant effect, meaning that in the period with S3 we have a higher rate of return on RDI subsidy, suggesting that S3 is able to enhance productivity growth.

Table 9. Regional production function, by programming period using SAR (dependent variable: Production per worker)

Variables	SAR	
RDI sub. stock per worker (minus stock P1 in P2) in T-1	1.456**	(0.623)
S3 dummy (2016-2018)	8,717***	(2,674)
Interaction term: S3 * RDI sub stock per worker in T-1	3.339**	(1.583)
Remaining RDI sub. stock per worker from P1 in P2 in T-1	0.852	(0.525)
W*Productivity	-0.899***	(0.301)
Control variables, time fixed effect and regions NUTS 3 fixed effect	Yes	
Constant	Yes	
Observations (23 regions x 10 years)	230	
Pseudo R2	0.682	
Log likelihood (LL)	-1,961.6	
Akaike's information criterion (AIC)	3,955.16	
Wald test for joint significance	186.39***	
Wald test of spatial terms	8.95***	

Source: Authors' own elaboration.
Note: Standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05, * p<0.1. Control variables include stock of capital per worker and human capital. Dummy variable is equal to 1 for the years 2016-2018 and 0 otherwise. Since the first year of RDI subsidies flows in the second period happens in 2015 and we are lagging the independent variable, the first years of S3 effect occurs in 2016.

([32]) For corporate R&D subsidies (supported by SI IDT) alignment is a mandatory condition and for innovation subsidies (SI INOV and SI QUAL) is a criterion in the merit of the project.
([33]) SAR is again our preferred model based on the results of LL, Pseudo-R2 and AIC.

Table 10 displays the estimated direct, indirect and total effects of the SAR. The total net effect is equal to 1.76, implying that an increase of one euro in RDI funds stock per worker in the second period generates additional increases of productivity by 1.76 in comparison with the previous period ([34]).

Table 10. Direct, indirect and total effects derived from Table 9

Estimated effects	SAR		
	dy/dx	Std. Err.	P>z
Direct			
RDI sub. stock per worker (minus stock P1 in P2) in T-1	1.51	0.647	0.020
Remaining RDI sub. stock per worker from P1 in P2 in T-1	0.88	0.545	0.106
Interaction term: S3 * RDI sub stock per worker in T-1	3.45	1.631	0.034
Indirect			
RDI sub. stock per worker (minus stock P1 in P2) in T-1	-0.74	0.362	0.041
Remaining RDI sub. stock per worker from P1 in P2 in T-1	-0.43	0.287	0.132
Interaction term: S3 * RDI sub stock per worker in T-1	-1.70	0.834	0.042
Total			
RDI sub. stock per worker (minus stock P1 in P2) in T-1	0.77	0.340	0.024
Remaining RDI sub. stock per worker from P1 in P2 in T-1	0.45	0.280	0.110
Interaction term: S3 * RDI sub stock per worker in T-1	1.76	0.912	0.054

5.3 Complementary analysis: Results by type of RDI subsidies

Table 11 presents the results of the regional productivity function dividing by typologies of RDI subsidies (R&D subsidies - SI IDT and innovation subsidies - SI INOV + SI QUAL), and their estimated effect in Table 12. Table 13 presents the results by programming period of both types of RDI subsidies. Both tables refer to the SAR results. The SDM results are reported in Table 26 and Table 27 in Appendix.

Table 11. Regional production function, by type of RDI subsidies using SAR (dependent variable: Production per worker)

Variables	SAR	SAR	SAR
	(1)	(2)	(3)
SI IDT Sub. Stock per worker in T-1	2.991	-	2.262
	(2.403)	-	(2.364)
SI INOV + SI QUAL Sub. Stock per worker in T-1	-	1.439***	1.390***
	-	(0.476)	(0.477)
Control variables	Yes	Yes	Yes
W*Productivity	-0.891***	-0.943***	-0.953***
	(0.302)	(0.302)	(0.302)
Time fixed effect and regions NUTS 3 fixed effect	Yes	Yes	Yes
Constant	3,201***	3,138***	3,130***
	(161.6)	(158.8)	(158.4)
Observations (23 regions x 10 years)	230	230	230
R-squared (or Pseudo R2)	0.6728	0.6515	0.6576
Log likelihood (LL)	-1,968.4	-1,964.7	-1,964.2
Akaike's information criterion (AIC)	3,964.7	3,957.4	3,958.5
Wald test for joint significance	160.73***	174.95***	176.80***
Wald test of spatial terms	8.70***	9.76***	9.96***

Source: Authors' own elaboration. Note: Standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05, * p<0.1. Due to multi-collinearity issues between SI INOV and SI QUAL the stock of both are aggregated.

([34]) Table 24 in appendix reports the results of the model specification with non-factorial interactions (#), to show the size of the rate of return of both programming periods (Table 25).

Table 12. Direct, indirect and total effects derived from **Table 11**

Estimated effects	SAR		
	dy/dx	Std. Err.	P>z
Direct			
SI IDT Sub. Stock per worker in T-1	2.348	2.456	0.339
SI INOV + SI QUAL Sub. Stock per worker in T-1	1.443	0.497	0.004
Indirect			
SI IDT Sub. Stock per worker in T-1	-1.190	1.269	0.349
SI INOV + SI QUAL Sub. Stock per worker in T-1	-0.731	0.292	0.012
Total			
SI IDT Sub. Stock per worker in T-1	1.158	1.220	0.342
SI INOV + SI QUAL Sub. Stock per worker in T-1	0.712	0.264	0.007

Table 13. Regional production function, by type of RDI subsidies and programming period using SAR (dependent variable: Production per worker)

Variables	SAR (1)	SAR (2)
SI IDT sub. stock per worker (minus stock P1 in P2) in T-1	1.810	-
	(2.731)	-
S3 dummy (2016-2018)	9,874***	9,328***
	(2,537)	(2,692)
Interaction term: S3 * SI IDT sub stock per worker in T-1	27.93	-
	(17.69)	-
Remaining SI IDT sub. stock per worker from P1 in P2 in T-1	0.383	-
	(3.103)	-
SI INOV + SI QUAL Sub. Stock per worker in T-1	1.269***	-
	(0.481)	-
Control variables	Yes	Yes
	-	-
SI IDT Sub. Stock per worker in T-1	-	2.240
	-	(2.471)
SI INNOV_QUAL sub. stock per worker (minus stock P1 in P2) in T-1	-	-2.42e-06
	-	(5.00e-06)
Interaction term: S3 * SI INNOV_QUAL sub stock per worker in T-1	-	4.613***
	-	(1.654)
Remaining SI INNOV_QUAL sub. stock per worker from P1 in P2 in T-1	-	0.203
	-	(0.476)
W*Productivity	-0.922***	-0.838***
	(0.301)	(0.299)
Time fixed effect and regions NUTS 3 fixed effect	Yes	Yes
Constant	3,114***	3,138***
	(157.4)	(158.0)
Observations (23 regions x 10 years)	230	230
R-squared (or Pseudo R2)	0.666	0.690
Log likelihood (LL)	-1,963.0	-1,963.9
Akaike's information criterion (AIC)	3,959.9	3,959.8
Wald test for joint significance	181.26***	176.91***
Wald test of spatial terms	9.38***	7.86***

Source: Authors' own elaboration.

Note: Standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05, * p<0.1.

Results in column (1) and (3) in Table 11 reveal that the R&D subsidy (SI IDT) has no significant effect in regional productivity, whereas the innovation subsidy (SI INOV + SI QUAL) has a significant positive effect. However, this does not mean that at firm-level R&D subsidies have no effect on the productivity of subsidised firms. Results only demonstrate that at an aggregate level, if any direct effect exists, it is not sufficiently strong to have a dragging effect upstream and downstream of the production cycle, while corporate innovation subsidies,

targeted to support the last phase of the innovation process seems to have this capacity. This could suggest a certain degree of complementarity between financing instruments. Indeed, when the analysis is performed combining the sum of the three financing instruments, they reveal to have a significant and positive influence on productivity, whereas when the analysis is performed dividing them, only the innovation subsidy has a positive effect and its total net effect is smaller (Table 12). As each instrument was designed to support different phases of the innovation process, this finding reveals the importance of the funding scheme as a whole to achieve a higher level of competitiveness.

6 Conclusion and policy recommendations

One of the main challenges to evaluate S3 lies in its all-encompassing nature. It requires an integrated policy mix grounded in a bottom-up governance model of entrepreneurial discovery, and as such it is difficult to establish a cause-effect relationship that can be directly quantified. Another reason is that since S3 implementation is recent, the existence of harmonised data between regions on S3 implementation is not available, and as such, we need to use proxy variables.

Notwithstanding the limitations, this study nevertheless is one of the first to assess the effect of an S3 implementing instrument on productivity, one of the economic indicators that the approach was originally designed to improve. The database covers the years 2008-2018, including two programming periods, 2007-2013 and 2014-2020. In the period 2014-2020, S3 is an *ex-ante* conditionality that Member States need to meet to spend the ESIF on innovation. In Portugal, the eligibility criteria of the main funding instrument to support corporate R&D (SI IDT) created for the programming period 2007-2013 was adapted to S3, making alignment with S3 priorities an eligibility criterion. For the corporate innovation subsidy (SI INOV and SI QUAL) alignment with S3 priorities is a criterion for the evaluation of project merit, but we know that almost all the projects are in fact also aligned ([35]). Furthermore, analysis of the main characteristics of supported RDI projects, and comparing both programming periods, also reveals that in the programming period 2014-2020:

- RDI funds are less concentrated in some regions;
- Larger amounts of funding were dedicated to partnership projects and inter-regional collaboration; and
- Lower concentration of funds in the same beneficiary and economic activities are observed

Therefore, as the financing instrument to support corporate RDI are the same between the periods, differences regarding their effect on regional productivity could be used as a proxy to measure the added-value of S3 on competitiveness.

Using spatial econometrics analysis with fixed effects, the results show that RDI has a positive effect on regional productivity and that the rate of return in the programming period with S3 is higher than in the previous one (without S3). Furthermore, a certain degree of dependence between funding instruments was found: corporate R&D subsidy alone appears not to generate any significant effect at the regional level, but when combined with the innovation subsidy, the overall net effect is higher than the individual effect.

The R&D financing instrument under analysis (SI IDT) aims to support applied R&D and experimental development, whereas the other innovation financing instruments (SI INOV and QUAL) are more market-oriented (Figure 4) and targeted to technology and knowledge transfer (Table 17 - Appendix). Different R&I financing instruments were designed to financially support the different phases of the innovation process. However, this doesn't mean that the same entity needs to use them together. Regional actors have different needs, depending on their size, capabilities, and technology level. From previous studies (see e.g. **Potters, 2009**), we know that low-tech industries prefer to acquire technology (or knowledge) developed by high-tech industries (or in partnership with research centres). In such cases, R&D subsidies can be used by high-tech industries or Knowledge Intensive Services to develop a new product or service, and then be transferred to low-tech industries, through acquisition and thanks to innovation subsidies. Indeed, according to **Almudi et al.** (2020), to ensure the full potential of innovation policy, a multi-sectoral approach should be applied to address issues of knowledge coordination, related to knowledge absorption. By showing some synergies between funding instruments and on the basis of innovation patterns observed by sectors, the results of this study support this argument.

Altogether the findings of the present study suggest that the benefit of smart specialisation in Portugal could be improved, if better synergies between funding instruments can be achieved. Indeed, although alignment with S3 priorities is a pre-condition for projects funded by SI IDT, in the 2014-2020 funding programme, this is not the case for SI INOV and SI QUAL (alignment with S3 is only considered in scoring the project). Since the coincidence of these instruments were not designed purposefully, our results suggest that if they were to be combined strategically in the next programming period, as part of a coherent smart specialisation policy mix, the benefits could be substantial.

This report is a first attempt to analyse the relationship between investments in RDI and productivity in the context of S3. There is however much scope for further research, such as by comparing the impact between

([35]) For instance, based on a recent monitoring report of the Portuguese Centro region (**CCDR, 2020**) about 92% of the applications to SI INOV and around 80% of SI QUAL were also aligned with S3 priorities.

regions within Portugal as well as with other European countries that have deployed a similar instrument under different local conditions. Furthermore, combining territorial and firm level analyses could shed light on what type of sectors most benefit from this type of support instrument, which could be explained through more qualitative case studies.

References

Almudi, I.; Fatas-Villafranca, F.; Fernández-Márquez, C.M.; Potts, J.; Vazquez, F.J. (2020). “Absorptive capacity in a two-sector neo-Schumpeterian model: a new role for innovation policy”, *Industrial and Corporate Change*, 29(2):507–531. doi: 10.1093/icc/dtz052

ANI (2019). “Portuguese R&D Funding programmes & Synergies – Action Lines managed by ANI”, Workshop “Research and Innovation Public Private Partnerships for RIS3 Implementation – Approaches for widening stakeholder engagement and networking”, Porto, 4 November 2019. Available in https://s3platform.jrc.ec.europa.eu/documents/20182/373793/WSHOP_PPP_RIS3_SynergiesProgramming_ANI_Miguel+Antunes.pdf/96a3a5ec-2d78-42d8-bcb6-e8f74ecd9c57 (Accessed on 31 January 2020)

Balland, P.A.; Boschma, R.; Crespo, J. and Rigby, D.L. (2019) “Smart specialization policy in the European Union: relatedness, knowledge complexity and regional diversification, Regional Studies, 53:9, 1252-1268, DOI: 10.1080/00343404.2018.1437900

Barbero, J., Diukanova, O., Gianelle, C., Salotti, S., and Santoalha, A. (2020). Economic modelling to evaluate Smart Specialisation: An analysis on research and innovation targets in Southern Europe. JRC Working Papers on Territorial Modelling and Analysis No. 01/2020, European Commission, Seville, JRC120397.

Baum, C.F. (2006). An introduction to Modern Econometrics Using Stata, Stata Press, Massachusetts.

Bellemare, M.F. ; Masaki, T. and Pepinsky, T.B. (2017). “Lagged Explanatory Variables and the Estimation of Causal Effects”, Journal of Politics, 79(3): 949-963.

Boschma, R. (2014). Constructing Regional Advantage and Smart Specialization: Comparison of Two European Policy Concepts. In Papers in Evolutionary Economic Geography # 13.22. Utrecht University. http://econ.geo.uu.nl/peeg/peeg1322.pdf

Brunow, S. and Hirte, G. (2007). “The age pattern of human capital and regional productivity: A spatial econometric study on german regions”, Papers in Regional Science, 88(4):799-824.

CCDR (2020). Preparatory work for the webinars on "Assessment of Smart Specialisation Strategies implementation and impact". Available at: https://s3platform.jrc.ec.europa.eu/documents/20182/173082/CENTRO_PT_Assessment+of+S3+implementation+and+Impact_sept_2020.pdf/41e8ab7f-13c6-46ff-a965-eb405c1f9f69 (Accessed on 9 February 2021)

Crescenzi, R.; de Blasio, G.; Giua, M. (2020). “Cohesion Policy incentives for collaborative industrial research: evaluation of a Smart Specialisation forerunner programme”, Regional Studies, 54:10, 1341-1353, DOI: 10.1080/00343404.2018.1502422

Dall'Erba, S. and Fang, F. (2017). “Meta-analysis of the impact of European Union Structural Funds on regional growth”, *Regional Studies*, 51(6): 822-832, DOI: 10.1080/00343404.2015.1100285

de la Fuente A and Doménech R. (2002). “Human capital in growth regressions: How much difference does data quality make? An update and further results”, CEPR Discussion Paper 3587

de la Fuente, A.; Doménech, F.; Jimeno, J.F. (2003). Human capital as a factor of growth and employment at the regional level: The case of Spain. Report for the European Commission

Dumitrescu, E.-I. and Hurlin, C. (2012). Testing for Granger non-causality in heterogeneous panels. *Economic Modelling*, 29(4):1450-1460.

European Commission (2012). *Guide to Research and Innovation Strategies for Smart Specialisation*, Luxembourg: Publications Office of the European Union.

Fischer, M.M.; Bartkowska, M.; Riedl, A.; Sardadvar, A. and Kunnert, A. (2009) The impact of human capital on regional labour productivity in Europe. Letters in Spatial and Resource Sciences 2: 97–108

Foray, D. (2013). “The economic fundamentals of smart specialisation”, *Ekonomiaz*, 83(2):54-78.

Foray, D.; David, P.A. and Hall, B. (2009). “Smart Specialisation – The concept”, Knowledge Economists Policy Brief n° 9. Available at: http://ec.europa.eu/invest-in-research/pdf/download_en/kfg_policy_brief_no9.pdf?11111 [Accessed on June 24, 2019].

Gianelle, C, Guzzo F and Mieszkowski, K (2019). “Smart Specialisation: what gets lost in translation from concept to practice?”, *Regional Studies* 49(8). DOI: 10.1080/00343404.2019.1607970

Griffith, D.A. and Arbia, G. (2010). “Detecting negative spatial autocorrelation in georeferenced random variables”, International Journal of Geographical Information Science, 24(3): 417-437.

Guellec, D. and B. van Pottelsberghe de la Potterie (2000). “The Impact of Public R&D Expenditure on Business R&D”, *OECD Science, Technology and Industry Working Papers*, 2000/04, OECD Publishing. http://dx.doi.org/10.1787/670385851815

Hall, B. H. and Mairesse, J. (1995). “Exploring the relationship between R&D and productivity in French manufacturing firms”, Journal of Econometrics, 65(1), pp. 263 – 293. https://doi.org/10.1016/0304-4076(94)01604-X

Kao, S. Y.H and Bera, A.K. (2016). “Spatial Regression: The Curious Case of Negative Spatial Dependence”. . University of Illinois, Urbana-Champaign.

Kaulich, F. (2012). “Diversification vs. specialization as alternative strategies for economic development/ Can we settle a debate by looking at the empirical evidence?”, *Development Policy, Statistics and Research Branch Working Paper* 3/2012, United Nations Industrial Development Organization, Vienna.

Laranja, M., Edwards, J., Pinto, H. and Foray, D., *Implementation of Smart Specialisation Strategies in Portugal: An assessment*, EUR 30287 EN, Publications Office of the European Union, Luxembourg, 2020,ISBN 978-92-76-20400-8, doi:10.2760/363370, JRC121189

Le Gallo, J. and Ertur, C. (2003). “Exploratory spatial data analysis of the distribution of regional per capita GDP in Europe, 1980−1995”, Papers in Regional Sciences, 82: 175–201. https://doi.org/10.1007/s101100300145

LeSage, J.P. and Pace, R.K. (2009). Introduction to Spatial Econometrics. CRC Press, Boca Raton.

Lopez, L. and Weber, S. (2017). “Testing for Granger causality in panel data”, IRENE Working paper 17-03.

McCann, P and Ortega-Argilés, R (2015). “Smart Specialization, Regional Growth and Applications to European Union Cohesion Policy”, *Regional Studies*, 49:8, 1291-1302

Myrdal, G. (1957). Economic theory of underdeveloped regions, London: Gerard Dicksworth

Neto, P. and Santos, A. (2020). “Guidelines for Territorial Impact Assessment Applied to Regional Research and Innovation Strategies for Smart Specialisation”. In: Medeiros E. (eds) *Territorial Impact Assessment*. Advances in Spatial Science (The Regional Science Series). Springer, Cham. https://doi.org/10.1007/978-3-030-54502-4_12

OECD (2005). *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data, The Measurement of Scientific and Technological Activities*, 3rd edition,. OECD Publishing, Paris. doi: http://dx.doi.org/10.1787/9789264013100-en.

Potters, L. (2009). “R&D in Low-Tech sectors”, *IPTS Working Paper on Corporate R&D and Innovation* No. 08/2009, JRC Technical Notes, European Commission.

Ramos, R.; Suriñach, J.; Artís, M. (2010). “Human capital spillovers, productivity and regional convergence in Spain”, Papers in Regional Science, 89(2):435-448.

Santoalha, A. (2019a). “New indicators of related diversification applied to smart specialization in European regions”, Spatial Economic Analysis, 14:4, 404-424, DOI: 10.1080/17421772.2019.1584328

Santoalha, A. (2019b). “Technological diversification and Smart Specialisation: the role of cooperation”, Regional Studies, 53:9, 1269-1283, DOI: 10.1080/00343404.2018.1530753

Santos, A. (2019). “Do selected firms show higher performance? The case of Portugal’s innovation subsidy”, *Structural Change and Economic Dynamics*, 50:39-50.

Santos, A.; Cincera, M.; Neto, P. and Serrano, M. M. (2018). “Competition effect on innovation and productivity - The Portuguese case”, *Public Policy Portuguese Journal* 3(2): 52-84.

Santos, A.; Cincera, M.; Neto, P.; Serrano, M.M. (2019). “Which projects are selected for an innovation subsidy? The Portuguese Case”, *Portuguese Economic Journal*, 18(3): 165-202. https://doi.org/10.1007/s10258-019-00159-y

Varga, A.; Sebestyén, T.; Szabó, N.; Szerb, L. (2020). “Estimating the economic impacts of knowledge network and entrepreneurship development in smart specialization policy”, Regional Studies, 54:1, 48-59, DOI: 10.1080/00343404.2018.1527026

Appendix

Table 14. Economic priority domains of RIS3 in Portugal, by regions

ECONOMIC DOMAINS		Portugal	Norte	Centro	Lisboa	Alentejo	Algarve
A	**Agriculture, forestry and fishing**						
1	Crop and animal production, hunting and related service activities	X	X	X		X	X
2	Forestry and logging	X		X		X	X
3	Fishing and aquaculture	X	X	X		X	X
B	**Mining and quarrying**						
7	Mining of metal ores	X				X	
8	Other mining and quarrying	X				X	
9	Mining support service activities					X	
C	**Manufacturing**						
10	Manufacture of food products			X		X	X
13	Manufacture of textiles	X			X		
16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials			X			
17	Manufacture of paper and paper products	X					
20	Manufacture of chemicals and chemical products	X			X		
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations				X		
23	Manufacture of other non-metallic mineral products			X			
25	Manufacture of fabricated metal products, except machinery and equipment			X			
28	Manufacture of machinery and equipment n.e.c.						X
29	Manufacture of motor vehicles, trailers and semi-trailers	X	X		X		
30	Manufacture of other transport equipment	X	X		X		
32	Other manufacturing		X	X			
D	**Electricity, gas, steam and air conditioning supply**						
35	Electricity, gas, steam and air conditioning supply	X				X	X
E	**Water supply; sewerage, waste management and remediation activities**						
36	Water collection, treatment and supply	X				X	
37	Sewerage	X				X	
38	Waste collection, treatment and disposal activities; materials recovery	X				X	
39	Remediation activities and other waste management services	X				X	
F	**Construction**						
41	Construction of buildings						X
42	Civil engineering				X		
43	Specialised construction activities	X			X		X
H	**Transportation and storage**						
49	Land transport and transport via pipelines	X				X	
50	Water transport	X		X		X	X
51	Air transport	X					
52	Warehousing and support activities for transportation	X					
53	Postal and courier activities	X					
I	**Accommodation and food services activities**						
55	Accommodation	X	X	X	X		X
56	Food and beverage service activities	X	X	X	X		X
J	**Information and communication**						
58	Publishing activities						X
59	Motion picture, video and television programme production, sound recording and music publishing activities						X
60	Programming and broadcasting activities						X
61	Telecommunications	X	X	X			X
62	Computer programming, consultancy and related activities	X		X		X	X
63	Information service activities	X	X	X		X	X
L	**Real estate activities**						
68	Real estate activities				X		X

Continued in the next page…

Table 14. Economic priority domains of RIS3 in Portugal, by regions (continuation)

ECONOMIC DOMAINS		Portugal	Norte	Centro	Lisboa	Alentejo	Algarve
M	**Professional, scientific and technical activities**						
70	Activities of head offices; management consultancy activities						X
72	Scientific research and development		X		X		X
74	Other professional, scientific and technical activities		X		X		
N	**Administrative and support service activities**						
77	Rental and leasing activities		X		X		X
78	Employment activities				X		X
79	Travel agency, tour operator reservation service and related activities		X		X		X
80	Security and investigation activities				X		X
81	Services to buildings and landscape activities		X		X		X
82	Office administrative, office support and other business support activities		X		X		X
Q	**Human health and social work activities**						
86	Education	X	X	X	X	X	X
87	Residential care activities			X		X	X
88	Social work activities without accommodation					X	X
R	**Arts, entertainment and recreation**						
90	Creative, arts and entertainment activities	X	X		X	X	X
91	Libraries, archives, museums and other cultural activities				X	X	
93	Sports activities and amusement and recreation activities			X	X	X	X

Source: Author's own elaboration based on Eye@RIS3 tool of the European Commission's S3 Platform.

Table 15. Descriptive statistics

Variables	Obs	Mean	Std. Dev.	Min	Max
Productivity	230	53,852	13,429	28,729	93,669
RDI subsidy Stock per employee in T-1	230	1,349	1,129	5.0	5,607
Capital Stock per employee in T-1	230	65,010	30,141	23,157	157,872
Human Capital in T-1	230	10,892	2,404	5,403	18,805

Source: Authors' own elaboration.
Note: The number of observations is equal to 225.

Table 16. Correlation matrix

			Correlation Matrix		
#	Variables	VIF	1	2	3
1	Subsidy Stock per employee in T-1	1.02	1		
2	Capital Stock per employee in T-1	1.02	0.125	1	
3	Human Capital in T-1	1.01	-0.091	-0.047	1
	Mean VIF	1.02			

Source: Authors' own elaboration.
Note: The number of observations is equal to 225.

Table 17. Eligible expenditures by R&I funding instrument under PT 2020

R&I funding instrument	Eligible expenditures
SI IDT Incentive System for Technological Research and Development	• Tangible assets/expenditures: - Scientific and technical equipment - Raw materials, consumables and others for experiments and prototypes - Adaptation of buildings and facilities (under some restrictions) • Intangible assets/expenditures: - Cost with own R&D personnel - Acquisition of patents from or by external sources - Software - Specialised services - Project dissemination - Costs with certification process - Training of employees (under some restrictions)
SI INOV Incentive System for Business Innovation and Entrepreneurship	• Tangible assets: - Machinery and equipment - Construction of buildings and remodelling works (only for tourism and manufacturing) - Rolling stock (only for tourism) • Intangible assets: - Technology and knowledge transfer - Software - Specialised services (e.g. accounting, architectural, engineering or consultancy services) - Training of employees - Up to two-years wage costs of hiring a new highly qualified worker
SI QUAL Incentive System for Qualification and Internationalization of SMEs	• Tangible assets: - Equipment • Intangible assets: - Software - Specialised services (e.g. accounting, architectural, engineering or consultancy services) - Costs of patent registration and other IPR protection - Costs of participating in fairs and exhibitions abroad - Up to two-years wage costs of hiring a new highly qualified worker - Training of employees

Source: Author's own elaboration based on "Portaria n.º 57-A/2015 de 27 de fevereiro".

Table 18. SI IDT funds by economic sectors and framework programme

NACE 2 digits	Sector group	QREN 2007-2013		PT2020	
		Eur	% Total	Eur	% Total
1	Others	34,875	0.01%	199,854	0.13%
2	Others	49,000	0.02%	14,625	0.01%
7	Others	25,000	0.01%	0	0.00%
8	Others	38,250	0.01%	411,471	0.27%
10	Low tech	6,543,980	2.39%	1,985,754	1.32%
11	Low tech	1,169,887	0.43%	250,282	0.17%
13	Low tech	1,013,723	0.37%	1,214,033	0.81%
14	Low tech	1,883,600	0.69%	620,666	0.41%
15	Low tech	1,965,835	0.72%	201,045	0.13%
16	Low tech	1,624,356	0.59%	362,302	0.24%
17	Low tech	74,325	0.03%	125,849	0.08%
18	Low tech	200,453	0.07%	105,807	0.07%
20	Medium-High tech	7,844,815	2.87%	7,987,400	5.32%
21	High tech	5,733,546	2.10%	668,800	0.45%
22	Medium-Low tech	1,664,042	0.61%	1,676,836	1.12%
23	Medium-Low tech	1,958,959	0.72%	2,136,523	1.42%
24	Medium-Low tech	114,030	0.04%	43,514	0.03%
25	Medium-Low tech	5,658,673	2.07%	4,383,510	2.92%
26	High tech	9,999,871	3.66%	3,511,098	2.34%
27	Medium-High tech	5,080,130	1.86%	1,435,499	0.96%
28	Medium-High tech	8,607,278	3.15%	2,692,662	1.79%
29	Medium-High tech	1,421,709	0.52%	749,696	0.50%
30	Medium-High tech	2,646,682	0.97%	4,420,583	2.94%
31	Low tech	1,053,443	0.39%	770,285	0.51%
32	Low tech	1,445,008	0.53%	2,933,394	1.95%
33	Medium-Low tech	2,307,822	0.84%	1,069,716	0.71%
35	Others	1,449,335	0.53%	0	0.00%
37	Others	0	0.00%	201,699	0.13%
38	Others	2,757,753	1.01%	345,701	0.23%
41	Others	434,392	0.16%	574,430	0.38%
42	Others	419,489	0.15%	276,099	0.18%
43	Others	1,881,706	0.69%	373,332	0.25%
45	Others	18,750	0.01%	44,625	0.03%
46	Others	3,407,514	1.25%	4,631,032	3.08%
47	Others	1,236,577	0.45%	1,143,511	0.76%
49	Others	24,319	0.01%	14,625	0.01%
52	Others	16,950	0.01%	65,462	0.04%
55	Others	0	0.00%	14,406	0.01%
56	Others	24,750	0.01%	134,630	0.09%
58	KIS	5,628,433	2.06%	2,354,056	1.57%
59	KIS	1,807,890	0.66%	227,072	0.15%
61	KIS	0	0.00%	155,309	0.10%

Continued in the next page...

Table 18. SI IDT funds by economic sectors and framework programme (continuation)

NACE 2 digits	Sector group	QREN 2007-2013		PT2020	
		Eur	% Total	Eur	% Total
62	KIS	91,028,191	33.28%	41,492,568	27.63%
63	KIS	3,462,987	1.27%	1,106,016	0.74%
70	KIS	3,685,074	1.35%	1,854,717	1.24%
71	KIS	32,642,846	11.93%	20,972,957	13.97%
72	KIS	45,085,698	16.48%	24,009,126	15.99%
73	KIS	1,028,348	0.38%	223,173	0.15%
74	KIS	5,205,141	1.90%	2,822,808	1.88%
75	KIS	0	0.00%	81,770	0.05%
79	Others	102,124	0.04%	0	0.00%
80	KIS	1,353,243	0.49%	331,511	0.22%
82	Others	546,610	0.20%	30,000	0.02%
84	KIS	0	0.00%	271,401	0.18%
85	KIS	0	0.00%	5,499,600	3.66%
86	KIS	24,750	0.01%	531,032	0.35%
91	KIS	48,188	0.02%	15,000	0.01%
94	Others	0	0.00%	179,047	0.12%
95	Others	49,740	0.02%	218,262	0.15%
	TOTAL	273,530,091	100.00%	150,166,179	100.00%

Source: Authors' own elaboration based on data from ANI, CCDRs[36], COMPETE[37] and PORTUGAL2020 websites and Eye@RIS3 tool.

Note: Except for Algarve, values only refer to funding managed under the Regional Operational Programme since it is only for that ones we have information about the NACE code of the project (sometimes different of the NACE code of the beneficiary).

(36) CCDR-Norte: https://www.norte2020.pt/; CCDR-Centro: http://centro.portugal2020.pt/; CCDR-Alentejo: https://www.ccdr-a.gov.pt/; CCDR-Lisboa: http://www.ccdr-lvt.pt/pt/; CCDR-Algarve: https://www.ccdr-alg.pt (CCDR – Algarve) - data extracted on 19/12/2019.

(37) http://pofc.qren.pt/ - data extracted on 2/10/2019.

Table 19. SI INOV and SI QUAL funds by economic sectors and framework programme

CAE 2 digits	Sector group	QREN 2007-2013		PT2020	
		Eur	% Total	Eur	% Total
1	Others	99,854	0.00%	9,199,145	0.48%
2	Others	1,077,929	0.05%	936,620	0.05%
8	Others	24,983,701	1.10%	20,183,120	1.05%
9	Others	26,250	0.00%	14,344	0.00%
10	Low tech	92,403,414	4.09%	55,715,809	2.89%
11	Low tech	36,063,017	1.59%	35,287,887	1.83%
13	Low tech	59,668,854	2.64%	81,420,330	4.22%
14	Low tech	57,740,868	2.55%	64,048,138	3.32%
15	Low tech	75,632,920	3.34%	37,887,764	1.96%
16	Low tech	87,305,211	3.86%	41,444,482	2.15%
17	Low tech	11,935,680	0.53%	17,271,926	0.89%
18	Low tech	28,717,803	1.27%	27,783,644	1.44%
19	Medium-Low tech	13,420,800	0.59%	688,465	0.04%
20	Medium-High tech	76,368,219	3.38%	39,809,337	2.06%
21	High tech	6,920,086	0.31%	15,352,996	0.80%
22	Medium-Low tech	76,396,569	3.38%	90,569,863	4.69%
23	Medium-Low tech	103,237,671	4.57%	82,990,331	4.30%
24	Medium-Low tech	19,681,778	0.87%	16,358,082	0.85%
25	Medium-Low tech	146,577,114	6.48%	254,881,518	13.21%
26	High tech	11,501,861	0.51%	26,755,130	1.39%
27	Medium-High tech	40,582,897	1.79%	28,121,176	1.46%
28	Medium-High tech	71,877,123	3.18%	91,513,081	4.74%
29	Medium-High tech	33,812,324	1.50%	23,051,653	1.19%
30	Medium-High tech	14,815,518	0.66%	18,527,547	0.96%
31	Low tech	93,842,139	4.15%	101,973,323	5.28%
32	Low tech	24,283,215	1.07%	24,642,653	1.28%
33	Medium-Low tech	3,751,896	0.17%	7,148,190	0.37%
35	Others	1,561,990	0.07%	123,795	0.01%
37	Others	899,350	0.04%	58,111	0.00%
38	Others	53,531,474	2.37%	13,922,479	0.72%
41	Others	13,175,094	0.58%	7,731,354	0.40%
42	Others	5,399,286	0.24%	5,019,939	0.26%
43	Others	12,882,928	0.57%	11,722,953	0.61%
45	Others	7,144,044	0.32%	2,627,318	0.14%
46	Others	159,183,246	7.04%	97,686,717	5.06%
47	Others	43,469,028	1.92%	36,454,688	1.89%
49	Others	9,037,153	0.40%	4,229,599	0.22%
50	KIS	0	0.00%	771,763	0.04%
51	KIS	0	0.00%	385,005	0.02%
52	Others	5,020,335	0.22%	9,361,341	0.49%

Continued in the next page...

Table 19. SI INOV and SI QUAL funds by economic sectors and framework programme (continuation)

CAE 2 digits	Sector group	QREN 2007-2013		PT2020	
		Eur	% Total	Eur	% Total
53	Others	0	0.00%	118,777	0.01%
55	Others	355,045,736	15.70%	118,184,810	6.12%
56	Others	15,804,650	0.70%	10,328,920	0.54%
58	KIS	12,362,749	0.55%	5,699,335	0.30%
59	KIS	9,639,785	0.43%	2,415,437	0.13%
60	Others	320,599	0.01%	240,768	0.01%
61	KIS	0	0.00%	483,896	0.03%
62	KIS	98,196,696	4.34%	61,418,009	3.18%
63	KIS	15,720,817	0.70%	6,956,709	0.36%
64	KIS	165,299	0.01%	0	0.00%
68	Others	0	0.00%	6,482,863	0.34%
69	KIS	4,355,966	0.19%	4,106,391	0.21%
70	KIS	19,448,920	0.86%	16,160,446	0.84%
71	KIS	59,392,371	2.63%	29,466,903	1.53%
72	KIS	11,970,796	0.53%	11,020,474	0.57%
73	KIS	17,188,383	0.76%	5,268,203	0.27%
74	KIS	16,702,539	0.74%	17,931,573	0.93%
75	KIS	0	0.00%	312,422	0.02%
77	Others	6,139,209	0.27%	2,590,505	0.13%
78	KIS	364,430	0.02%	802,719	0.04%
79	Others	9,055,674	0.40%	11,800,910	0.61%
80	KIS	435,099	0.02%	284,865	0.01%
81	Others	2,108,901	0.09%	451,030	0.02%
82	Others	11,308,169	0.50%	11,023,408	0.57%
85	KIS	5,623,095	0.25%	4,748,446	0.25%
86	KIS	115,901	0.01%	4,913,365	0.25%
87	KIS	0	0.00%	250,189	0.01%
88	KIS	0	0.00%	373,374	0.02%
90	KIS	2,442,084	0.11%	1,280,134	0.07%
91	KIS	168,203	0.01%	5,495,389	0.28%
93	KIS	60,659,772	2.68%	15,276,748	0.79%
94	Others	41,632	0.00%	169,567,587	8.79%
95	Others	709,431	0.03%	108,428	0.01%
96	Others	1,746,603	0.08%	719,801	0.04%
	TOTAL	2,261,262,148	100.00%	1,929,954,452	100.00%

Source: Authors' own elaboration based on data from ANI, CCDRs[38], COMPETE[39] and PORTUGAL2020 websites and Eye@RIS3 tool.

Note: Except for Algarve, values only refer to funding managed under the Regional Operational Programme since it is only for that ones we have information about the NACE code of the project (sometimes different of the NACE code of the beneficiary).

(38) CCDR-Norte: https://www.norte2020.pt/; CCDR-Centro: http://centro.portugal2020.pt/; CCDR-Alentejo: https://www.ccdr-a.gov.pt/; CCDR-Lisboa: http://www.ccdr-lvt.pt/pt/; CCDR-Algarve: https://www.ccdr-alg.pt (CCDR – Algarve) - data extracted on 19/12/2019.

(39) http://pofc.qren.pt/ - data extracted on 2/10/2019.

Table 20. Granger causality test results

Hypothesis	p-value
H0: RDI Subsidy Stock per worker in T does not Granger-cause Productivity	0.140
H0: Productivity does not Granger-cause RDI Subsidy Stock per worker in T	0.480
H0: RDI Subsidy Stock per worker in T-1 does not Granger-cause Productivity	0.040
H0: Productivity does not Granger-cause RDI Subsidy Stock per worker in T-1	0.740

Source: Authors' own elaboration.

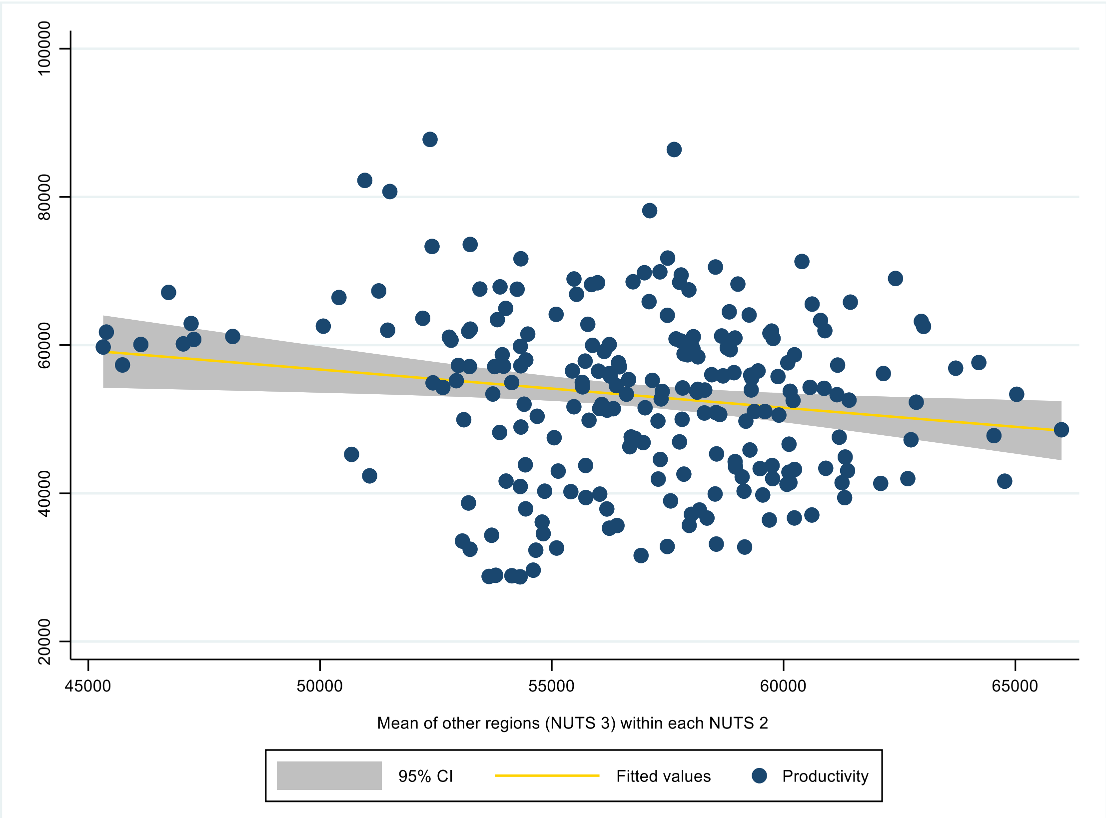
Note: Results of **Dumitrescu and Hurlin** (2012) Granger non-causality test results using the **Lopez and Weber** (2017) Stata user-written command and using boostrapping procedure with 100 replications.

Table 21. Regional production function (subsample), Pooled OLS regression and 2-step GMM (dependent variable: Production per worker)

Variables	OLS	IV (2SLS)	Z-test Diff. Coefficients	
	(1)	(2)	|Z|	p-value
Lag independent variable	**Yes**	**No**		
Subsidy Stock per worker	0.929*	1.056*	0.162	0.871
	(0.544)	(0.561)		
Capital Stock per worker	0.0851**	0.0768**	0.146	0.884
	(0.0429)	(0.0374)		
Human Capital	2.629***	3.718***	0.847	0.398
	(0.862)	(0.954)		
Year dummy	Yes	Yes		
Region fixed effect	Yes	Yes		
Constant	28,270***	15,042		
	(8,393)	(9,830)		
Observations	207	207		
R-squared	0.948	0.959		
Wald test for joint significance (p-value)	0.000	0.000		
Underidentification test (p-value)	-	0.000		
Sargan statistic (p-value)	-	0.174		

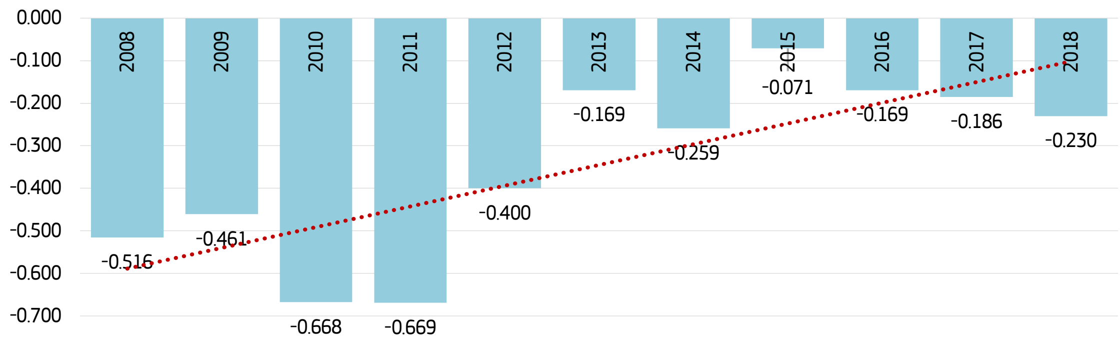
Source: Authors' own elaboration.
Note: Standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05, * p<0.1. In column (2) all the explanatory variables are considered endogenous. Excluded instrumental variables used are the first-order lag of the RDI subsidy stock per worker, first and second-order lag of capital stock per worker and the first-order lag of human capital.

Figure 23. Scatterplot productivity in region i and the mean of regional productivity in other regions NUTS 3 within each NUTS 2, 2008-2018



Source: Author's own elaboration.

Figure 24. Correlation coefficients between productivity in region i and the mean of regional productivity in other regions NUTS 3 within each NUTS 2, by year



Source: Author's own elaboration.

Table 22. Sensitivity analysis, Results SAR model: (dependent variable: Production per worker)

Variables	SAR (1)	SAR (2)	SAR (3)
Subsidy Stock per employee in T-1	1.569***	1.845***	-
	(0.462)	(0.452)	-
Capital Stock per employee in T-1	-	0.136***	0.109***
	-	(0.0350)	(0.0367)
Human Capital in T-1	3.219***	-	3.199***
	(0.728)	-	(0.747)
W*Productivity	-0.927***	-0.995***	-0.875***
	(0.303)	(0.306)	(0.302)
Time fixed effect	Yes	Yes	Yes
Regions NUTS 3 fixed effect	Yes	Yes	Yes
Constant	3,188***	3,212***	3,214***
	(161.2)	(163.0)	(162.2)
Observations (23 regions x 10 years)	230	230	230
R-squared (or Pseudo R2)	0.7224	0.0364	0.6668
Log likelihood (LL)	-1,967.85	-1,969.98	-1,969.14
Wald for joint significance	162.98***	155.88***	157.80***
Wald test of spatial terms	9.33***	10.56***	8.41***

Source: Authors' own elaboration.
Note: Standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05, * p<0.1

Table 23. Regional production function, by programming period - SDM (dependent variable: Production per worker)

Variables	SDM (1)
RDI sub. stock per worker (minus stock P1 in P2) in T-1	1.594***
	(0.606)
S3 dummy (2016-2018)	3,160
	(14,939)
Interaction term: S3 * RDI sub stock per worker in T-1	3.898**
	(1.633)
Remaining RDI sub. stock per worker from P1 in P2 in T-1	0.622
	(0.525)
Control variables	Yes
W*RDI sub. stock per worker (minus stock P1 in P2) in T-1	8.198**
	(3.943)
W*Interaction term: S3 * RDI sub stock per worker in T-1	-7.345
	(12.22)
W*Remaining RDI sub. stock per worker from P1 in P2 in T-1	4.475
	(3.244)
W*Control variables	Yes
W*Productivity	-1.070***
	(0.324)
Time fixed effect and regions NUTS 3 fixed effect	Yes
Constant	Yes
Observations	230
Observations (23 regions x 10 years)	23
Pseudo R2	0.295
Log likelihood (LL)	-1,953.8
Akaike's information criterion (AIC)	3,949.62
Wald test for joint significance	220.29***
Wald test of spatial terms	26.32***

Source: Authors' own elaboration.

Note: Standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05, * p<0.1. Control variables include stock of capital per worker and human capital. Dummy variable is equal to 1 for the years 2016-2018 and 0 otherwise. Since the first year of RDI subsidies flows in the second period happens in 2015 and we are lagging the independent variable, the first years of S3 effect occurs in 2016.

Table 24. Sensitivity analysis: Results SAR and SDM with non-factorial interactions term (dependent variable: Production per worker)

Variables	SAR (1)	SDM (2)
Period 1: RDI sub. stock per worker in T-1	1.053**	0.924*
	(0.489)	(0.489)
Period 2: RDI sub. stock per worker in T-1	4.371***	5.141***
	(1.473)	(1.542)
Control variables	Yes	Yes
W*Period 1: RDI sub stock per worker in T-1	-	4.828
	-	(3.192)
W*Period 2: RDI sub stock per worker in T-1	-	3.004
	-	(12.67)
W*Control variables	No	Yes
W*Productivity	-0.887***	-0.999***
	(0.300)	(0.320)
Time fixed effect	Yes	Yes
Regions NUTS 3 fixed effect	Yes	Yes
Constant	3,106***	3,003***
	(156.7)	(152.9)
Observations	230	230
Observations (23 regions x 10 years)	23	23
Pseudo R2	0.677	0.341
Log likelihood (LL)	-1,962.1	-1,956.1
Akaike's information criterion (AIC)	3,954.24	3,950.16
Wald test for joint significance	184.17***	209.73***
Wald test of spatial terms	8.72***	22.08***
Wald test Period 1 = Period 2	4.37** (0.0367)	6.73***(0.0095)

Source: Authors' own elaboration.
Note: Standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05, * p<0.1

Table 25. Direct, indirect and total effects derived from Table 24

Estimated impact	SAR (1)		
	dy/dx	Std. Err.	P>z
Direct			
Period 1: RDI sub stock per worker in T-1	1.09	0.508	0.032
Period 2: RDI sub stock per worker in T-1	4.52	1.516	0.003
Indirect			
Period 1: RDI sub stock per worker in T-1	-0.53	0.278	0.057
Period 2: RDI sub stock per worker in T-1	-2.20	0.829	0.008
Total			
Period 1: RDI sub stock per worker in T-1	0.56	0.266	0.036
Period 2: RDI sub stock per worker in T-1	2.32	0.898	0.010
Difference: P2-P1	1.76		0.037

Table 26. Regional production function using SDM, by type of RDI subsidies (dependent variable: Production per worker)

Variables	SDM (1)	SDM (2)	SDM (3)
SI IDT Sub. Stock per worker in T-1	4.541*	-	4.895**
	(2.408)	-	(2.440)
SI INOV and QUAL Sub. Stock per worker in T-1	-	1.339***	1.402***
	-	(0.468)	(0.482)
Control variables	Yes	Yes	Yes
W*SI IDT Sub. Stock per worker in T-1	2.092	-	28.96
	(19.53)	-	(21.69)
W*SI INOV and QUAL Sub. Stock per worker in T-1	-	1.944	4.816
	-	(2.999)	(3.324)
W*Control variables	Yes	Yes	Yes
W*Productivity	-1.006***	-1.012***	-1.078***
	(0.324)	(0.323)	(0.324)
Time fixed effect	Yes	Yes	Yes
Regions NUTS 3 fixed effect	Yes	Yes	Yes
Constant	3,104***	3,068***	3,024***
	(158.3)	(156.4)	(154.8)
Observations (23 regions x 10 years)	230	230	230
R-squared (or Pseudo R2)	0.2916	0.3471	0.2905
Log likelihood (LL)	-1,963.0	-1,960.6	-1,958.2
Akaike's information criterion (AIC)	3,960.0	3,955.2	3,954.4
Wald test for joint significance	182.09***	191.66***	202.11***
Wald test of spatial terms	20.49***	18.82***	23.41***

Source: Authors' own elaboration.

Note: Standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05, * p<0.1.

Table 27. Regional production function, by type of RDI subsidies and programming period using SDM (dependent variable: Production per worker)

Variables	SDM (1)	SDM (2)
SI IDT sub. stock per worker (minus stock P1 in P2) in T-1	3.938	-
	(2.689)	-
S3 dummy (2016-2018)	-3,611	16,648
	(13,245)	(13,942)
Interaction term: S3 * SI IDT sub stock per worker in T-1	27.57	-
	(17.14)	-
Remaining SI IDT sub. stock per worker from P1 in P2 in T-1	4.419	-
	(3.120)	-
SI INOV + SI QUAL Sub. Stock per worker in T-1	1.303***	-
	(0.481)	-
Control variables	Yes	Yes
W*SI IDT sub. stock per worker (minus stock P1 in P2) in T-1	23.70	-
	(23.21)	-
S3 dummy (2016-2018)	0	-
	(0)	-
W*Interaction term: S3 * SI IDT sub stock per worker in T-1	-198.5	-
	(134.1)	-
W*Remaining SI IDT sub. stock per worker from P1 in P2 in T-1	66.03**	-
	(28.09)	-
W*SI INOV + SI QUAL Sub. Stock per worker in T-1	7.082**	-
	(3.410)	-
SI IDT Sub. Stock per worker in T-1	-	4.341*
	-	(2.481)
SI INNOV_QUAL sub. stock per worker (minus stock P1 in P2) in T-1	-	-2.99e-06
	-	(4.93e-06)
Interaction term: S3 * SI INNOV_QUAL sub stock per worker in T-1	-	4.936***
	-	(1.786)
Remaining SI INNOV_QUAL sub. stock per worker from P1 in P2 in T-1	-	-0.108
	-	(0.498)
W*SI IDT Sub. Stock per worker in T-1	-	14.19
	-	(21.72)
W*SI INNOV_QUAL sub. stock per worker (minus stock P1 in P2) in T-1	-	-5.36e-05
	-	(3.72e-05)
W*Interaction term: S3 * SI INNOV_QUAL sub stock per worker in T-1	-	-3.654
	-	(14.68)
W*Remaining SI INNOV_QUAL sub. stock per worker from P1 in P2 in T-1	-	1.451
	-	(2.569)
W* Control variables	Yes	Yes
W*Productivity	-1.131***	-1.057***
	(0.327)	(0.329)
Time fixed effect and regions NUTS 3 fixed effect	Yes	Yes
Constant	2,961***	3,006***
	(152.1)	(153.8)
Observations (23 regions x 10 years)	230	230
R-squared (or Pseudo R2)	0.298	0.338
Log likelihood (LL)	-1,954.3	-1,956.8
Akaike's information criterion (AIC)	3,954.6	3,955.6
Wald test for joint significance	219.12***	207.58***
Wald test of spatial terms	28.92***	23.37***

Source: Authors' own elaboration.

Note: Standard errors in parentheses. Significance level: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

List of abbreviations and definitions

2SLS	Two-Stage Least Squared
AIC	Akaike's information criterion
ANI	Portuguese Innovation Agency
CCDR	Regional Coordination and Development Commission
COMPETE	Thematic Operational Programme for competitiveness and internationalization
CSF	Community Support Framework
ERDF	European Regional Development Fund
ESIF	European Structural and Investment Funds
GDP	gross domestic product
INE	National Statistics Office of Portugal
IV	Instrumental variables
KIS	Knowledge intensive-services
LL	Log likelihood (LL)
ML	Maximum Likehood
NACE	Statistical Classification of Economic Activities in the European Community
NUTS	Nomenclature of Territorial Units for Statistics
OLS	Ordinary Least-Squares
OP	Operational Programme
PT2020	Portugal 2020
QREN	Quadro de Referência Estratégico National (National Strategic Reference Framework)
R&D	Research and Development
R&I	Research and Innovation
RDI	R&D and Innovation
RIS3	Research and Innovation Strategies for Smart Specialisation
S3	Smart Specialisation Strategy
SAR	Spatial Autoregressive Model
SDM	Spatial Durbin Model
SI IDT	Incentive System for Technological Research and Development
SI INOV	Incentive System for Business Innovation and Entrepreneurship
SI QUAL	Incentive System for Qualification and Internationalization of SMEs
STS	scientific and technological system
TO1	Thematic Objective for Research and Innovation
TO3	Thematic Objective for Enhancing the competitiveness of SMEs
TO8	Thematic Objective for promoting sustainable and quality employment and supporting labour mobility
TRL	Technology Readiness Levels

List of figures

List of tables

GETTING IN TOUCH WITH THE EU

In person

All over the European Union there are hundreds of Europe Direct information centres. You can find the address of the centre nearest you at: https://europa.eu/european-union/contact_en

On the phone or by email

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

- by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),

- at the following standard number: +32 22999696, or

- by electronic mail via: https://europa.eu/european-union/contact_en

FINDING INFORMATION ABOUT THE EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website at: https://europa.eu/european-union/index_en

EU publications

You can download or order free and priced EU publications from EU Bookshop at: https://publications.europa.eu/en/publications. Multiple copies of free publications may be obtained by contacting Europe Direct or your local information centre (see https://europa.eu/european-union/contact_en).

KJ-NA-30623-EN-N

The European Commission's science and knowledge service

Joint Research Centre

JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

EU Science Hub
ec.europa.eu/jrc

@EU_ScienceHub

EU Science Hub - Joint Research Centre

EU Science, Research and Innovation

EU Science Hub

Publications Office
of the European Union

doi:10.2760/002330
ISBN 978-92-76-31375-5