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Regional Analysis of ICT R&D Targets for the Rhomolo Model

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Abstract

This study describes construction of two series of projections for R&D expenditures for 2010-2020 at regional and sectoral levels for EU Member States (MS), to be simulated with Rhomolo – a regional CGE model. The first series builds on the MS-specific R&D targets of EU2020 policy and it derives implications for R&D intensities for six broad sectors across NUTS2 regions. The second series, in addition to the EU2020, takes into account Digital Agenda for Europe (DAE) policy with its target of doubling public spending on ICT R&D by the year 2020. The difference between the two series is interpreted as impact of DAE.

The theoretical motivation for this research stems from ongoing discussion on the complementarity and substitutability between public and private R&D spending, and on the impact of R&D investment on growth and employment. We aim to contribute to this discussion by looking at the ICT sector and by providing theoretical and empirical evidence of the effects of the increased public ICT R&D on private ICT R&D, and its economic impact on economy as a whole. The policy background for the study, as formulated by the recently adopted DAE, re-emphasises the importance of ICT for boosting European performance and competiveness. DAE, a part of Europe 2020 strategy[1], identifies areas where ICT can contribute toward European development and sets relevant targets. The target with respect to ICT R&D is a doubling of public expenditure on ICT research in ways which leverage equivalent increases in private spending on ICT R&D. With this study we expect to provide theoretical and empirical reasoning for this policy initiative.

Although the analysis is not taken into the Rhomolo model at this stage of research yet, the paper outlines the next steps towards this objective.

[1] Europe 2020 (http://ec.europa.eu/europe2020/index_en.htm), as well as Digital Agenda for Europe (COM(2010) 245) at http://ec.europa.eu/information_society/digital-agenda/index_en.htm, or Innovation Union (SEC(2010) 1161) at http://ec.europa.eu/research/innovation-union/pdf/innovation-union-communication_en.pdf.

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1. Introduction

1.1 Background, motivation and purpose

Research and Development (R&D) expenditure on Information and Communication Technologies (ICT) and the resulting innovation, both public and private, is critical for sustainability of ICT-induced growth of European Union. R&D investment fuels inventive activities that play a key role in development of new and improvement of existing technologies, and lead to innovation-based economic growth. R&D-induced technological progress has firmly entered economic research and a policy discourse, and the overall process of technology diffusion has been addressed by several CGE models. All previous attempts to model generation and diffusion of technology define technological progress as a general change in the set of feasible production possibilities. Being an essential part of the theoretic economic reasoning, such an abstraction, however, does not prove helpful in the policy design, where a need of a nuanced and systematic understanding of the factors of technological change attain the primary importance in capturing the welfare gains and losses of the involved social agents. We suggest a more nuanced view on the sources of technological progress, as well as on subsequent productivity gains, by looking specifically at the R&D associated with ICT (ICT R&D).

ICT R&D is particular in their widespread use and large scope for product, process and organizational improvement. Though total R&D spending has declined in the last few years due to the recent economic crisis, private ICT R&D investments revealed a market growing tendency. This tendency indicates the belief of private industrial investors into a direct relationship between the level of ICT R&D and derived profit and growth benefits. Such beliefs correspond to the contemporary policy attitude towards creation of the right conditions for sustaining and increasing the support for ICT R&D and its translation into the ICT-based economic growth.

The two key policies which determine future spending on ICT R&D are: Europe 2020 with the 3% of GDP to be spent on R&D by the year 2020, and the Digital Agenda for Europe (DAE) which envisages 'doubling of public spending on ICT R&D in ways which leverage equivalent increase in private expenditure on ICT R&D'. At the EU policy level it has been recognised that strengthening the competitiveness of European firms and industries would be maintained by substantial contributions derived from public R&D.

The limited resources which can be invested in ICT R&D make it increasingly important to carefully plan and monitor how those resources are invested and how the productivity gains are generated and translated throughout sectors and regions. To this aim we attempt to provide a modelling tool that allows creating a more nuanced depiction of the changes in the ICT R&D intensities throughout the EU regions and thus help policy makers to project how ICT R&D expenditure turns into invention and innovation and how created products and technologies impact economy and society.

Although the EU2020 and DAE policies put in place specific targets to ensure that the ICT innovation is adequately financed, the resulting impact on specific industries, growth and employment is yet to be assessed. The study is motivated by need to help in understanding economic impact of policies which aim at stimulation of economic factors as important as knowledge, innovation and new technology.

This study derives implications from 2020 R&D and ICT R&D policy targets for EU regions at NUTS2 level. This aim is achieved by constructing a regional ICT R&D database and preparing an associated scenario to be simulated with regional SCGE model (RHOMOLO).

1.2 Remaining chapters

The next chapter focuses on the RHOMOLO model. A general introduction is provided, followed by a description of how R&D is treated and the transmission mechanisms through which its effects are modelled. It finishes by considering how the model might be modified further to incorporate ICT R&D as part of its basic structure, in comparison with other models that already make such a distinction.

Chapter 3 provides information on the construction of the ICTR&D and R&D projections, starting with the definite (EU and national targets) and moving down through sectors and regions while maintaining consistency.

Chapter 4 presents a summary of the findings, and proposes future developments for the data and modelling work, while Chapter 5 contains references.

2. The RHOMOLO Model

2.1 General introduction

The regional holistic model (RHOMOLO) is built for all 27 European Member States, including all their NUTS2 regions. The model integrates economic and some social dimensions in a unique framework. From here comes the adjective 'holistic'[2]. RHOMOLO can be used not only for ex-ante European Cohesion Policy (ECP) impact assessment but also for ex-post impact assessment, other policy simulations and comparison between policy scenarios. RHOMOLO is not, however, a forecasting model.

RHOMOLOv2 incorporates the following important features:

- full NUTS2 regional coverage of the EU27;
- six activities or sectors are identified (see Table 1), each of which produces its own commodity;
- labour, capital, and commodities are included as productive factors;
- a government sector is included which collects taxes and pays subsidies;
- it is a dynamic model with time periods linked by savings and investments;
- inter-regional trade (exports and imports) is modelled and provides a key linkage and policy spillover mechanism between regions;
- a total factor productivity (TFP) relationship with R&D intensity as the main driver… This will be discussed in more detail in the next section;
- new economic geography (NEG) features which also act to link regions through forces of agglomeration and dispersion, including migration.

Each European country in RHOMOLO consists of one or more NUTS2 regions, which are connected by inter-regional trade flows of goods and services. Trade takes place between the regions of the same country as well as between the regions of two different countries. The pattern of inter-regional trade flows depends upon the preferences of consumers for buying goods from particular destinations and upon the prices of goods and associated transportation costs. Transportation costs in RHOMOLO differ by type of good and depend upon the distance between the regions of origin and destination. The larger is this distance the higher are the transportation costs.

Each NUTS2 region in RHOMOLO includes various economic agents: households, production sectors, and government. Activities (or sectors) in RHOMOLO are differentiated according to EUROSTAT NACE classification, and each activity is assumed to produce only one type of good or service (commonly known as a commodity). Service sectors in RHOMOLO include both market and public sectors. Production sectors use various inputs in order to produce their output. These inputs are used in accordance with sector-specific production technology and include labour, machinery, buildings, other goods and services. Table 1 shows the sectoral disaggregation in RHOMOLO and how it corresponds to official NACE (rev 1.1) classifications.

Labour in RHOMOLO is not differentiated according to skill/education level, although wages are sector-specific and will vary according to the differing educational and productivity levels of their workers. Wages take the appropriate level that equalises demand and supply, and in this way are assumed to be determined by a negotiation process between the firms and trade-unions and depend on

[2] An earlier prototype version of the model also had additional social and environmental components, but these were removed as part of an exercise to simplify the model and get it solving across all regions. The plan is that these components will be added back in due course.

labour productivity and on the bargaining power of trade-unions. This allows the model to capture differences in the institutional arrangements across EU countries. There is currently no measure of unemployment in the model.

Table 1. Sector disaggregation in Rhomolo

Sector	NACE Section	Description
1	A + B	Agriculture, hunting and forestry
2	C + D + E	Mining and quarrying + Manufacturing + Electricity and Gas
3	F	Construction
4	G + H + I	Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods + Hotels and restaurants + Transport and Communications
5	J + K	Financial and Business Services
6	L + M + N + O + P	Non-Market Services

RHOMOLO is a dynamic model, calibrated on the year 2007, which allows analysis of each period of the simulation time horizon. This horizon is currently set until 2030 but it could, in principle, be extended to longer time periods. For each year of the time horizon, RHOMOLO calculates a set of various economic and social indicators. Time periods in RHOMOLO are linked by savings and investments. By the end of each time period households, firms and government in the model save a certain amount of money. This money goes to a notional 'investment bank' which distributes investments between sectors of the various regions according to their profitability.

RHOMOLO belongs to the same family models as the QUEST model[3]. The main similarities and differences include:

- RHOMOLO is a regional model of the EU27 and includes inter-regional trade, whereas QUEST is a macroeconomic model covering all 27 Member States;
- RHOMOLO has a more detailed sector dimension, albeit with a less detailed representation of the financial sector;
- QUEST has an endogenous growth engine where by investing in R&D and human capital higher economic growth can be achieved, whereas for RHOMOLOv1 technological change remains exogenous;

RHOMOLO uses recursive, or backward-looking, expectations, whereas QUEST uses forward-looking (model-consistent) expectations.

2.2 Treatment of R&D in Rhomolo

- Prototype version

In an earlier prototype version of the model, economic growth was made dependent on investments in R&D and education, linked through a total factor productivity (TFP) equation[4]. The logic was that by

[3] See http://ec.europa.eu/economy_finance/research/macroeconomic_models_en.htm.

investing in R&D and education each region is able to catch-up faster towards the region which is the technological leader and better adopt its technologies. The main elements assumed to explain the growth in TFP in this prototype version of RHOMOLO were human capital, R&D expenditure, technology transfer and a measure of absorptive capacity. Sector and region-specific TFP growth were also related to exogenous region-specific parameters and on the TFP level relative to the technological frontier (leader region) as well as the region's own absorptive capacity.

Empirically, the specification used was the following:

$$\Delta TFP_{r,s} = \beta_{0,s} + \beta_{1,s} H_r + \beta_{2,s} RD_r + \beta_{3,s} H_r \left(\frac{TFP_{r,s}}{TFP_s^*} \right) + \varepsilon$$

where the subscripts *r* stand for "region" and *s* for "sector", H is the average years of schooling, and RD R&D intensity. The proposed specification relies on the logistic diffusion function proposed by Benhabib and Spiegel (2005). A crucial factor affecting the productivity growth is the share of R&D expenditures on regional GVA. Relative R&D expenditures may, in fact, stimulate the generation of new productive ideas and easier the implementation of innovations developed beyond the regional barriers. The model considers a relative indicator (R&D intensity) in order to avoid biases due to scale effects. This is also in line with the recent suggestions in empirical research in response to the critique of Jones (1995) that the absolute scale of R&D resources show little correlation with technological advance.

- More recent versions

The prototype version of RHOMOLO only covered five Member States (Germany, Poland, Slovakia, Hungary and the Czech Republic). In order to broaden the geography to the entire EU27 and its 270-plus NUTS2 regions, the complexity of the model was reduced in order to make simulations more tractable. As part of this simplification process, the TFP equation was removed, as was R&D and human capital. Only now, in version 2 of the model, have TFP and R&D been re-introduced so that, from a base level of simplification, simulations can be made more interesting and policy-relevant.

In the first attempts to re-introduce TFP / R&D into the model, we have decided to use a rather simple specification of the TFP equation, in which TFP growth in any region r is a function of an exogenous component (β_0), the average R&D intensity in the region, and the the gap between the follower TFP level in 2005 and that of the maximum (leader) TFP level in the same year:

$$\Delta TFP_r = \beta_0 + \beta_1 RD_r + \beta_2 \frac{TFP_r}{TFP_r^*} + \varepsilon$$

Note that, at this stage, there is no sectoral differentiation in the R&D and TFP relationship as was previously identified in the prototype version of the model.

2.3 Model requirements for ICT simulation

With the structure of the RHOMOLO model as it currently stands, it is capable of an R&D related scenario, which can itself be linked to an ICT policy simulation in a somewhat limited manner – this much will become clear in the next chapter. This section takes things a little further by suggesting how a model like RHOMOLO could be further enhanced to actually incorporate the ICT R&D decision

[4] In summary, TFP is the portion of output not explained by the amount of inputs (eg labour, capital, energy, land) used in production. As such, its level is determined by how efficiently and intensely the inputs are utilised in production.

within its structure, which would make it a much more powerful tool for analysing the impacts of these types of policy.

Report commissioned by EC DG INFSO (College of Europe, 2006) provides some overview of selection of CGE models' structure suitability for modelling of ICT as GPT. Although there are no existing models which would encompass both ICT sector and endogenous technological change with representation of relevant R&D-related instruments, there are models which have some parts of the required solution. The following models were considered: Worldscan, Nemesis, Quest, Multimod, IFs, Nigem, OEF, GEM-E3. Out of this group, however, Quest, Nigem, OEF and GEM-E3 do not constitute endogenous treatment of innovation process and/or technological change, hence are not suitable for modelling of the R&D related policies. The following table summarises relevant characteristics of the four remaining CGE models:

Table 2. CGE models with endogenous treatment of innovation and technological change.

	Worldscan	Nemesis	Ifs	Multimod	Rhomolo
Technology transmission mechanism	R&D→TFP	R&D→supply R&D→demand	R&D→output	R&D→TFP	R&D→TFP
Spillovers	Yes	Yes	No	Yes	Yes

The most detailed specification of technology transmission appears to be embodied in the **Nemesis** model. The mechanism is structured in three stages:

> *from R&D to knowledge* – the model contains sector-specific knowledge stocks which depend not only on the sector's R&D, but also on other sectors' R&D and government R&D.
> *from knowledge to innovation* – changes in stock of knowledge transmit into process and product innovations which, in turn, translate in to change in TFP and change in product quality respectively; the two types of innovation have different impact on economic performance.
> *from innovation to economic performance* – process innovations (TFP change) impact upon unit price of output and the respective demand (wrt. price elasticity of demand), whereas the product innovations impact on unit efficiency and unit price with subsequent effect on demand.

Although the original **Multimod** model does not endogenise technological change, in its extension in it has TFP set as a function of domestic and foreign R&D stocks.

Similarly to Multimod, the **Worldscan** has an extension which endogenises technological change. In the Worldscan it takes a form of another nest in the value added tree-like structure part of the production structure. The additional nest combines R&D specific labour and capital to produce knowledge which, in turn, supplements value added from traditional factors of production to form an augmented value added to be later combined with intermediate inputs. Such specification allows firms to optimise between traditional factors of production and investment into R&D activities.

RHOMOLO, in its prototype version, accounted for R&D stock in conjunction with human capital factor. The depreciable R&D stock's services impact upon sectoral productivity. RHOMOLO's uniqye contribution derives from taking the analysis to regional, NUTS2, level, which allows accounting for regional heterogeneity of countries, and incorporating features from New Economic Geography, hence better resemblance of their economies and accuracy of simulations.

The described models, those with endogenous technology specification and other, however, do not distinguish between different types of R&D activities. The separate treatment of ICT R&D is essential due to its particularly widespread diffusion and omnipresence in economy with ubiquitous potential impact on not only ICT producing sectors, but also on the ICT using industries. By leading the product and process innovations in application sectors, ICT generates successive waves of technological complementarities, from micro-processes in production to the organizational technologies in marketing and management, and new consumption modes. The availability of cheap and efficient ICT capital allows firms to deploy their other inputs in radically different and productivity-enhancing ways. In so doing cheap computers and telecommunications equipment can foster an ever-expanding sequence of complementary inventions in the ICT-using industries. Innovations in ICT cause unexpected ripples of co-invention and co-investment in sectors that seem almost arbitrarily far away[5]. These complementary inventions and investments fuel further advancements by up-shifting the demand curve for ICT, thereby offsetting the effects of diminishing returns and further stimulating the R&D in the ICT sectors.

[5] Bresnahan and Trajtenberg (1995), Helpman and Trajtenberg (1998).

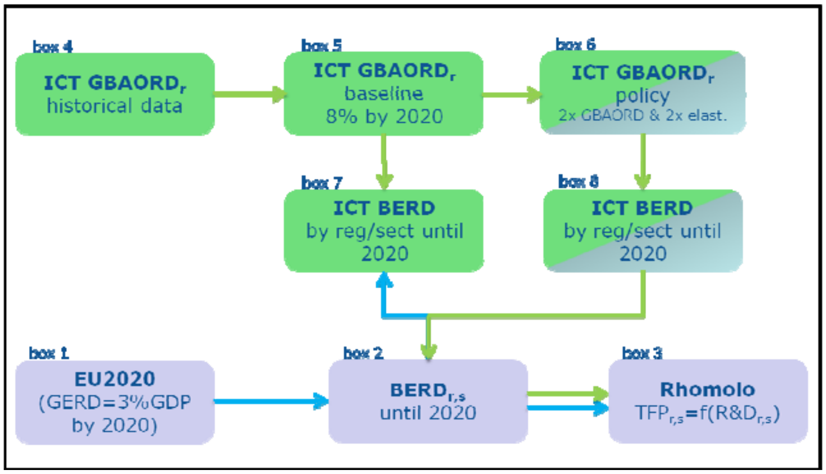
3. Constructing Regional ICT R&D scenarios for Rhomolo

3.1 Introduction

Digital Agenda for Europe (DAE) sets doubling of public spending on ICT R&D (ICT GBAORD) as the target to be reached by year 2020. This chapter describes construction of scenarios to simulate impact of the DAE target on EU economy at the regional level. Because Rhomolo model does not account for different types of R&D (e.g. ICT R&D), the scenarios represent impact of increased spending on ICT R&D on the total R&D, and the total R&D is what will be utilised by Rhomolo.

A schematic representation of the steps undertaken to create the scenarios is presented on Figure **1**:

Figure 1. Representation of the scenario construction.



The scenarios creation process consists of the following steps:

- Creating projections for total R&D expenditure at sectoral/MS levels (BERD$_{r,s}$) which are consistent with EU2020 targets. Those projections would be used as the baseline to feed Rhomolo's TFP equations (box 1, 2 and 3).
- Beginning with historical data on public expenditures on ICT R&D (ICT GBAORD$_r$), create two series of projections for the ICT GBAORD up to year 2020: (i) *baseline* which assumes 8% growth in ICT GBAORD from 2010 to 2020 (compared to 4% growth from 2004 to 2010), and (ii) *policy* which reflects DAE target of doubling spending on ICT GBAORD. Additionally, for the policy scenario, we also assume doubling of the relevant public-private additionality, i.e. that unit of public expenditure on ICT R&D will invoke twice as much of the private spending on ICT R&D for the projected period (box 4, 5 and 6).
- Compute projections on private ICT R&D spending (ICT BERD) are computed to be consistent with the ICT GBAORD projections, as well as with the total BERD for baseline (box 7)
- Re-compute projections for ICT BERD under the policy assumptions (box 8).
- Finally, the overall growth at MS level is allocated across sectors and regions to prepare projections in the format consistent with the Rhomolo structure (box 2 and 3).

The next section describes in detail each of the above steps.

Box 1. Definition of ICT sector and ICT R&D

The reference definition of the Information and Communication Technologies (ICT) sector and for the related R&D expenditures for this paper is based on the operational definition from OECD (Frascati Manual (2002), p.188). The ICT sector consists of the following NACE1.1 industrial activities:

Manufacturing:
30 Manufacture of office, accounting and computing machinery
32 Manufacture of radio, television and communication equipment and apparatus
33 Manufacture of medical, precision and optical instruments, watches and clocks
Services:
642 Telecommunications Services[1]
72 Computer and related activities

The ICT R&D refers to R&D undertaken in the ICT sector (BERD). A legitimate concern of whether the R&D in the ICT sector fully captures the total ICT R&D is based on the fact that in practice ICT-related R&D can be found virtually everywhere in the economy. Yet, the identification of R&D in the sub-sectors whose *main activity* is to produce or distribute ICT products constitutes *a* first-order approximation of the ICT R&D. Moreover, the rise of the TFP growth due to R&D in the ICT sector is a reflection of technological progress in production of semi-conductors and related products and services. The R&D activities in the ICT sector is thus an important determinant of the economic impacts associated with ICT. Having a strong ICT sector may help ICT-using sectors since the close proximity of producing firms might have advantages when developing ICT applications for specific purposes. It should also help generate the skills and competencies needed to benefit from ICT use. Moreover, it could lead to spin-offs, as in the case of high technology (ICT) clusters.

3.2 Total R&D expenditure

As part of a different but related (internal) study (European Commission, 2011), R&D intensity scenarios had been previously built to assess the regional impact of alternative R&D policies, including those in line with Europe 2020. In all of them the same procedure was applied to obtain the regionalised figures for each scenario. In brief, the procedure was as follows:

(i) Europe 2020 and nationally agreed targets

Most people are familiar with the Europe 2020 headline target of a 3% average R&D intensity for the EU27. Linked to, and feeding into, this target are nationally agreed targets for each Member State – see http://ec.europa.eu/europe2020/pdf/targets_en.pdf. It should be borne in mind that the target for countries with low initial values of R&D intensity (eg the Slovak Republic or Hungary) will still be reasonably below the 3% by the 2020 period. The Member State R&D intensities are fixed so that the national provisional targets are achieved by 2020, and remain so thereafter in the simulation. This is done (for each Member State) by joining the objective in 2020 with the value for the last available year (2009) of data (obtained from Eurostat / GERD) by linear extrapolation. An imputed EU27 total (which is broadly similar) is also calculated using GDP weights fixed from 2012 onwards, as we do not know exactly what weights were used to calculate the EU27 total in Eurostat

(ii) Obtaining consistent / believable sectoral forecasts

Sectoral R&D intensities are obtained for the base year. Some manipulation of the data is required here, because Member State sectoral R&D intensities only refer to BERD (Business and Enterprise Sector) and so are always less than the GERD R&D intensities. In order to match more closely with the GERD totals, the % of GDP for remaining sectors (government, higher education, not-for-profit) is added together and applied to GDP for the year in question. This total is then added to the sector R&D for non-market services to get a revised non-market services figure. The sector intensities for the base year are accordingly scaled up or down according to the relative difference between the GERD MS total and the imputed sectoral MS total. In this way, any remaining residual errors are spread across all sectors rather than being concentrated in one single sector.

Because, using a relative (to total) adjustment mechanism, the sector intensities for any MS are tied to how fast the country is growing there is potential for unlikely intensities to emerge. For example, in a country such as Bulgaria with an already high Non-Market Services R&D intensity, the required growth of total R&D intensity means this sector must reach highly improbable R&D intensity rates. For this reason, an alternative mechanism was imposed:

- firstly, country leaders for R&D intensity in each sector were identified for the base year

- the selected sector leaders are allowed to grow at the rate necessary to achieve the overall country R&D target

- no other MS is allowed to have an R&D intensity which is greater than the leader, ie the R&D intensity leader remains the same in 2020 as in the base year

Finally, because (downward) adjustments have been made to sectors that exceed the sectoral leader's R&D intensity, this means that agreed country targets will no longer be met by 2020. For this reason, an imputed R&D intensity (using fixed GDP weights) is calculated to see what the shortfall is Adjustments are then made to other sectors (typically manufacturing, but generally where the sector is low relative to the leader) to ensure that overall country targets are met for 2020. This can mean that the intervening years (from last year of data to 2020) do not exactly match the linear interpolation, but the 2020 goal is still achieved.

3.3 Public expenditures on ICT R&D

This section describes construction of projections for public spending on ICT R&D. The proposed method takes into account three factors when constructing the projections. The first factor is dynamism of historical growth in public expenditures on ICT R&D. The historical data suggests that growth rates for public expenditures on specific research domains do not change rapidly, and it takes many years to significantly change the trend. Therefore, the past trend in expenditure level is an important determinant of future spending. The second factor impacting on level of public expenditure on ICT research is a distance from a leader, and greater distance implies lower potential for growth. The distance from leader in this context refers to intensity of public ICT research funding relative to highest possible such intensity within the EU member states. Logic of this metric derives from specialization, absorption capacity and frontier technology theory. Finally, the last factor taken into account for determination of public ICT R&D expenditures is national strategy for overall public R&D development. For countries with more ambitious policy targets for R&D expenditure with ICT R&D being part of it, the potential for growth in ICT research expenditure is greater than in countries which do not plan significant investment in R&D.

The specification employed to resemble the above framework is as follows:

$$gRD_r^{ICT} = \left[\left(RD_r^{EU20} \right)^{\phi DIST_r} + S_r \right] \cdot \alpha \qquad (1.1)$$

Where gRD_r^{ICT} is growth rate in intensity (as share of GVA) of public expenditure on ICT research (GBAORD) for country r for period 2010-2020, RD_r^{EU20} is growth rate in public R&D expenditure between 2010 and 2020 determined by EU2020 targets, $DIST_r$ is distance of country r from ICT R&D leader based calculated as difference in ICT R&D intensities in year 2010, S_r is slope of the fitted linear growth model for country r for years 2007-2010, and ϕ and α are technical coefficients.

<u>Computations</u>

The following normalisation was applied to the data used[6]:

> national strategy for R&D growth indicator is calculated as difference between the R&D intensity target for year 2020, $GERD_r^{EU20T}$, and historical R&D intensity from year 2010, $GERD_r^{2010}$, and then scaled for the maximum of the sample to equal unity:

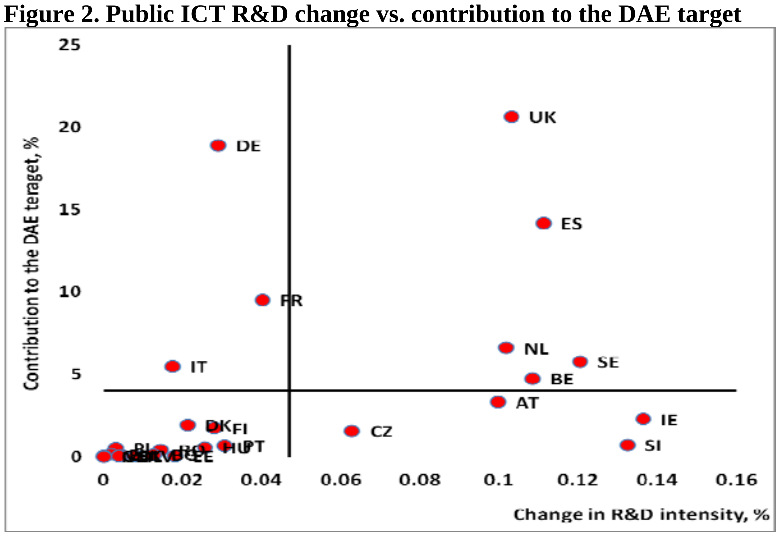
$$RD_r^{EU20} = \left(GERD_r^{EU20T} - GERD_r^{2010} \right) / \max \left[GERD_r^{EU20T} - GERD_r^{2010} \right]$$

> distance from the leader is calculated as difference between a country's ICT GBAORD in 2010 intensity and the maximum intensity recorded among member states for this year:

$$DIST_r = \max \left[RDi_{EU}^{ICT,2010} \right] - RDi_r^{ICT,2010}$$

The final step is solving equation (1.1) for parameter α so the EU-aggregate increase in ICT GBAORD between 2010 and 2020 exactly doubles as envisaged in the DAE policy, the estimation result is $\alpha = 2.13$

Figure 2. Public ICT R&D change vs. contribution to the DAE target



6 Calculations are based on data for 2004-2010 for public expenditures on ICT R&D (Stancik 2012)

Figure 2 presents change in MS ICT GBAORD intensity induced by the DAE target when compared to 8% 'business as usual' baseline growth along the horizontal axis, and contribution of each MS to the aggregate EU increase along the vertical axis. The four quadrants divide the MS countries into below- and above- average change in intensity and contribution to the EU target. The north-east quadrant groups countries which significantly increase their ICT GBAORD spending and contribute to the EU target at above-average level. The south-east quadrant groups countries which significantly increase the ICT GBAORD intensity, but which do not have large enough economies to significantly contribute to the EU target. In the south-west quadrant there are countries which do not invest much into ICT GBAORD and make rather low contribution to the DAE EU target. Finally, the north-west quadrant comprises countries which do not increase, more than average, their ICT GBAORD intensity, but which are large enough to make substantial contribution to the aggregate EU target.

3.4 Private expenditures on ICT R&D

This section describes construction detail for projection on private R&D on ICT. The following equation is estimated on historical data:

$$\ln RD_{r,t}^{ICT} = c + \beta_r + \alpha_1 \ln RD_{r,t}^{noICT} + \alpha_2 \ln GRD_{r,t}^{ICT} + \alpha_3 \ln TG_{r,t-2} + \mu_{r,t} \quad (1.2)$$

Where subscript t is for years from 2004 to 2010 for analysis of historical data (calibration), and from 2010 to 2020 for the projections; subscript r is for countries, RD^{ICT} is BERD spending on ICT, RD^{noICT} is BERD expenditure on non-ICT , TG is the availability of technology graduates, GRD^{ICT} is the public spending on ICT R&D; $c, \beta, \alpha_1, \alpha_2, \alpha_3$ are parameters, and μ is the error term.

The explanatory variables are chosen under three constraints: (i) justified to be used as ICT R&D explanators (literature), (ii) available historical values, and (iii) can be forecasted up to 2020.

The direct forecasts for explanatory variables are based on the following:

>for total R&D – EU2020 MS targets

>for technology graduates – enrolment into ICT-related fields lagged by 7 years (5years of education + 2 years for reaching full related employment)

>for GBAORD – doubling of spending by 2020 (DAE) with distribution used as policy instrument.

Data used:

ICT R&D and total R&D by country is sourced from Eurostat and OECD (Anberd) databases. The ICT R&D is defined as R&D performed within sectors 30, 32, 33, 642 and 72 (nace1.1)

Graduates by field of education: Eurostat and OECD, the relevant to ICT field of education is chosen as:

460: Mathematics and Statistics (ISC 46)
480: Computing (ISC 48)

Public spending on ICT R&D based on IPTS Technical Paper (Stancik 2012)

Analysis of historical data

Initial estimates indicate significant correlation between the coefficients from the random effects and the fixed effects panel results (Hausman < 0.05), hence the fixed effects (OLS with time invariant country dummies) were chosen as the estimation method.

The estimate results are presented in the Table 3 below, discussion follows.

Table 3. Estimation results

Varaible	Coef.	st.Coef.	Std.Err.	t
nICT RnD	**0.47**	**0.51**	**0.10**	**4.5**
GBOARD	0.07	0.07	0.04	1.6
ICT Grads	**0.09**	**0.15**	**0.04**	**2.0**
BE	0.63	0.14	0.14	4.5
BG	0.10	0.02	0.15	0.7
CZ	0.41	0.09	0.11	3.8
DK	0.86	0.20	0.15	5.6
DE	0.77	0.18	0.18	4.3
EE	0.50	0.11	0.16	3.1
IE	0.89	0.20	0.09	9.4
EL	0.63	0.10	0.09	6.7
ES	0.48	0.11	0.12	4.1
FR	0.79	0.16	0.15	5.2
IT	0.71	0.15	0.13	5.5
CY	0.40	0.09	0.22	1.8
LV	-0.20	-0.04	0.16	-1.2
LT	-0.04	-0.01	0.14	-0.3
HU	0.28	0.06	0.12	2.5
MT	0.54	0.11	0.24	2.2
NL	0.87	0.20	0.13	6.4
AT	0.77	0.18	0.16	4.9
PL	0.00			
PT	0.49	0.11	0.09	5.5
RO	0.01	0.00	0.08	0.2
SI	0.40	0.09	0.18	2.2
SK	-0.21	-0.05	0.11	-1.9
FI	1.25	0.28	0.14	9.1
SE	1.07	0.24	0.16	6.6
UK	0.63	0.14	0.15	4.3
_cons	-1.17	.	0.47	-2.5

Brief discussion of results:

Non-ICT R&D: The relation between non-ICT and ICT R&D spending is positive and significant (standardised coefficient is 0.51). One interpretation of this finding is that ICT and non-ICT R&D activities are complimentary and increased activity in one required greater investment in another.

GBOARD: Although estimate of impact of public spending on ICT R&D (GBOARD) is not strongly significant (it becomes at 90% though), it points toward positive relationship, where every Euro invested by governments (ICT GBOARD) is associated with 0.07 Euro increase in private spending on the field.

IT Graduates: availability of the skilled graduates is critical for expansion of R&D operations which is confirmed by the positive estimate.

MS fixed effects: the series of coefficient which reflect other, country-specific characteristics which impact upon level of spending on ICT R&D. Values are to interpreted relative to Poland, with only

Slovakia, Lithuania and Latvia returning negative estimates; the two latter ones, however, being insignificant. The greatest national advantage has Finland (1.25), followed by Sweden (1.07) and Ireland (0.89).

Forecast

Once all the parameters are estimated, they are used for constructing predicted values for the RD^{ICT} with the following explanatory predictors used with equation (1.2):

$RD^{noICT}_{r,t}$ - the total spending on R&D up to year 2020 consistent with national targets in EU2020; TG - lagged (5 years) enrolment into technology training leading to ICT R&D positions[7]; $GRD^{ICT}_{r,t}$ - public expenditure on ICT R&D as determined in DAE.

3.5 Sectoral and regional allocation to fit Rhomolo structure

Combining the definition of ICT sector with the sectoral structure of Rhomolo, allows to identify the correspondence as presented in Table 4.

Table 4: RHOMOLO sectors and ICT components

Sector	NACE Section	ICT component	Description
1	A + B	None	Agriculture, hunting and forestry
2	C + D + E	30+32+33	Mining and quarrying + Manufacturing + Electricity and Gas
3	F	None	Construction
4	G + H + I	64	Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods + Hotels and restaurants + Transport and Communications
5	J + K	72	Financial and Business Services
6	L + M + N + O + P	None	Non-Market Services

The sectors which have the ICT component (2, 4 and 5) are subsequently referred to with subscript 'ICT', e.g.: s_{ICT}, and the sectors without the ICT component as s_{nICT}.

The modified ICT R&D intensities at the MS level, $RD'^{ICT}_{r,t}$, are allocated to the constituent sectors according to their relative R&D expenditures and adjusted for the size of the sectors in economy :

[7] Initially here is used data on graduates with the ICT degrees up to 2010, which is then extrapolated up to 2020.

$$RD'^{ICT}_{s_{ICT},r,t} = RD^{ICT}_{s_{ICT},r,t} + \left(RD'^{ICT}_{r,t} - RD^{ICT}_{r,t}\right)\left(\frac{RE_{s_{ICT},r}}{\sum_{s_{ICT}} RE_{s_{ICT},r}}\right)\left(\frac{GVA_r}{\sum_{s_{ICT}} GVA_{s_{ICT},r}}\right) \qquad (1.3)$$

Once the new intensities for the ICT sectors are computed, the change in the non-ICT sectors is calculated as:

$$RD'^{ICT}_{s_{nICT},r,t} = RD^{ICT}_{s_{nICT},r,t} - \left(RD'^{ICT}_{r,t} - RD^{ICT}_{r,t}\right)\left(\frac{RE_{s,r}}{\sum_{s} RE_{s,r}}\right) \qquad (1.4)$$

Regionalising the R&D/ICT targets

In the final stage, the Member State sector scenarios have to be regionalized in order for them to be used by the RHOMOLO model in constructing a model run. This is done by the following three broad stages:

1. Take the set of Member State / sector scenarios that are compatible with the EU2020 / ICT targets, as calculated / described previously.

2. Take region/sector GVA data and construct region/sector GVA shares for 2005, and region GVA shares for 2005-09. These sector/region shares for 2005 are used for creating an initial set of R&D intensities that use only the fixed weights for this year, although in some cases (eg where sector structure is changing quite rapidly, as is the case with some eastern European Member States) region/sector weights are used for all years in 2005-09 and then fixed at 2009 thereafter. The region shares for 2005-09 are used for subsequently imputing an ES total R&D intensity. This set of intensities are consistent with Europe 2020 / ICT targets, but do not contain any region-specific information.

3. Use historical regional R&D intensity from 2005-09, which embeds region-specific factors, as a starting point. Apply the changes in the sector-weighted regional R&D intensity from Stage 1 onto the historical R&D intensity. This way, the region-specific factors are treated as fixed effects, while Europe 2020/ICT induced changes are assumed to affect sectors across regions in the same way.

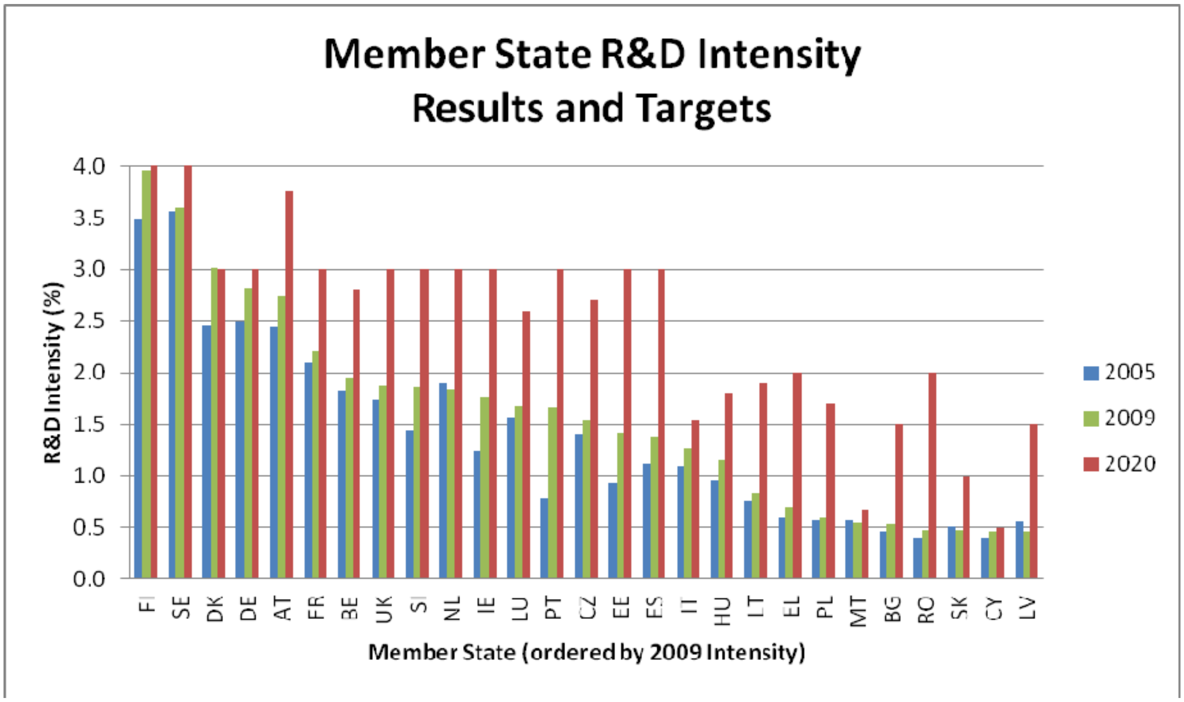
This method allows a set of forecast R&D intensities to be calculated which are consistent with the agreed targets, and which are also consistent with the latest available regional R&D historical data.

3.6 Main findings and results

This section presents some analysis of the results from above-described process of constructing the R&D simulation in two sections The results are organised in two sections: the first is presenting results as calculated for the baseline, and the second section presents differences between the policy and baseline results, i.e. the change in which is due to accounting for the DAE ICT R&D target.

Baseline results

- Member State analysis



The above chart shows the R&D intensities for two historical periods (2005 and 2009) and then the nationally-agreed targets compatible for Europe2020, with the countries ranked in order of their 2009 intensity result. It is clear that, between the two historical periods, during what was generally a strong period of growth for the EU (at least up to 2008-09) there was reasonable growth in R&D intensity, particularly among those Member States already at the top end of the ranking. The increase required between 2009 and 2020 falls mainly on the middle-ranked Member States, and makes the targets look rather ambitious, to say the least, particularly in light of the financial crisis and expected cutting back on R&D as firms re-consider risky investments and credit is less freely available than before the crisis.

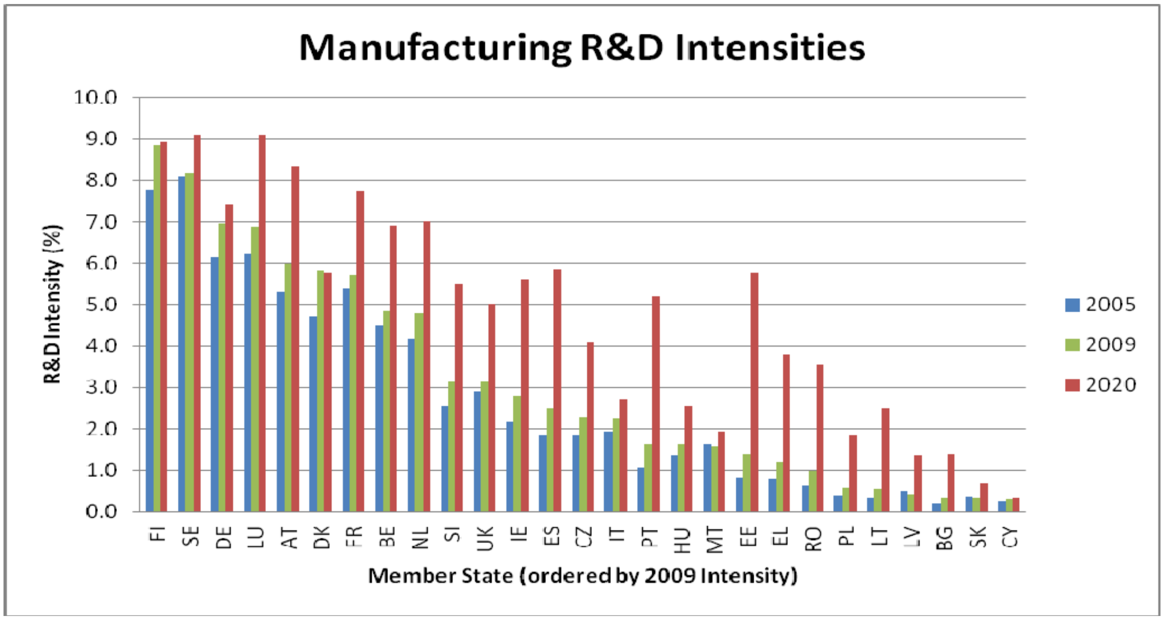
- Sectoral analysis

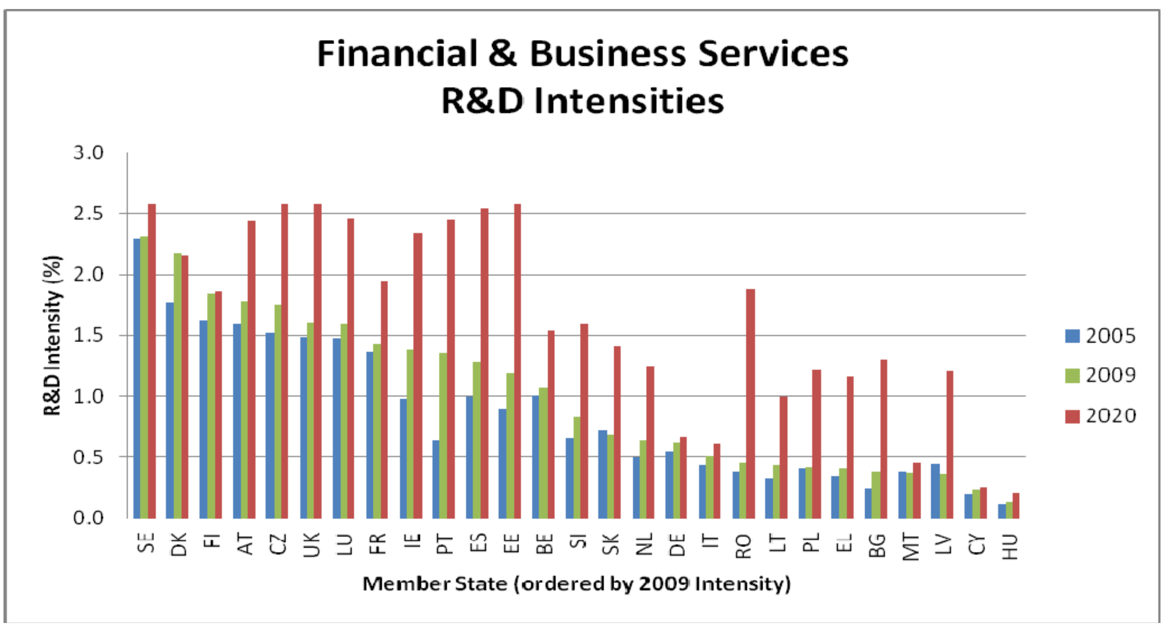
The next set of charts look at sectoral R&D intensities, particularly those sectors that are most important in terms of R&D – namely, manufacturing, financial and business services (FBS), and non-market services.

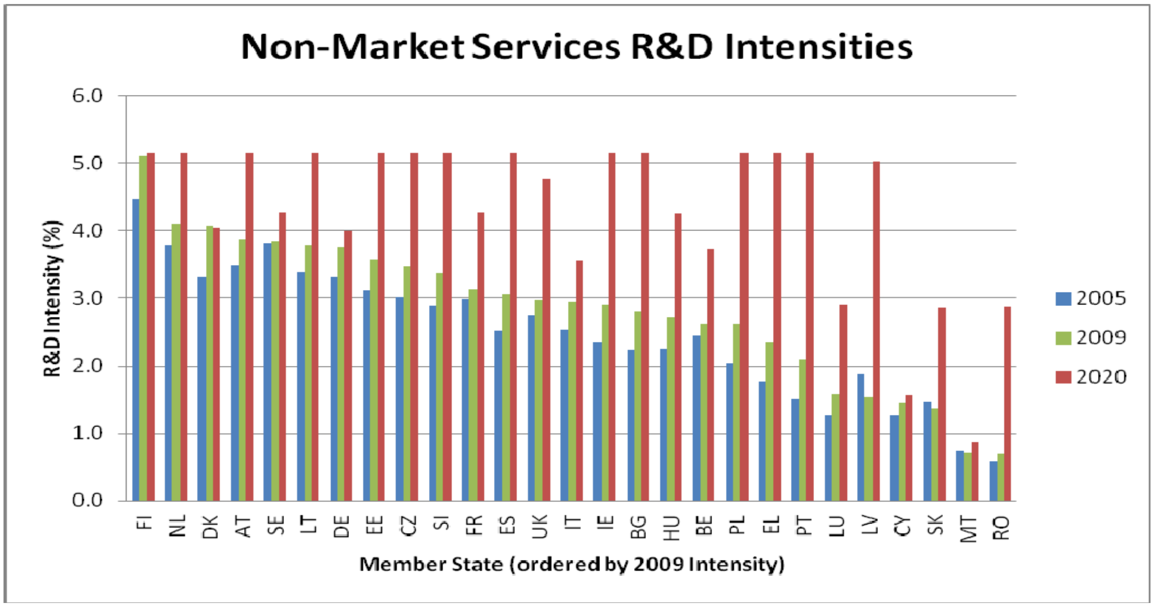
The sectoral intensity targets for 2020 are determined using the method described in the previous chapter. For manufacturing, the ranking is similar to that at the Member State level, albeit with an average level that is much higher because this is the sector where much of the R&D takes place. For

FBS, the average intensity level is quite a bit lower, but at the same time there are quite a few Member States (from Austria through to Estonia) where the target level in 2020 is anticipated to be among the highest across Europe, despite where they are currently placed in 2009. Finally, for public services it seems as if much of the burden of raising the R&D intensity falls on this category, particularly in the lower-ranked Member States as of 2009.

What these charts do more than anything is lay bare the difficulty that some Member States will have in raising their R&D intensities anywhere near the Europe 2020 targets. Even without the global financial crisis and ensuing recession, the effects of which are still being felt across many countries, many targets would be seen as optimistic given progress made between 2005-09. In the context of these occurrences, the targets could best be said to be aspirational rather than realistic.



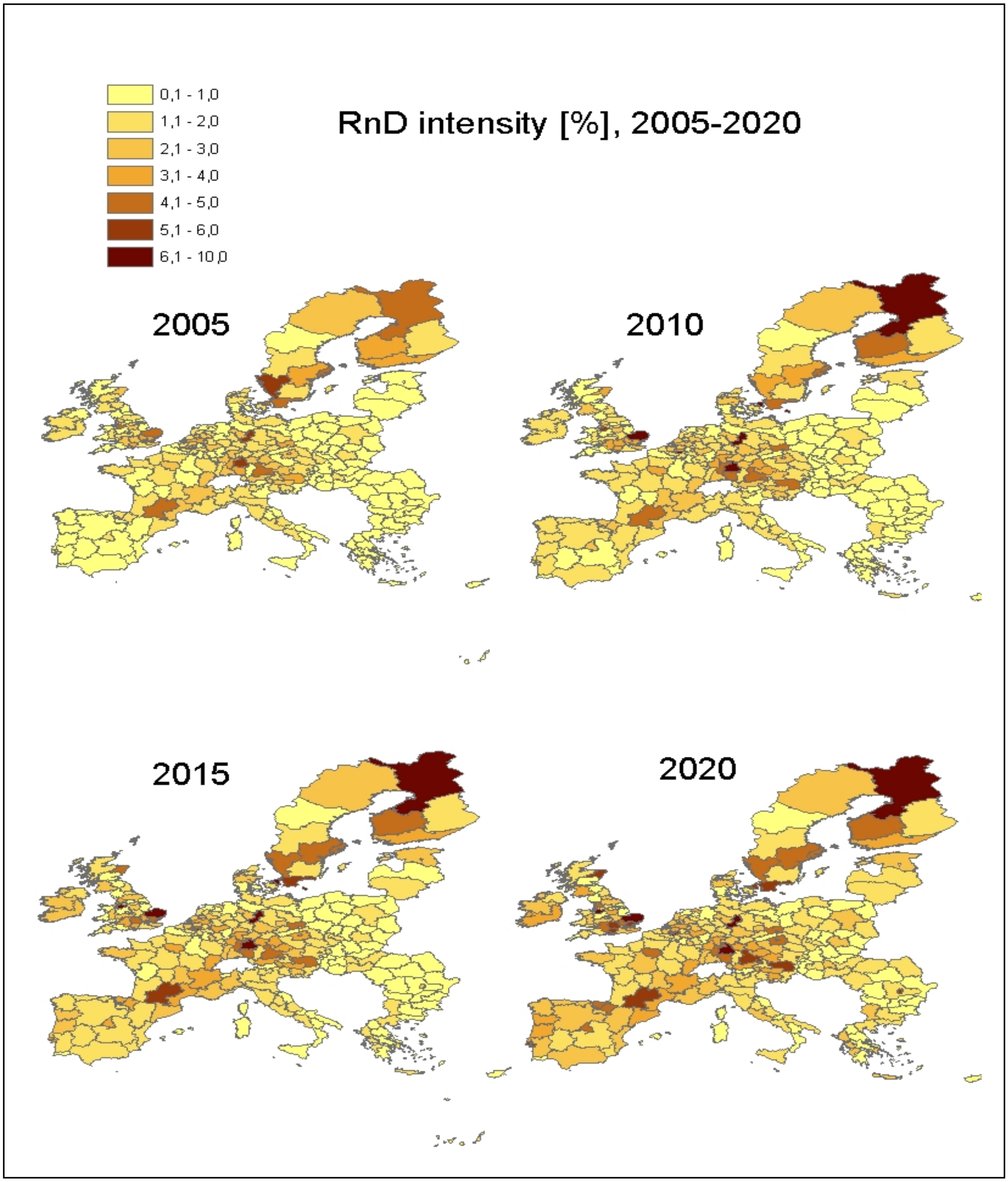



Non-Market Services R&D Intensities
R&D Intensity (%)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
FI NL DK AT SE LT DE EE CZ SI FR ES UK IT IE BG HU BE PL EL PT LU LV CY SK MT RO
Member State (ordered by 2009 Intensity)
2005
2009
2020

- Regional analysis

Analysing the result along geographical / regional dimension allows identifying regions which, in particular, would benefit if the DAE targets are fully implemented. Figure 3 presents a set of shaded maps portraying R&D intensity levels for NUTS2 regions fore years 2005, 2010, 2015 and 2020 across EU.

Figure 3. R&D intensity level in 2005, 2010, 2015 and 2020 for NUTS2 EU regions.



The regions which reach R&D intensity above 6% by year 2020 are: East Anglia (UKH1; 10.05%), Brabant Wallon province (BE31; 10.01%), Cheshire (UKD2; 9.66%), Braunschweig (DE91; 8%), Stuttgart (DE11; 6.91), Pohjois-Suomi (FI1A; 6.31%) and Hovedstaden (DK01; 6%). These are regions are established R&D centres with already existing high R&D intensities, largely above national averages, as summarised in Table 5.

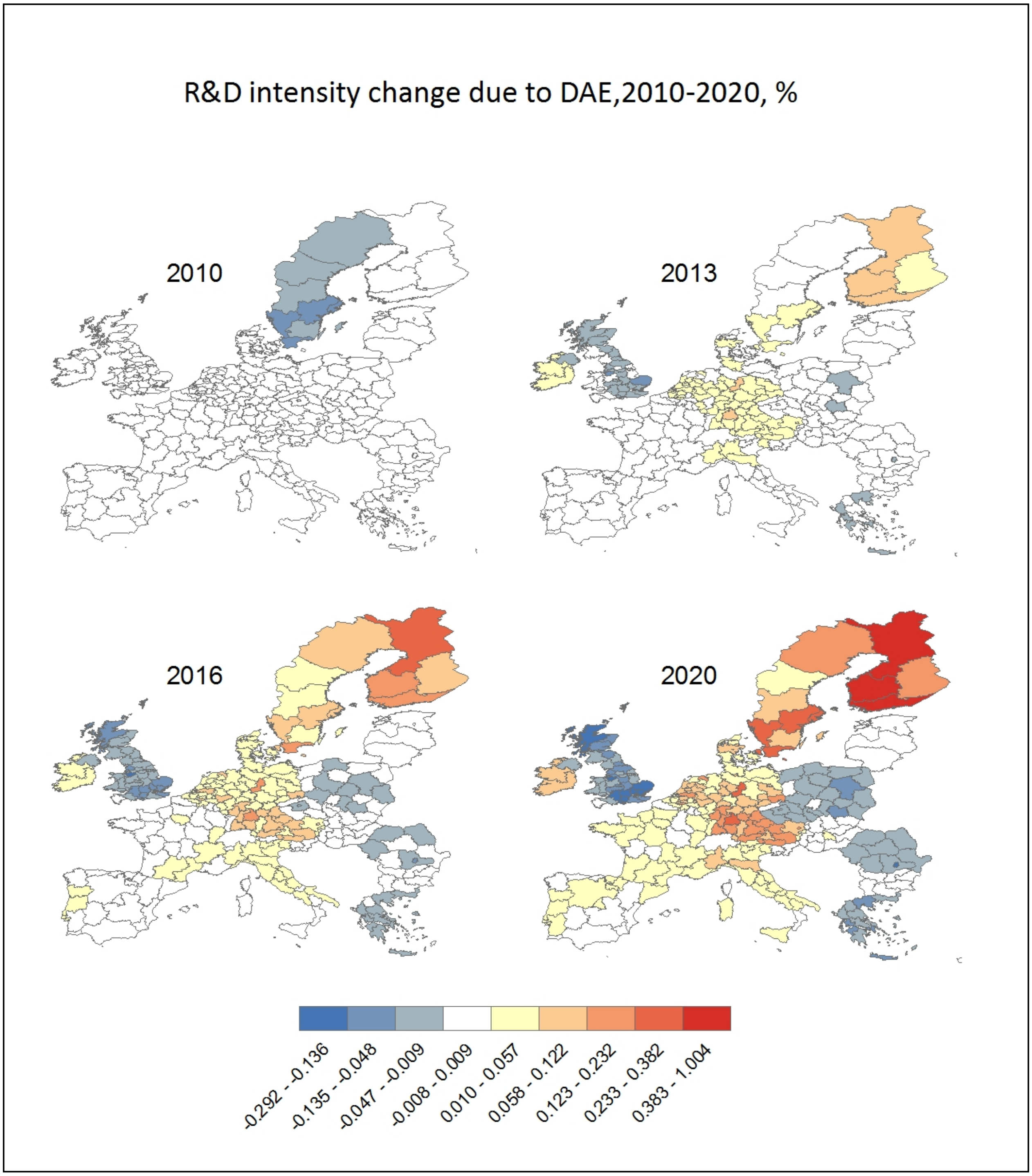
Table 5. R&D intensities in 2008, 2020 and national average, [%].

Region	***R&D intensity 2008***	***National average 2008***	***R&D intensity 2020***
UKH1	5.90	1.7	10.05
BE31	7.00	1.9	10.00
UKD2	5.70	1.7	9.60
DE91	6.75	2.5	8.00
DE11	5.83	2.5	6.90
FI1A	5.80	3.7	6.31
DK01	5.10	2.5	6.00

Policy vs baseline results

This section presents difference between the series of results calculated with account to the EU2020 and between the series calculated with account to both the EU2020 and the DAE targets. Hence the difference between the two series is interpreted as impact of DAE. Figure 4 below schematically represents the difference for NUTS2 regions.

Figure 4. Represetation between the two policy and baseline results.



The difference between the two scenarios should be interpreted in the context of their representation: for example a negative value of a percentage change variable does not imply a decline in the value of the variable between 2010 and 2020, but rather a lower value for the variable in the policy scenario in 2020 than for the baseline scenario in 2020.

The top five regions which would benefit the most from the DAE implementation are listed in Table 6 below.

Table 6. Change in the R&D intensity for the top five regions.

NUTS	*Change in R&D intensity, 2020*
FI1A	1.00
FI19	0.69
FI18	0.63
DE91	0.38
SE22	0.36

The first three regions are Finnish Pohjois-Suomi, Länsi-Suomi and Etelä-Suomi which, although sparsely populated, are very R&D intensive as for now (5.4%, 3.7% and 5.4% respectively), particularly in terms of the ICT-related research, hence it is justifiable for this region to increase its R&D intensity even further if funding becomes available.

The German Braunschweig (DE91) is the most research-intensive region in the whole EU, with its R&D investment intensity reaching over 7%. And, finally, the Swedish Sydsverige was ranked at the 8th place by the European Regional Innovation Scoreboard, with high R&D concentration.

4 Concluding Remarks

4.1 Summary of findings

The paper has presented construction of regional and sectoral R&D intensity projections for EU up to year 2020. The projections are based on country-specific historical R&D dynamics, and consistent with targets established by EU2020 and Digital Agenda for Europe policies.

Two data series for two scenarios have been constructed. The first is based on the EU2020 national targets for the total R&D intensity. The second scenario, in addition to the EU2020, considers implementation of the ICT R&D target specified in Digital Agenda for Europe. The differences between the two scenarios are interpreted as impact of DAE, while keeping other factors constant.

The constructed scenarios help to identify regions which would be affected by implementation of the DAE target. The projections are designed to feed into the Rhomolo SCGE model, in order to estimate implications of the R&D policies on economies of EU regions. Although the Rhomolo model is not implemented at this stage of research, description of the model's R&D and TFP modules is included.

4.2 Future developments

The short-term development of the RHOMOLO model is governed by a timetable of adding in various features to make the model more policy relevant. As stated previously, the strategy is to gradually re-introduce certain components that were in an earlier prototype version of the model which was constructed for only five countries. The re-introduction of R&D expenditure has already been completed through its inclusion in the TFP equation, although the endogenisation of this expenditure is still a matter of discussion. The distinction between ICT and non-ICT R&D would only take place after the endogenisation of total R&D expenditure, and is not something that has been discussed, although as has already been shown there are modelling examples to look at from which the RHOMOLO model can learn and potentially incorporate interesting features.

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